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AFRICAN IRRIGATION OVERVIEW

SUMMARY

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WMS REPORT 37

AFRICAN IRRIGATION OVERVIEW

SUMMARY

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PREFACE

This study was conducted as part of the Water Management Synthesis II Project, a program funded and assisted by the United States Agency for International Development through the Consortium for International Development. Utah State University, Colorado State University and Cornell University serve as co-lead universities for the Project.

The key objective is to provide services in irrigated regions of the world for improving water management practices in the design and operation of existing and future irrigation projects and give guidance for USAID for selecting and implementing development options and investment strategies.

For more information about the Project and any of its services, contact the Water Management Synthesis II Project.

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ACKNOWLEDGMENTS

This report is the first of three, summarizing the results of the African Irrigation Overview study. The second volume consists of the Project's Main Report, and the third of an Annotated Bibliograpny.

In preparing this report, we have drawn upon the work of a number of consultants, whose names appear on the title page. Four of the more technical background papers are summarized in Appendix A of this volume. (Additional background papers are available on request.) While we used consultants' ideas and experience freely, they did not have the opportunity to meet and review our general conclusions. Several made use of the Commonwealth Agricultural Bureau abstracts, reflected in the annotations contained in our third volume. We have benefited from Jack Keller's continuing advice and commentary, although we have reached our own conclusions on matters where technical specialists may disagree. Valuable also have been the excellent work of R. Carter, M. Kay and others at England's Silsoe College (used in Tables 5 and 6 of this volume) and similarly, FAO's Investment Centre review of African irrigation (used for Tables 2 and 7 to 9).

Again, we thank the WMS II team leadership and AID/Washington staff, particularly Richard McConnen of WMS II and Worth Fitzgerald, Cal Martin and Patrick Fleuret of AID for their patience and support. We wish to acknowledge the continuing assistance received on short notice from Janet Chambers, Carolyn Fullmer and Linda Fields. The inevitable errors and omissions remain our own responsibility.

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EXECUTIVE SUMMARY

Part I. Introduction

1. The motivation behind doing an overview of irrigation in Africa is the question of whether irrigation technologies might counteract the growing gap between rising population and declining food production.

2. FAO estimates there are 33.6 million hectares of irrigable land in sub-Saharan Africa. Out of 5.6 million hectares under irrigation, only 2.7 consist of "modern" forms, and of this, 1.7 million hectares are found in Sudan alone.

3. Only nine countries in Africa have 50,000 hectares of modern irrigation. However, aggregate figures on existing irrigation, and especially on irrigation potential, are at best "guesstimates."

4. The largest undeveloped irrigation potential is found in countries often overlooked when irrigation is discussed: Zaire, Zambia, Sudan, Mozambique and Tanzania (each with over 2 million hectares potential).

5. Several key countries outside the sphere of positive U.S. assistance control their neighbors' hydraulic resources: Guinea, Ethiopia, Tanzania and Angola. Ethiopia's control of water for Somalia, Sudan and Egypt is particularly salient.

6. This suggests that international cooperation and adoption of a non-political basis for water-related technical assistance is vital.

7. There are eight countries in the drought-affected zone where irrigation is a priority concern: Senegal, Mauritania, Burkina Faso, Mali, Niger, Somalia, Kenya and Botswana. Others where local drought can be expected are Chad, Sudan, Ethiopia, Tanzania and Zimbabwe. The large traditional irrigation in Madagascar might justify its inclusion also.

8. The high costs--generally $10,000 or more per hectare--and poor performance of Africa's existing formal schemes explain why irrigation is mostly confined to high value or export crops, not food production.

9. There are three viewpoints about the future potential of irrigation:

   a. Some emphasize its high costs in comparison to rainfed production, so that assistance should concentrate on rehabilitating existing schemes.

b. Others take a long run perspective, and in view of Africa's rapid urbanization, suggest that investment should be increased.

c. An in-between, medium-term perspective adopted in this report is to search for lower-cost types of irrigation while improving African countries' institutional base.

10. Five basic questions about irrigation in Africa need to be answered:

a. Are present difficulties just "first generation" problems?

b. How serious are environmental limitations?

c. Is some kind of irrigation essential for achieving food security?

d. Can less expensive types of irrigation be devised?

e. What organizational frameworks can substitute for the absence of operator-controlled, demand-led irrigation development?

Part II. Lessons of Experience

Potential versus Demand for Irrigation

1. The lack of reliable and stable estimates on African irrigation are a serious limitation on overall irrigation planning.

2. While demand is often assumed to reflect climate alone, the degree of aridity does not explain fully the present distribution of irrigation types; irrigation technologies are used across a wide range of ecological conditions.

3. There are many technical difficulties in using limited recharge "boreholes" for small-scale irrigation.

4. A valuable source of experience with such supplies are the Scandinavians and Dutch, who have been active in promoting community water systems.

5. The major exceptions where groundwater can be cheaply developed for small-scale irrigation are along the alluvial plains of major rivers (e.g., Nigeria's "fadama" development) and on the toe-slopes of hilly and escarpment areas.

Soils Aspects

1. Soil conditions heavily influence project location and site design. Soils information is required to:

- Estimate land capability at a regional scale;
- Screen out sites where soils are problematic;
- Assist in determining layout and agricultural potential; and
- Arrive at cost estimates for surface irrigation.

2. Frequently, soils information is not available at the appropriate scale and survey results done under project funding arrive after a commitment to a particular location is already reached.

3. Different donors employ different soils taxonomies, with the FAO and French systems being in the widest use within Africa. This limits the transfer of soils information between USAID-financed surveys (using the USDA system) and counterparts.

4. Field staff confirm that soil-related problems are frequently encountered in African irrigation. Areas of difficulty include:

   - Water losses on sandy soils;
   - Problems in working clay soils where irrigation is usually done; and
   - Pronounced fertility limitations (see Humpal's background paper, Appendix A).

5. This suggests that the success of irrigation on Africa's broad, alluvial plains in Sudan, Mali and Kenya may be a special case.

Existing Systems

1. African irrigation systems include both large-scale ones, either parastatal or commercially-managed, and small-scale ones. The absence of middle-sized, operator-controlled units is striking, and makes it difficult for incremental changes in technological improvement to occur.

2. Large systems are highly bureaucratic in nature, whether "public" or "private." They usually have uniform layout and standardized procedures, grow commercial crops under subsidy, and involve people as "tenants" or laborers.

3. Small systems show greater diversity in organization. Usually less than 1,000 hectares in extent, some are connected to irrigation parastatals like SAED in Senegal and others are assisted by NGOs. Such systems may be just as bureaucratic as large ones, though this is not intended.

4. Traditional and nonformal small-scale irrigation tends to be associated with either ancient water lifting devices like the shaduf or modern, farmer-purchased pumps. Such "oasis" or "garden" systems are spreading spontaneously.

5. Least known to outsiders are "valley bottom" or "swamp" systems

where farmers have learned how to exploit the greater moisture found in depressional areas.

Engineering Aspects

1. Securing a reliable water supply is often a particular problem in African contexts, whether because of fluctuating levels, high evaporation, sediment loads, salinity or unreliable equipment.

2. Field visits indicate a high rate of failure in intake structures, leaving the distribution system unprotected because the outside engineers who supervise construction usually cannot be called back for help.

3. Standard operating procedures must be revised to compensate for the environmental bottlenecks frequently encountered in the rural areas of Africa: shoddy workmanship, mismatched parts, fuel shortages and high transport costs are common. Systemic unreliability may make it impossible to adhere to workplans.

4. Keeping pumps operating is becoming more difficult as the national economic system deteriorates. This strongly affects some USAID projects, where pump-based irrigation has seemed the cheapest alternative.

5. Expectations about what farmers can contribute have been overly optimistic. Night irrigation and field leveling are two areas where African peasants have not provided the inputs assumed in scheme design.

6. Maintenance of physical works after completed is seen as a major problem everywhere in Africa. Reasons include:

   - Its "common property resource" nature;
   - Competing demands upon the farm labor force;
   - Farmers' part-time commitment to irrigation; and
   - Consequences of poor initial design.

7. Drainage is essential to protect field systems under intense thundershowers and to forestall salinity buildup. A difficulty in West Africa has been the extremely flat terrain, requiring expensive diking.

8. Engineers must anticipate multiple uses of irrigation water, particularly during the dry season when people and livestock may depend on it.

Agronomy

1. Most formal irrigation in Africa is concentrated upon three commercial crops--rice, sugarcane and cotton--for which a backlog

of experimental work does exist (again, see Humpal's paper in Appendix A).

2. Irrigated cotton is concentrated in Sudan, Ethiopia and Zimbabwe. Rice and sugar production are widespread throughout the continent. Of 6.45 million tons of rice in 1982, FAO estimates 17 percent came from modern irrigation, while roughly half of the 41 million tons of sugarcane did.

3. The prominence of these three crops, with most sugarcane grown under semi-industrial conditions oriented toward urban consumer use, explains why at present irrigation does not substantially increase African food security.

4. The key policy question remains the extent to which moisture availability is the main constraint on crop production. Humpal argues that often soil fertility is a more limiting factor, though to correct nutrient deficiencies may require adding water also.

5. The limited impact of irrigation on food security is best explained by the fact that Africa's most important staple is maize. While maize yields are quite sensitive to drought at germination and tasseling, the value of the crop per hectare cannot repay installation of full irrigation.

6. Monthly rainfall statistics have in the past masked the occurrence of dry spells at the start of the rains or within the season, both being common over much of sub-Saharan Africa. Here the need is to find cheaper technologies for supplemental irrigation.

7. The introduction of Asian "high yielding" rice varieties from IRRI has not been as successful as hoped.

8. The swamp cultivation of rice in West Africa was developed by farmers themselves. Recent government projects aimed at converting mangrove swamps to wet rice have a mixed record, and the money might have been better spent assisting West Africa's upland rice growers.

9. Irrigation development in Africa may actually spread weeds, which rapidly colonize disturbed soil and out-compete introduced crops. Poor seed inspection increases this risk.

10. Attempts to institute double-cycle cropping have usually not succeeded.

11. The results of farming systems research in Africa are greatly expanding our knowledge, but have neglected attention to irrigation subsystems.

Environmental Impacts

1. Diseases linked to provision of water in a hot, tropical environment need to be recognized when designing hydraulic structures. The spread of schistosomiasis almost always follows introduction of irrigation, and should be reckoned as one of its costs.

2. Spread of water weeds, especially the water hyacinth, has become a serious problem in the Sudan, but also in other parts of East and southern Africa.

Social Aspects

1. The main interface between water delivery and social systems occurs in regard to:

   - Land and water rights;
   - Physical reorganization of land use;
   - Farmers' participation in planning and construction;
   - Timing of water releases;
   - Farmers' preferences;
   - Common services provided;
   - Conflict resolution;
   - Maintenance;
   - Joint crop marketing, if any;
   - Repayment of costs;
   - Backward and forward linkages; and
   - Increased health costs.

2. Irrigation technologies differ greatly in what is expected of farmers. The popularity of small-scale pump systems in comparison to Africa's large-scale schemes is that farmers remain in complete control when using their own pumps.

3. Socioeconomic features limiting the spread of modern irrigation are:

   - Small and irregular fields;
   - Autonomy of a woman and her children;
   - Perception of irrigation as a hedge against famine; and
   - Yield increases by expanding rather than intensifying production.

4. Acquisition of land and water rights by large schemes without paying attention to existing uses has been a problem, and is the main danger to anticipate in future river basin development projects.

5. Crucial issues in modifying land tenure are:

   - Incorporation of original rightholders;

- Recognition of easement rights;
- Which legal system determines inheritance;
- Protection for women and minors;
- Compensation arrangements;
- Whether irrigation is based on land or water rights;
- How to treat houseplots;
- Restrictions on use, leasehold and renting; and
- The size of plots given out.

6. The possibility of basing irrigation on access to water rather than land rights should be explored.

7. Women's involvement in irrigation appears to grow more onerous as schemes mature. Amenities of key importance to women could be incorporated with better planning: clear water, fuelwood, gardens, smallstock and market opportunities.

8. The assumption of tight integration within the farm household and freely substitutable labor is often not met in African societies. While women and children are vital because of the work they do in the fields, they do not enjoy automatic access to profits.

9. Irrigation provided in refugee settlements or to destitute pastoralists represents an especially difficult case, which may explain its poor record in parts of the Sahel and the dry lands of East Africa.

10. Given the general opinion that social constraints are a very important influence on African irrigation, it is notable how few systematic studies of this aspect have been carried out.

Economics

1. Economic issues impinge upon all aspects of irrigation development in Africa, not only because schemes have been very expensive, but also because in current economic conditions the recurrent cost component becomes unsupportable.

2. The low ceiling on the kinds of technology farmers can adopt is set by their limited degree of commercialization, the small size of farms and the predominance of subsistence production.

3. Eight strategies are identified for promoting greater adoption:

   - Changing the form of technology;
   - Subsidies;
   - Providing infrastructure as a grant;
   - Working with groups;
   - Establishing irrigation parastatals;
   - Let large farmers squeeze out the smallholders;
   - Grow only high value crops; and
   - Locate where demand is high.

4. The deteriorating national economic situation is having a strongly adverse impact on irrigation in many African countries, leading farmers to adopt risk-minimizing "rainfed" techniques even under irrigation.

5. Reasons for the high costs seen are partly because construction and transport costs are higher in Africa than Asia, but also because large African schemes require external management and substantial infrastructure. Kenya's Bura West scheme cost $25,000 per hectare in 1980.

6. However, small projects have not shown markedly lower unit costs than large ones--a warning to donors.

7. Appraisal for irrigation projects often assumes "free" family labor in an effort to make benefits appear more attractive. African farming systems instead show pronounced seasonal labor bottlenecks, and the costs of labor escalate as economic development takes root.

8. Many African countries have attempted to impose price controls, so that at all stages in the production-marketing process administered prices are used--except for the farmer's own activities. When schemes attempt to pass on increased production costs to farmers, the resulting cost-price squeeze makes irrigation unattractive.

9. The one neglected strategy has been to search for cheaper forms of irrigation technology. Data on the increments in paddy yield to repay various types of irrigation intervention show that the most cost-effective options are either assistance to swamp rice or minor improvements to existing schemes.

Institutional Aspects

1. African countries differ greatly in the availability of water management professionals, with the Sudan and Francophone countries enjoying a manpower advantage over the rest of sub-Saharan Africa.

2. Few countries know what their irrigation manpower situation is. This constitutes a priority area for possible donor assistance.

3. There is a general perception that management has been weak on many African schemes. Because of its many linkages to a problematic environment, irrigation is likely to be especially difficult to manage.

4. Seven types of management can be identified by level:

   - Sectorwide planning and supervision;
   - Construction management;
   - Scheme management;
   - Hydraulic or "main system" management;

- User organizations, if any;
- On-farm water management; and
- Management of environmental impacts.

5. African countries have usually relied upon external assistance when undertaking major irrigation projects. These days the sheer number of donors willing to assist is absorbing the time of scarce indigenous technical staff.

6. In the Sahel, the Club du Sahel and the CILSS organizations were established after the 1973-74 drought to coordinate donor activities.

7. Many countries have established river basin authorities (RBAs) as a device for dealing with neighboring countries if a river is shared and for doing long-run planning. Such organizations are a logical point of attachment for future irrigation studies.

8. An alternative is to create specialized irrigation parastatals, public corporations with a mandate to foster the development of individual schemes and perimeters. Good examples are Kenya's NIB or Senegal's SAED.

9. The scheme level is usually unfamiliar to Americans, and is necessitated because of the large number of farmers with very small holdings on a typical perimeter. Schemes act as surrogates for the farmers' interest, and do many of the functions which in the U.S. a large farmer might do directly. More attention is needed to understanding scheme management.

10. A current issue is whether by establishing user associations, these could take over many scheme functions and reduce the "top down," paternalistic style of African irrigation management. We consider this to be where the focus on institutional innovation should be placed.

Lessons for Field Projects

To summarize Africa's irrigation experience, twenty-five guidelines are presented concerning what is or is not likely to succeed.

For Further Study

Key references on African irrigation are identified for those who may not have access to the second and third volumes of this study.

Part III. Implications for Donors

1. Virtually all expert observers recommend against expanding finance for irrigation by the mere addition of new projects. Top priority at present must go to institutionalization and rehabilitation.

2. An initial analytic step would be to clarify which kinds of activities contribute most directly toward deepening institutional capacity in the irrigation sector. Terms like "planning" and "extension" are often used loosely, without recognizing that neither AID nor recipients know how these terms actually apply within irrigation.

3. AID should recognize that it will usually be a small donor in relation to irrigation. This suggests that to get maximum benefit from a wide spectrum of field activities AID should adopt a collaborative approach where many of the primary costs are borne by other donors.

4. U.S. expertise available to work on African irrigation is very thin, in part because of AID's small commitment in this area, but also because of language barriers (French, Arabic, Portuguese) and the predominance of the former colonial powers (France, England) in giving assistance. To change this situation will require a vigorous and planned effort, possibly by means of "tag-along" or rotating post-doctoral fellowship arrangements.

5. It should be recognized that the U.S. government is supporting African irrigation through World Bank/IDA funding to field projects. To date, the Bank has rarely used U.S. expertise for evaluating its irrigation projects. However, the weak performance of these projects indicates there is much scope for improvement. A joint AID/Bank effort aimed at strengthening institutional support for irrigation ought to be considered.

6. AID already has under way several "farming systems' research" (FSR) projects in countries where irrigation is important, e.g., Sudan, Niger, and Tanzania (among others). Because these are already operational, an irrigation "add-on" component could be rapidly implemented. There is a strong case to insist that FSR projects pay more attention to irrigation.

7. Many African countries have established river basin authorities (RBAs) of one type of another. We have noted the RBAs are usually the only base for existing irrigation planning in a given country. AID should explore a "package" of modest support measures aimed at buttressing the institutional effectiveness of such agencies. Possible components might include:

   - Training at the M.S. level (initially in the U.S. but with theses done in the home environment), followed by in-country workshops;

- Africa or region-wide seminars to direct RBA attention to new concepts, procedures and resources (e.g., farmer participation, remote sensing); and
- Simplified planning and monitoring procedures adapted to African conditions (rapid reconnaissance, etc.).

8. A major gap is the almost total absence of information on irrigation manpower on the African continent. A systematic approach to training for irrigation requires information on staff training needs, which is simply not available.

9. Another unexpected gap is in regard to irrigation economics, a key policy concern given the high costs of irrigation investment and the many complications arising from incorrect estimation of labor costs. Each REDSO office should have at least one irrigation economist, perhaps a rotating fellowship position, to rapidly expand the number of those familiar with African irrigation economics.

   AID's regionally-based REDSO offices would seem to afford a useful base for assignment of interns who would rapidly acquire a broad comparative experience. Such staff should have already completed a field assignment (M.S. or Ph.D. in an African rural setting). The REDSO framework allows maximum flexibility in arranging staff assignments, and spreads the load of support over several countries. We recommend a focused program to deepen the irrigation expertise located at the REDSO level.

11. Scheme management as presently found in Africa depends heavily on various internal routines -- precedents, rules of thumb, and administrative procedures. While rarely documented outside the agency concerned, these have an enormous influence on farmers' productivity and commitment. Both in regard to improving participation and women's involvement, the adequacy of such institutional arrangements is critical. We suggest that dialogue and comparative research on these procedural, "O&M" aspects would be a suitable area for special studies.

12. The question of why maintenance has been so poor on many African irrigation systems ought to be made a topic for multidisciplinary inquiry. If donors intend to finance project rehabilitation, they should first investigate the reasons why maintenance is generally neglected. The physical reconstruction of older schemes will be of only temporary benefit if changes are not instituted in how the system is operated.

13. Donors also have substantial leverage with rgard to the attention to beneficiary needs. There are a number of relatively simple procedural changes which would greatly increase the benefits of irrigation for women. Donors could sponsor exchanges of experience in this area to find ways of increasing the leverage which women can exercise on scheme management. For AID/Washington, the

comparative advantage of U.S. scholars interested in study of "WID" (Women in Development) topics provides an opportunity where a modest level of support would yield rapid results. Some assistance might also be given to a small unit in FAO which has been looking at the role of women in African agricultural development (perhaps by funding of a linked associate expert's position).

14. The potential of small-scale irrigation has attracted considerable attention from European donors in recent years (Underhill, 1984). Here AID's comparative experience with small-scale systems in Sri Lanka, Indonesia and the Philippines might be drawn upon when designing African projects. AID might also assist in documenting existing small-scale systems, and in promoting exchanges of experience between African countries. In particular, better documentation is required on the spread of irrigation technologies (and linked support needs) among small-scale entrepreneurs.

15. Greater involvement of the private sector remains an official U.S. government objective. In Africa, it is complicated by the presence of outside minorities and the pronounced duality of the agricultural sector. Possibilities for donor support include:

    - A systematic effort to retrieve the substantial experience of private consultancy firms, which have been very active in the design of African irrigation schemes;
    - Encouragement of exchanges of expertise within African countries between the large-scale commercial sector and the public or PVO agencies helping small-scale irrigation;
    - Establishing better technical "backstopping" for NGO and PVO irrigation projects; and
    - Possible credit assistance to the small-scale "market garden" farmers oriented around purchase and maintenance of pumps. However, great caution must be exercised since such projects are quite risky.

16. The evident lack of feedback from operational systems into project design arises because of a deep split between civil engineers doing construction and external agronomists (often FAO-provided) assisting crop production. In most African countries, irrigation engineering as a discipline does not yet exist. Donors should encourage any measures which facilitate the emergence of irrigation engineering as a unified field, combining aspects of design, construction, water management and agronomy.

17. AID/Washington needs to recognize that because of its few irrigation-related projects in East and Southern Africa, the usual "participant training" device for deepening in-country technical skills cannot be relied upon. If African countries are to send staff for training in the U.S.A., they must do so under some other mechanism. We see this as an opportunity to shape an emerging professional discipline, but warn that as presently given, much U.S. training is likely to be inappropriate to African conditions.

18. In regard to technology choice, this report has identified numerous problems. At a minimum, donors can avoid compounding managerial difficulties by introducing unsupportable "orphaned" equipment. They can also buttress in-country repair and servicing capacity, an objective AID has several times adopted (Senegal, Mali) but which appears exceedingly difficult to accomplish. Perhaps an exchange of experiences between countries and donors would help? More fundamentally, there are obvious gaps where present technologies are inadequate:

- An absence of low energy pumping systems, which would be within reach of smallholders' financial capability;
- Development of systems combining full irrigation for one crop cycle and supplemental irrigation for the rainfed crop;
- A frequent failure to anticipate multiple uses (livestock, households, etc.) of irrigation water;
- A need for an exchange of ideas about animal traction equipment suited to lighter weight African cattle;
- Exchange of experience concerning working in heavy clay soils; and
- Development of a means for applying supplemental irrigation to rainfed cereal crops during within-season droughts.

19. Irrigated production in Africa encounters severe difficulties related to soil exhaustion, nematode and pest buildup, and a proliferation of terrestrial and aquatic weeds. Because these are delayed impacts, their significance in depressing crop yields has probably been underestimated. We have no clear solutions, but note past U.S. assistance to the National Academy of Science for exchanges of technical information on such topics.

20. Another area of comparative U.S. advantage concerns support for agricultural applications of remote sensing (LANDSAT, etc.). Contrary to some U.S. opinion, a continuation of these activities, drawing particularly upon U.S. weather monitoring capability, is vital. (For example, such data was the best firm evidence that Africa's current drought was not primarily man-caused.) Cross-linkage of regional precipitation patterns to river-basin planning is a strategic necessity for the U.S.A. and any other donors concerned about African food availabilities. A missing element has been to focus on the "early warning" aspects, so that countries with installed irrigation capacity will have enough time to shift priority towards food grain production in the rainfall deficit years.

21. In general, environmental complications (especially those related to health) constitute a significant constraint upon African irrigation. Individual countries may lack the technology and interest to engage in long-run environmental monitoring. As in the past, donor pressure has been the main reason for inclusion of this focus in project designs. The presence of UNEP in Nairobi, which has often sponsored useful work on energy and environmental aspects

of African agriculture, offers a possible base for expanded attention to this aspect of African irrigation. There is also need to exchange information on public health costs associated with different types of irrigation technology.

22. Finally, this report would not have been feasible without access to the irrigation "network papers" provided by London's Overseas Development Institute (ODI). ODI is already in touch with many of Africa's irrigation practitioners, but the task has grown to unmanageable proportions beyond ODI's present resources. Since a substantial proportion of the passive membership in ODI's irrigation network are Americans, modest U.S. assistance might be welcomed.

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PART I
INTRODUCTION

The drought which afflicted much of sub-Saharan Africa in 1983-84 once again made dramatically evident the continent's inability to feed itself. Between 1964-66 and 1978-80 most African countries experienced a significant decline in food self-sufficiency (Table 1). This continuing decline is in striking contrast to the record achieved in Latin America and Asia over the same period. USDA figures taking mean per capita production in 1961-65 as a base (100) find that while Asia and Latin America had achieved 115 percent of 1961-65 production by 1983, the figure for Africa was below 80 percent.[1]

That there is an emerging gap between rising populations and declining agricultural production in Africa is well known, and has been commented upon.[2] What is not yet clear is why despite many rural development programs, the technology for increased food production is still problematic--if not in theory, then certainly in respect to actual output. A key issue is whether wider adoption of irrigation could relieve existing food production constraints, either by stabilizing food supplies in the drought affected zone or by permitting other farmers to use fertilizers and higher yielding varieties (as happened in Asia in the 1960s). This basic question underlies the African Irrigation Overview, which seeks to assess both the existing experience within African irrigation and the future potential of irrigation technologies when employed in African settings.

For sub-Saharan Africa it has been estimated that out of 33.6 million hectares suited to irrigation, only 2.7 million hectares have been developed under "modern" irrigation; of these, 1.7 million occur in just one country, the Sudan (Table 2). Even if indigenous and traditional forms of irrigation are included, only 5.3 million hectares are under

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[1] Figures cited (1985:65) in a booklet by the Independent Commission on International Humanitarian Issues, Famine, a Man-Made Disaster?

[2] The best introductory source on this issue remains Carl Eicher's (1982) "Facing Up to Africa's Food Crisis," Foreign Affairs, Vol. 61, No. 1 (Fall), pp. 151-174.

TABLE 1

FOOD SELF-SUFFICIENCY RATIOS[a]

	1964-66 Average %	1978-80 Average %	1980 Population (millions)
Low Income Sub-Saharan Africa			
Benin	95	89	3.4
Burkina Faso	99	94	6.1
Burundi	98	95	4.1
Cape Verde	58	8	0.3
Central African Republic	92	90	2.3
Chad	100	97	4.5
Comoros	56	50	0.4
Ethiopia	99	93	31.1
Gambia	89	56	0.6
Ghana	83	71	11.5
Guinea	91	85	5.4
Guinea-Bissau	88	60	0.8
Madagascar	98	91	8.7
Malawi	101	97	6.1
Mali	99	96	7.0
Mozambique	90	64	12.1
Niger	104	98	5.5
Rwanda	99	96	5.2
Sierra Leone	91	87	3.5
Somalia	81	54	4.3
Sudan	96	98	18.7
Tanzania	96	93	18.1
Togo	96	89	2.5
Uganda	98	99	12.6
Zaire	68	66	28.9
Middle Income Sub-Saharan Africa			
Angola	110	64	7.6
Botswana	25	37	0.9
Cameroon	95	87	8.4
Congo, P.R.	26	21	1.6
Gabon	23	24	0.7
Ivory Coast	73	71	8.3
Kenya	97	96	16.6
Lesotho	93	77	1.3
Liberia	79	73	1.9
Mauritania	69	20	1.5
Namibia	100	100	1.0
Nigeria	98	84	84.7
Senegal	73	68	5.7
Swaziland	86	85	0.6
Zambia	97	79	5.6
Zimbabwe	96	113	6.9

[a]Self-sufficiency = $\frac{\text{Production of cereals}}{\text{Production + imports - exports of cereals}} \times 100$

Source: World Bank, Economic Analysis and Projections Department. Cited in Singh, S., 1983, Sub-Saharan Agriculture. World Bank Staff Working Paper No. 608, Tables 1 and 6.

TABLE 2

FAO ESTIMATES OF AFRICAN IRRIGATION, 1982
(SUB-SAHARAN AFRICA)[a]

Country	Irrigation Potential ('000 ha)	Area Developed 1982			Developd as % of Potential
		Modern	Small-Scale or Traditional ('000 ha)	Total	
Angola	6,700	0	10	10	< 1
Benin	86	7	12	19	22
Botswana	100	0	12	12	12
Burkina Faso	350	9	20	29	8
Burundi	52	2	4	6	12
Cameroon	240	11	9	20	8
Central African Republic	1,900	0	4	4	< 1
Chad	1,200	11	35	46	4
Congo	340	3	5	8	2
Ethiopia	670	68	45	113	17
Gabon	440	0	1	1	< 1
Gambia	72	6	20	26	36
Ghana	120	8	50	58	78
Guinea	150	50	135	185	>100
Guinea Bissau	70	n.a.	n.a.	n.a.	n.a.
Ivory Coast	130	33	29	62	48
Kenya	350	21	28	49	14
Lesotho	8	0	1	1	13
Liberia	n.a.	8	16	24	n.a.
Madagascar	1,200	160	800	960	80
Malawi	290	19	2	21	7
Mali	340	93	57	150	44
Mauritania	39	3	20	23	59
Mauritius	n.a.	9	5	14	n.a.
Mozambique	2,400	66	4	70	3
Niger	100	7	17	24	24
Nigeria	2,000	35	805	840	42
Rwanda	44	0	15	15	34
Senegal	180	98	89	187	>100
Sierra Leone	100	5	100	105	>100
Somalia	87	35	50	85	98
Sudan	3,300	1,700	-	1,700	52
Swaziland	7	55	5	60	>100
Tanzania	2,300	34	106	140	6
Togo	86	2	8	10	12
Uganda	410	9	3	12	3
Zaire	4,000	4	38	42	1
Zambia	3,500	14	2	16	< 1
Zimbabwe	280	140	6	146	52
TOTAL	33,641	2,725	2,568	5,293	15.7

[a]Figures for Equatorial Guinea not available.

Source: FAO internal statistics, presented in FAO, 1985, p. 13.

irrigation in Africa as a whole--a mere 16 percent of potential (FAO, 1985:13). Existing irrigation is very unevenly distributed in terms of the size of schemes implemented. By FAO's reckoning, 1.8 million ha are found within large schemes of over 10,000 ha each, mostly developed under government funds; almost another million consist of units in the 500 to 10,000 ha range (about half of which occur in private estates). Traditional irrigation was done on very small plots, frequently not more than one hectare in size. At the two extremes one has a few large, government-controlled schemes under bureaucratic management occupying thousands in hectares, in contrast to thousands of smallholders irrigating tiny patches within (mostly) valley bottom land. Where private estates exist, they often have an agro-industrial character (e.g., growing sugarcane) which makes them more like the government schemes. Commercial operators in control of farms of several hundred hectares are strikingly absent from the African scene.

Table 2 indicates that there are major disparities in the degree to which irrigation has been developed within various sub-Saharan countries. As of 1982, only nine had 50,000 or more hectares of "modern" irrigation: Ethiopia (68,000 ha), Guinea (50,000 ha), Madagascar (160,000 ha), Mali (93,000 ha), Mozambique (66,000 ha), Senegal (93,000 ha), Sudan (1,700,000 ha), Swaziland (55,000 ha) and Zimbabwe (140,000 ha). Sudan's irrigated sector alone constitutes 62 percent of the total for all sub-Saharan countries. It is so much larger that Sudan constitutes a case unto itself in respect to most of the generalizations which will be made in this report. The prominence of Madagascar in second place may be unexpected to some: it reflects in part an irrigation tradition brought by immigrants centuries ago from Southeast Asia (note Madagascar's large extent of traditional irrigation, at 800,000 ha). If small-scale and traditional irrigation also count, Nigeria (840,000 ha), Tanzania (140,000 ha) and Sierra Leone (105,000 ha) are of significant size. Nigeria's small-scale irrigation of "fadama" lands--valley bottom, clay soils--and Sierra Leone's "swamp rice" cultivation are not well known outside of Africa, but constitute significant examples of spontaneous, small-scale irrigation development.

A problem with all aggregate figures on African irrigation--actual and potential--is their weak empirical basis, being little more than "guesstimates." The FAO totals given in Table 2 do, nevertheless, suggest two broad observations. First, African countries vary tremendously in the degree to which they have exploited their existing irrigation potentials. This ranges from full exploitation (95 percent or more) in Guinea, Senegal, Sierra Leone, Somalia and Swaziland to very low degrees of development (under 10 percent) in Tanzania, Mozambique, Malawi, Cameroon and Chad. While one may question individual totals (it seems hardly possible that Somalia's estimate reflects future development prospects in the Juba drainage), it does appear that historic factors rather than potential have determined where irrigation has been emphasized to date.

A second observation is that the countries with the largest undeveloped water resources tend to be those which are overlooked when irrigation is being discussed. Surprisingly, these are according to FAO Angola (6.7 million ha), Zaire (4.0 million ha), Zambia (3.5 million ha), Sudan (3.3 million ha), Mozambique (2.4 million ha), Tanzania (2.3 million ha) and Nigeria (2.0 million ha). Of these seven countries, only Sudan and Nigeria have under way major programs for irrigation development comparable in scale to their resources. Since several of these same countries also possess major hydroelectric potential, it would seem that the parts of the continent with the best long-run technological potential for intensified irrigation are not the areas receiving investment and attention at present. Indeed, several of the key countries which control their neighbor's hydrologic resources (e.g., Guinea, Ethiopia, Tanzania and Angola) lie outside the U.S. sphere of positive support. Ethiopia in particular has a high incentive to develop its own irrigation systems on rivers which are the main water resource for Egypt, Sudan and Somalia. These facts highlight the need for greater cooperation in water resources planning, and for the adoption of a non-political basis when considering Africa's future development potential. For Africa's future food self-suficiency, these remain vitally important issues, although they go beyond the scope of this review.

As an "add-on" component to existing production, irrigation is inherently more expensive than alternative, rainfed technologies. This is basically why irrigation is usually employed only where natural moisture is severely limiting, or where a special horticultural crop can offset increased production costs. The countries with Africa's highest irrigation potential are, however, generally poor ones where investment capital is scarce and where rainfall is usually sufficient to support present populations. The focus of existing irrigation development instead has been within the drought-prone countries of the Sahel, or in countries where commercial production justified increased investment (e.g., Zimbabwe, Swaziland and Mauritius).

By FAO's estimates there are eight countries where more than 85 percent of the area has less than a 200-day growing period and where present populations exceed their agricultural carrying capacity: Senegal, Mauritania, Burkina Faso, Mali, Niger, Somalia, Kenya and Botswana (FAO, 1985:5). If we include nations with a rainfed growing period of less than 120 days on over a quarter of their land (where a focus on irrigation would be required), Chad, Sudan, Ethiopia, Tanzania and Zimbabwe should be added to the list. With Madagascar as a thirteenth country (because of the large extent of its traditional irrigation), these would constitute the main countries where in the short-run irrigation development should receive priority attention.[1]

Complicating factors remain the high cost and relatively poor performance of Africa's existing irrigation schemes. In general, the construction costs on Africa's existing projects have been high, with $10,000 or more per hectare being frequently mentioned. When such high costs are loan financed, the inevitable consequence is to restrict the application of irrigation technology to higher value or export crops, where costs can be more readily recovered. This explains the paradox that while an initial motivation for adopting irrigation has often been the high hope of increasing food security, by and large African

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[1] Others might add Nigeria and Ghana, because of population concentrations in their drier northern zones, or countries like the Gambia, Sierra Leone or Cameroon because of their existing irrigation systems.

irrigation is not employed for growing the continent's main food staples.

To establishment costs must be added the substantial recurrent costs which may be associated with irrigation. Expatriate management, pumped water and transport can be very expensive in a rural African context, and all three draw on a country's hard currency reserves. For some crops, such as irrigated wheat, the import content may actually exceed what would be required in direct importation of the same crop. For countries without adequate manpower or in balance-of-payments difficulty, implementing irrigation requires the very resources which are already in shortest supply.

The overall performance of individual schemes is quite often not a matter of public record, though a few of the more succesful ones have been well described.[1] In general, performance has been below--sometimes far below--initial expectations. There have been long delays in completing schemes; the area under irrigation is often much less than had been planned (e..g, Bura in Kenya); average yields remain below what is needed to repay investments; many systems have deteriorated so rapidly that new loans had to be sought even before the old ones were completely disbursed. In Montgomery's comparison of irrigation system performance (1983), the Mwea Scheme was the only African example which was rated even moderately successful.

Taking stock of the high costs and high import content of irrigation, the poor performance of many existing schemes and the adverse environmental and economic trends, some would argue that no further investment in new schemes is justified. If assistance is to be extended to the irrigation subsector, it should concentrate on rehabilitating already malfunctioning schemes (a point of view we take up again in Part III). At the other extreme, and considering Africa's

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[1] Best described are Senegal's small-scale perimeters; see Adams (1981), Fresson (1978), Keller et al. (1982), Miller (1984) and Patterson (1984). Others include for the Sudan: Gezira (see Barnett, 1977 and 1981) and Gaitskell (1959); Rahad, Bennedict et al. (1982); and New Halfa (Pearson, 1980); Fahim (1981) and Salem-Murdock (1984). For Kenya's Mwea, see Chambers and Moris (1973 and 1977) and Clayton (1983); for Vuvulane in Swaziland, Cobban (1983) and Tuckett (1977).

high rates of urbanization and the large areas suited to irrigation lying unused, those adopting a long-run perspective might advise instead a heavy increase in irrigation investments. In between come those like ourselves, operating within a middle-range perspective, who prefer to search for lower cost approaches (perhaps extending assistance to NGOs and the private, nonformal sector) while improving the institutional capacities for suporting irrigated agriculture.

The lack of systematic information on present performance and the many contradictions embodied within existing programs have made it difficult to formulate sensible policies. There are five basic questions we feel ought to be addressed in order to put the choice of irrigation policy on a firmer basis:

1. Are the present field difficulties simply the natural consequence of "first generation" technological interventions? If they are, more investment to provide adequate infrastructure and support is justified, particularly in view of Africa's underexploited irrigation potential. If they are not, a larger volume of activity will only increase losses.

2. How serious are the various environmental limitations--natural, economic, social, administrative and political--and what is their varying influence in different settings or with regard to alternative irrigation technologies? Past programs paid scant attention to either setting or the choice of irrigation technology. It now seems obvious that both are critical dimensions in Africa contexts, so that even in one country no single type of irrigation will suit all conditions.

3. Is some form of irrigation essential in order to safeguard African food security over the longer run? Here one's attention shifts toward evaluating the long-run population carrying capacity of Africa's agricultural land. The central role of improved water management as a precondition for the adoption of higher yielding varieties in Asia raises the possibility that a similar transformation may be necessary to increase the productivity of African agriculture.

4. Can less expensive or more sustainable types of irrigation be devised which are suited to smallholders and which can be applied to

lower value crops? It is plain that if irrigation remains a high cost, high import content technology, it will be confined to schemes of an agro-industrial character ("estates") or their parastatal equivalent (the Gezira/Mwea model).

5. If the absence of middle-sized, operator-controlled units makes it unlikely that technology choice will be demand led, what institutional alternatives can be developed as surrogates for farmers' own initiative? How do we get the bureaucratic parastatals and multinational corporations which predominate within the irrigation subsector to behave responsibly, cost-effectively and innovatively?

These are fundamentally "meta-issues," which will remain unresolved if attention is directed primarily at the project level. A principal conclusion of this study is that many African countries need to evolve a sector-wide approach toward irrigation development. We are not for a moment proposing that countries require a uniform, all-purpose institutional or technological "model." Instead, we suggest that the design of individual projects is difficult if at a national level basic issues about food production and factor pricing are left unexamined. The policy issues which we feel should be addressed nationally are presented in Table 3, structured hierarchically so that the most basic ones are listed first. Indeed, the deteriorating economic situation in many sub-Saharan African countries makes a reassessment of investment priorities mandatory.

What this "overview" attempts is to summarize the African experience with irrigation so far, providing "lessons" for policy-makers and project designers (Part II) as well as for potential donors (Part III). The very unsatisfactory information base on African irrigated agriculture makes it impossible to answer all of the questions we have raised, but at least certain clear warnings emerge in regard to unsuccessful options. The combination of adverse economic trends, generally weak institutional capacities and a high degree of environmental challenge leave little room for mistakes. In this summary volume, we highlight the key issues and lessons. Those requiring detailed argument and evidence should consult Volumes Two and Three, consisting of the Main Report and a comprehensive, Annotated Bibliography.

TABLE 3

KEY IRRIGATION POLICY QUESTIONS

A. Food Policy

Consumption trends. Which staples?
Produce at home or buy from abroad?
What fluctuations tolerable?
Pricing policy?
What urban/rural subsidies?

B. Balance between Irrigated versus Rainfed Farming

Comparative costs of production by zone.
What import content in production?
Comparative transport costs.
What technical opportunities for each?
What role in supporting population intensification?
What complementarities?

C. What Kinds of Irrigation

Large-scale versus small-scale, formal versus nonformal.
Full versus partial, total versus supplemental.
Authority managed versus locally managed.
Supply and conveyance options.

D. What Crops

Present yields, irrigated versus non-irrigated.
Cost/price trends, internal and external.
Available technical packages, input implications.
Foreign exchange implications.
Food security implications.
Integration between enterprises.

E. Where, When and With Whom

Phases in development.
Location of projects.
Acquisition of rights?
Infrastructural costs.
Cost recovery mechanisms.
Is settlement included?
Sources of staff, expertise.
Supervisory structures.
Farmer participation.

Source: Adapted from Moris, Thom and Norman (1984), Prospects for Small-Scale Irrigation Development in the Sahel, p. 3.

PART II
LESSONS OF EXPERIENCE

1. Potential versus Demand for Irrigation

A serious limitation on overall irrigation planning for the African continent is the lack of stable estimates, both of the areas now under irrigation, and of lands suitable for future development. With regard to areas presently irrigated, sources employ different definitions and data for certain countries are completely missing. While the extent of modern irrigation is roughly known--here figures are probably an overestimate, since they often assume completion according to plan--coverage is better for the public than the private sector, and estimates of the extent of traditional or small-scale systems are usually mere guesses.

The demand for irrigation is often assumed to be a function of climate alone; the more arid an area, the higher its need for irrigation (Table 4). At the extreme of oasis cultivation in the Sahara, this relationship obviously holds. The main reason why irrigation figures so prominently in reviews of the Sahel (and of the eastern extension of this zone into Sudan, Ethiopia and Somalia) is because here there really is no alternative (Bingen, 1985; Katz and Glantz, 1977; Norman et al., 1982; Wickens and White, 1979). The historic concentration of African populations outside of the humid zone in West Africa accounts for the vulnerability of parts of Mali, Burkina Faso, northern Ghana and northern Nigeria during times of drought. By FAO's estimates, 14 percent of the population of sub-Saharan Africa resides in the eight most drought afflicted countries (FAO, 1985:5).

As Tables 4, 5 and 6 indicate, the degree of aridity does not fully explain the present distribution of irrigation types in Africa. Irrigation technologies are used on the continent across a wide range of ecological conditions, far wider than one might assume from gross estimates of rainfall availability. In all zones except the very most humid ones, some form of irrigation is also found. There are several likely explanations. Under tropical conditions, potential evaporation

TABLE 4

FARMING SYSTEMS IN RELATION TO ARIDITY

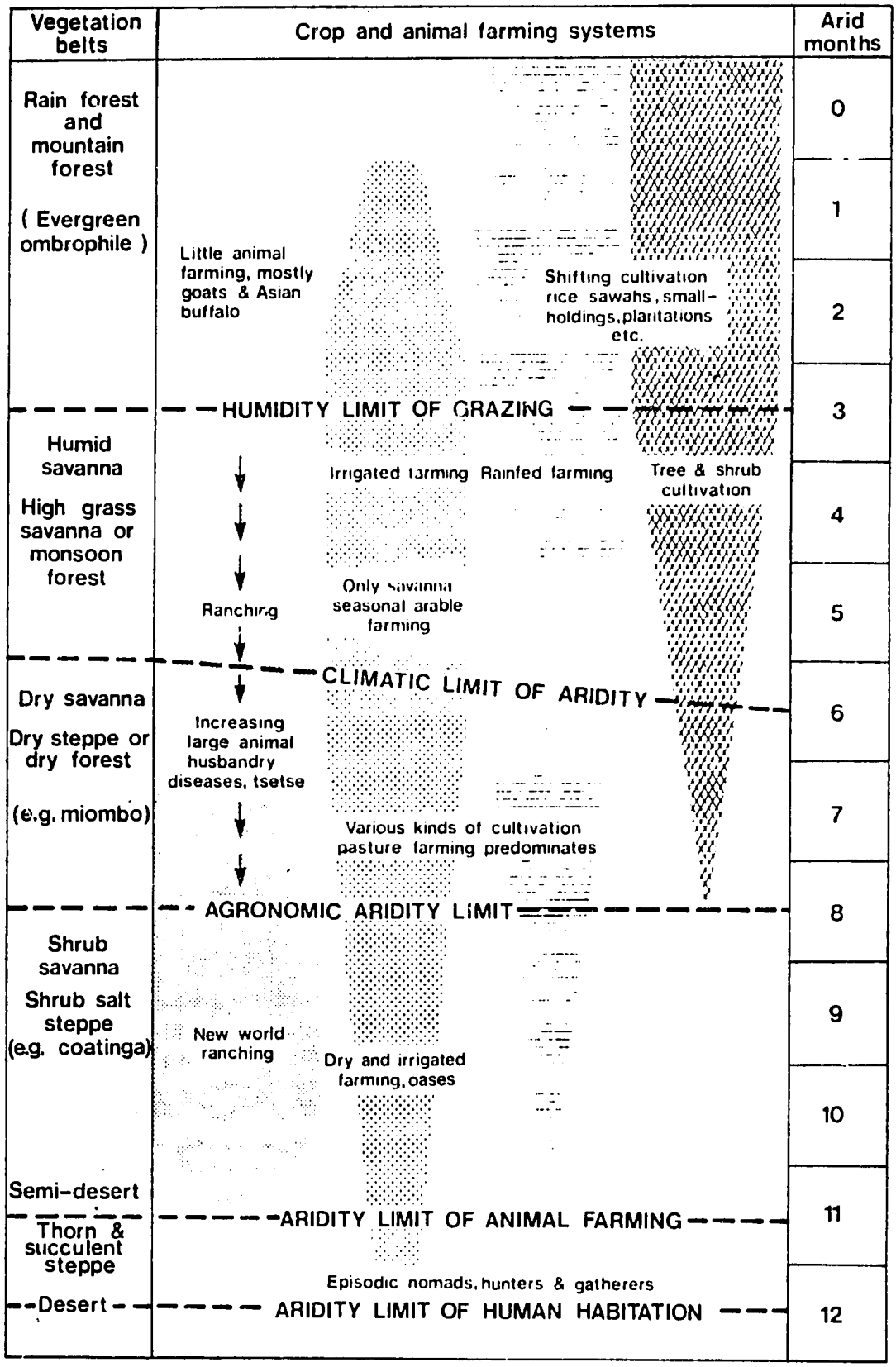

TABLE 5

PHYSICAL CLASSIFICATION OF SMALL-SCALE IRRIGATION

Classification	Description	Some Examples
Runoff farming	Involves making better use of natural rainfall. Many approaches.	Ancient agricultural areas, Negev Desert, Israel.
	Rain-water harvesting--collecting runoff from a catchment and concentrating water in a smaller cultivated area. Large schemes, several hectares of catchment, small schemes may involve individual plants. Success depends on having right ratio of catchment to cropped area.	Pasture improvement by flood water retention, Agades, Niger. Micro-catchments for fruit trees in Botswana. 'Banto Faro' rice cultivation, Gambia.
	New developments applying chemicals, plastics to catchments to increase runoff.	
	Water spreading--(spate irrigation) spreading flood water in rivers and wadis across cultivated land in a controlled manner.	Lower Omo Valley, Ethiopia, food and fodder crops.
	Fallow farming--using soil as a reservoir to store water with fields kept free of vegetation for part or all of a rainy season.	
River flood plains or extensive plains		
Wet season	Usually rice grown in flood waters. Many techniques.	
	Bolilands--depressions in swamp grasslands.	c. 30,000 ha, Rokel River, Sierra Leona. Also Guinea, Mali, Upper Volta, Ivory Coast, Ghana.
	Inland valley swamps--small valleys (1-100 ha) where season/perennial streams can be used/controlled for paddy rice cultivation.	Sierra Leone Burundi
	Lake swamps-large areas of flat plain flooded as lake level rises.	Lake Victoria, Tanzania.
	Controlled irrigation--controlling the rise in flood water using dykes, canals and sluice gates. Used for both deep water and paddy rice.	Niger and Bani Rivers, Mali.

TABLE 5 (Continued)

Classification	Description	Some Examples
Dry season	Large areas of flood plain where surface water storage and shallow groundwater can be exploited using lifting devices, often for vegetables.	River Omo, Ethiopia, 40 low-lift windmills, maintenance problems.
	Shaduf irrigation--traditional technique of lifting small quantities of water using the "lever principle." Usually low-lift 1-2 m.	Most large river flood plains in West Africa, Niger, Bani Senegal, common along Nile. Tana River, Kenya.
	Calabash irrigation--scooping water using calabash, small quantities, low-lift.	Large areas in Sokoto, Nigeria.
	Pumps--a wide variety from archimedean screws to small diesel pumps.	Increasingly common in Nigeria. Also along most large rivers in West Africa.
	Recessional irrigation--impounding receding floodwaters with earth bunds.	Rice cultivation along most large rivers in West
	Residual moisture--similar to recessional but water is stored in soil rather than on the surface.	Dry season cultivation of dambos or vleis in Malawi, Zambia, Zimbabwe.
Non-seasonal	Involves exploitation of groundwater down to 15 m.	Exploited for small gardens, e.g., Burkina Faso, Niger, Togo, Benin, Zimbabwe, Botswana.
Small areas commanded by channels	Land irrigated some distance from water source, supplied by canal or pipe. Source may be a stream, small dam storage, gravity or pumped.	Traditional cultivation by the Chagga tribe on the slopes of Mount Kilimanjaro, Tanzania. Rumphi area; Malawi.
Mangrove/coastal swamp	Fresh water swamps protected from saline sea water by bunds/dykes.	Gambia River, Gambia.
	Used for growing rice. Also tidal swamps planted after rains leach soil.	

Source: M.G. Kay et al., 1985. "The Prospects for Small-Scale Irrigation in Sub-Saharan Africa." Outlook on Agriculture, Vol. 14, No. 3, p. 116 (Table 1).

TABLE 6

TYPES OF SMALL-SCALE IRRIGATION BY AGRICULTURAL REGIONS

Region	Description	Types of Small-Scale Irrigation	Examples
Desert and Semi-Desert	Low erratic rainfall (less than 500 mm/year); normal rainfed agriculture impossible. Major activity, nomadic stock raising, camels, goats, sheep, cattle. Irrigation involves settlement of nomadic tribes, which will be difficult.	Runoff farming Non-seasonal	Fodder and crop production in Lower Omo Valley, Ethiopia. Irrigation in desert oases.
Dry Savanna Agriculture	Extends over large areas of Africa, rainfall 500-1000 mm falling in a 3-6 month season. Normally sufficient rain for one crop. Irrigation can ensure crop survival.	Runoff farming Wet season and non-seasonal	Agroforestry in micro-catchments, Burkina Faso; Tuareg nomads lifting shallow groundwater with oxen or cattle.
Humid Savanna Agriculture	Rainfall 1000-2000 mm/year, close to equator two rainy seasons, further north or south one longer rainy season. Sufficient for two rainfed crops near equator (e.g., Rwanda, Burundi, CAR) and one rainfed crop in more northerly/southerly areas. Irrigation can extend cropping season and improve yields.	Dry season Wet season Non-season and small areas commanded by channels	Water control and drainage in swampy areas of Burundi (Carter, pers. comm.); deep water and floating rice with minimal water control.
Humid Tropical Forest Agriculture	Wettest region with rainfall greater than 1500 mm/year. Usually no constraints to rainfed agriculture. Main emphasis on water control and drainage of coastal and inland swamps, although some irrigation of vegetables in short dry season.	Dry season and small areas commanded by channels Wet season and mangrove/coastal swamps	Small earth dams commanding downstream area in Togo and Benin. Mangrove and coastal swamps with small bunds to prevent seawater instrusion in Sierra Leone and other West Coast countries.
Pastoral Stock Raising	Separated from Dry Savanna because of agricultural practice of sedentary stock raising. Irrigation possible, but involves a radical change in the people's way of life.	Runoff farming	Fodder production from rainwater harvesting in Somalia.
Semi-Nomadic Stock Raising	Climatically corresponds to semi-desert but with establishd semi-nomadic tribes with stock raising as the only agricultural activity. Irrigation involves a radical change in people's way of life but there are notable successes.	Runoff farming	Water harvesting in Turkana for pasture, firewood, crops.
High Tropical and Sub-Tropical Plateau Agriculture	Characterized by elevation (greater than 1500 m above sea level) and low temperatures, which can restrict crops.	Small areas commanded by channels	Chagga tribe, traditional irrigation. Rumphi district, Malawi.
Irrigated Agriculture	Usually situated in the flood plains of large perennial rivers and have traditionaly depended on irrigation.	Dry season Wet season Non-seasonal	Niger, Bani, Senegal, Gambia Rivers in West Africa. Nile, Juba and Shabelli Rivers in Egypt, Sudan and Somalia.

Source: M.G. Kay, et al., 1985. "The Prospects for Small-Scale Irrigation in Sub-Saharan Africa." Outlook on Agriculture, Vol. 14, No. 3, p. 118 (Table 2).

may be very high, and the intensity of rainstorms may lessen the effectiveness of precipitation received. Rainfall averages tend to conceal within season dry spells--which are crucially important over much of the continent--and also do not fully mirror the higher variability at the start and close of each growing season. As it happens, yields of the continent's most important food staple, maize, are especially sensitive to dry periods at germination and tasseling. There is a question of interaction effects between nitrogen and moisture availability. And, of course, some of the crops with the highest calorific returns per unit of labor input (such as manioc, plantains and yams) are now being cultivated on drier lands where supplemental watering may be essential--a natural consequence of population intensification. In the modern sector, it is noteworthy that large farmers have for years used supplemental sprinkler irrigation on their coffee in Kenya, just as others have done on their maize in Zimbabwe. It is unlikely that either traditional or modern farmers would spontaneously devise systems for supplemental, on-farm irrigation if this practice were not necessary and cost-effective.[1]

There are many reasons why in a given country irrigation development may seem necessary to policy-makers. Aridity, removing the threat of drought-induced food deficits, a response to population intensification, creating employment benefits, reducing food imports, growing special horticultural crops and the building of a long-term institutional capability have all been motivating factors. However, perhaps the most potent reasons for perservering in irrigation remain the intangible aspects of its association with modernity, and its apparent promise of increasing political independence. These may be false hopes, but they should be recognized as being perceptually important despite the high costs and poor actual performance of Africa's existing irrigation schemes. Each time the continent experiences a major drought, irrigation comes back into vogue as a "preferred solution."

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[1]A finding consistent with data from other sources, such as remote sensing imagery on African vegetation, which indicates that "dry periods are more severe and frequent than the climate diagrams indicate" (Tucker et al., 1985:373).

The potential for developing irrigation is most obvious where a major river, drawing its water from a distance, crosses into a semi-arid zone. Those countries which in the past were earmarked for irrigation tended to be the ones where a major river passes through dry lands (e.g., Senegal, Mali, Niger, Sudan and Somalia). In these countries, the potential for irrigation depends upon a number of interactive factors:

- Existing commitments (upstream and downstream) of the water budget;
- International control issues where a drainage is shared;
- Degree of seasonal fluctuation in water levels;
- Attractive sites for increasing water storage;
- Hydropower generation with irrigation as an incidental benefit;
- Participation within multinational river basin agencies; and
- Existence of soils suited to irrigation.

There are, however, other opportunities which were missed in the first generation development plans. First, Africa has many medium-sized river systems which have only recently begun to receive serious scrutiny: the Juba in Somalia or the Rufiji in Tanzania are good examples. While some of these systems have begun to be developed, e.g., the Awash in Ethiopia or the Cassamance in Senegal, there are many others whose potential has not yet been assessed. In all, Africa has some 60 major rivers with potential for irrigation development, mostly as yet untapped. This supports Toksoz's contention that "water and irrigation potentials of most developing countries are revised upwards as their information base on hydrology, soils and water resources improves" (1981:9). The most dramatic expansion in estimation of water resources has been in regard to several countries that are not mainly semi-arid: Angola, Zaire, Zambia, Mozambique and Tanzania.

Second, in many African countries a significant proportion of the land surface consists of "valley bottom" or "swamp" lands. The concentration of runoff into these areas, and the presence of clay soils which can retain moisture, offer a widespread opportunity for agronomic exploitation. Indeed, much of the existing population absorption in

places like Burundi or northern Nigeria is occurring on such lands already, through the spontaneous spread of small-scale technologies (involving a mixture of drainage and pumping). We suggest that this is where the major breakthroughs to support increased populations are likely to occur, even if the technology will require an unconventional mixture of drainage and irrigation employed in an horticultural rather than field crop setting.

Third, little attention has been paid to the prospects for lakeside or reservoir-based pumping (Sudan again being an exception). Africa now has several reservoirs larger than 3,000 sq.km. in size, with lengths well in excess of 100 km. (Akosombo Dam on Ghana's Volta River created a reservoir of 8,730 sq.km. and required resettlement of 80,000 people.) As more large dams continue to be built, many countries are acquiring a lengthy reservoir upstream from hydro-power generation--a situation which if it occurred in Idaho or California would be followed by rapid exploitation for irrigation. In East Africa, there are already freshwater lakes from which water could be pumped, and hydro-electricity is surplus to national needs. On the negative side, the very high voltages being installed for long-distance power transmission make it extremely expensive for irrigation operators to tap into the national power grid.

This report does not endorse the high estimates of African irrigation potential as discussed above, but neither can they be rejected out-of-hand. Basically, such estimates are arrived at by overlaying information on water availability on a mapped distribution of moderate to high potential soils. For much of Africa, neither source of data is complete and reliable. Any estimate of irrigation potential remains hypothetical until verified by actual field surveys--a daunting task when such huge areas must be evaluated. Here imagery from remote sensing might provide a usefull cross-check upon national estimates (see the National Academy of Sciences, 1977; Deutsch, et al., 1981; Barret and Martin, 1981; and Tucker et al., 1985). General reviews of African hydrology are available in the working paper prepared by Vincent (1984) for this study (see Appendix A) and in Jackson (1977), Pereira (1973), Lal and Russell (1981), Ledger (1969), Rodier (1963) and Walling,

et al. (1984). A final word of caution is that any system of resource assessment based only on natural factors can lead to misleading policy implications if comparative costs and returns are ignored. The physical possibility of there being major hydro-electric and irrigation developments in tropical Africa does not insure that such investments would be cost-effective.

2. Conjunctive Groundwater Use

There are also substantial areas of Africa where because the higher lands are situated around the periphery, the lay of the land would seem to favor groundwater accumulation within the interior. Geographers recognize five major river basins on the continent: the Djouf Basin (Niger River); the Chad Basin (the Logoni/Chari Rivers); the Sudd Basin (the Nile River); the Zaire Basin (the Congo River); and the Okavango Basin (the Zambezi River). If, for purpose of illustration, we take the Chad Basin, it is claimed that Quaternary sedimentation is about 2,000 feet (470 m) deep and contains sandy zones which are important aquifers (Pullan, 1969:126). The other river basins also contain sites which are locally favorable for groundwater extraction, as do some of the coastal plains and deltas (though such water is often saline). These prospects have led some observers to speculate that conjunctive groundwater use should be developed for irrigation similar to what has been achieved in parts of Pakistan and northern India.

In actuality, however, even in the Sahel and Sudanic zones of West Africa, there are large areas where rocks underlying the catchments are impermeable, the soils have low infiltration capacities and evaporation losses are high. Such areas produce little groundwater recharge, despite topographically favorable conditions (Ledger, 1969:90). Rodier (1963) points out that there is little variation in geological conditions in Africa's vast tropical regions (excluding East Africa's highlands), which are underlain either by the old granite gneissic shelf of pre-Cambrian rocks or a cover of Ordovician sandstones. In the former, "There is no possibility of finding deep underground reserves," while in the latter there is "...very little possibility" (Rodier, 1963:184).

Along the continent's eastern side, the groundwater situation is complicated by the Rift Valley system of volcanic mountains and internal drainages. The mountains do sometimes provide aquifers, but water quality is often a problem both on the slopes and in the alkaline basins. Elsewhere one encounters the same pre-Cambrian continental shield, which produces a characteristic topography of peneplain and inselberg hills. Boreholes (i.e., tubewells in U.S. terminology) drilled into this kind of weathered, metamorphic rock typically have limited yield and slow recharge.

There are many technical difficulties which accompany the use of limited recharge borehole supplies for small-scale irrigation: the high opportunity cost of water (which is also being used by people and livestock), dangers of drawing a well dry and consequent damage to the drill rods, problems of shut-down when fuel cannot be obtained, etc. To date, the communication between hydrogeologists, drillers and consumers of water has been poor. Drillers have seemed unaware that in weathered, hard rock conditions most recharge occurs in the first 10 to 15 m of depth; except by lucky accident when a fracture zone is crossed, little is gained by continuing to the 100 to 150 m depth commonly seen. Most boreholes have been operated as domestic or community supplies, where the Scandinavians and Dutch have been especially active as donors. Their experience with problems of institutionalizing borehole pumping and maintenance should be drawn upon by any small-scale irrigation projects utilizing this kind of supply (see especialy, Lium and Skofteland, 1983; Falkenmark and Lundqvist, 1984).[1] On the whole, the "hardrock" conditions common over much of Africa do not constitute a favorable setting for irrigation based on conjunctive groundwater use.

The two main exceptions where groundwater can be cheaply developed for small-scale irrigation are along major rivers where the water table may lie close to the surface or on the toe-slopes of hilly and escarpment topography. Both can be significant locally, and do not

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[1] The World Bank has several recent publications dealing with the technical aspects of pumping and water supply. On this topic, see O'Mara (1984).

require deep well drilling with all of its complications. Much of the development of Nigeria's "fadama" soils in depressional areas has been based on provision of shallow wells for irrigation. Carter and others at England's Silsoe College have assisted the Nigerians in experimenting with Asian "washbore" (jetted) low-cost drilling, sometimes with favorable results. The toe-slope situation may not permit "washbore" drilling, but it is a widespread option because of the many places where the ancient African continental plateau has been down-cut by rivers. Planners have been slow to recognize that human populations are already concentrated within this zone because of easier access to dry season water. While the water volume usually cannot support commercial irrigation, it may be sufficient for small-scale or supplemental systems.

3. Soils Aspects

Soils conditions heavily influence project location and site design in those areas where water supplies permit irrigation development. Soils information is required for four distinct purposes: (a) to estimate how much land falls under different land capability classes, a necessary input for area-based planning; (b) to screen out potential irrigation sites where soil conditions will be problematic; (c) to assist in determining project layout, based on topography and estimates of agricultural potential; and (d) to arrive at cost estimates for surface irrigation, since potential water losses may determine whether or not canal lining is required.

These four uses of soils information require quite different densities in regard to data coverage. A good reconnaissance survey may be quite sufficient for regional planning at a district level, but inadequate to show whether or not irrigated development is actually feasible. Similarly, to classify soils under the USDA system may require laboratory tests far in excess of what a field engineer may feel is necessary in determining canal layout. A tenet of faith underlying all soil taxonomies is that the soil will reflect local conditions: parent material, slope and past climate. Accurate determination of

soils properties thus requires site specific information, obtained in the past by expensive ground surveys. Aerial photography may speed up the process of soil mapping, but a fairly intensive degree of "ground truthing" remains essential. It should also be noted that different soils properties are significant when evaluating construction costs from those that determine agronomic capability (the difference in the United States between the USBR's "unified soil taxonomy" and USDA's agronomically-related classification system).

A frequent problem in Africa has been that the necessary types of soils information are not available on an appropriate scale at the times when projects are being selected or when they are being designed. Because soil surveys tend to be expensive, they are easiest to finance under project funding--but this assumes ipso facto that the project itself should proceed. If a country is lucky, irrigation planners may have access to an experienced soil scientist willing to undertake a quick site visit before project funding is "locked in." More typically, what happens is that survey results do not become available until the project is already at an advanced stage when relocation or redesign cannot be considered.

Contributing to the difficulty of using existing soils surveys is the employment of different taxonomies between the various major donors active in Africa. While other donors have often used the "unified systems" preferred by USBR and the Army Corps of Engineers for construction purposes, in assessing agricultural potential, each tends to prefer its own classification. Most widely used in Africa is the FAO world system, followed probably by the French-derived system in Francophone countries, and sometimes USDA's system. However, in Zaire one will encounter the Belgian system and in Angola and Mozambique a Portuguese version (also employed in Brazil). It is at present difficult to cross-relate soil types between these five systems. While USAID typically requires that the USDA soils classification be used in its projects, local counterparts are likely to have been trained in either the FAO or the French system. The overall effect of having several overlapping and noncomparable typologies in use is to minimize

the carryover between projects and to limit the accumulation of soils expertise within individual countries.

Whatever the difficulties, access to relevant soils information remains a critical need within African irrigation development. By general consensus among those working in the field, soils related problems are often significant. If soils are sandy, water losses will be high and it becomes uneconomic to employ surface irrigation (here, despite higher investment costs, sprinkler irrigation might become desirable). Clay soils retain moisture, making canal lining unnecessary, but during the rainy period become waterlogged, and thus are most suited to "wet foot" crops (like rice). Certain types of clay permit pre-irrigation (e.g., in coastal Somaliland), others do not. The peaty soils in highland marshes (of Rwanda, Burundi and western Tanzania) may be quite acidic, as are also West Africa's coastal mangrove swamps. Under acidic conditions plants may suffer from ferric or aluminum toxicity as well as from rapid depletion of micronutrients (IITA, 1984:123). Similar appearing clayey pans in the Rift Valley zone of East Africa are instead quite alkaline, and may behave quite differently under cultivation. Being part of a very ancient land surface, African soils in the lowland tropics are often leached of their nutrients, whereas the plateau soils may soon form an "ironstone" cap when intensively used. One must go above the 6,000 foot level before humus is accumulated in the soil in the way it would within temperate lands. (It is no accident that the "agrarian miracles" of Africa occur in the Kenya highlands and on the Zimbabwean plateau.) Elsewhere, instead, some agronomists regard soil fertility limitations as being an even more severe constraint upon long-run agricultural development than are moisture deficits (see the summary of Humpal's paper in Appendix A).

The prominence of such problems throughout much of the continent indicates that the success of irrigation on the alluvial plains of the Sudan (the Gezira and Rahad schemes), Mali (the Office du Niger) and in Kenya (the Mwea Scheme) may represent a special case. Sites which have rich and uniform alluvial soils near a major river are unusually advantageous for irrigation. Its success in these environments does not mean that equivalent productivity can be achieved on the highly

variable, nutrient depleted soils otherwise seen--particularly if the intention is to establish large-scale systems employing a uniform layout. At a minimum, careful review of soil characteristics should precede a commitment to particular project sites.

4. Existing Systems

Most African countries display a range of irrigation technologies, traditional as well as modern, at varying levels of scale (Tables 5 and 6). However, the gap in middle-sized schemes (200 to 500 ha) makes a smooth transition from small to large schemes unlikely. Technology choice has not been demand led, and policy-makers have tended to ignore the less glamorous, indigenous alternatives (sometimes flooding traditional irrigation in order to introduce the modern, large-scale equivalent). Thus, the bipolar categorization of projects into "large" versus "small" types is in this instance justified. While some government-sponsored "small" schemes may mimic the faults of the large ones, there are virtually no large schemes of the owner-operated variety.

Africa's large-scale schemes--with Gezira being one of the largest in the world, big even by Asian standards--are usually bureaucratically operated, irrespective of whether they are ostensibly "public" or "private." Usually, they have specialized management, resident engineers, bureaucratic staff, single-channel marketing and a uniform layout accompanied by standardized operating procedures. When one speaks of "the Gezira" or "the Mwea" system, this is no mere figure of speech: the field organizations follow a distinctive set of rules which constitute the core of main system water management within the scheme's territory. The commercial variant is largely comprised of "turnkey" sugar irrigation complexes, perhaps more efficient than the government schemes, but quite similar organizationally with the added twist that the local people may be involved only as day laborers. Since such schemes are usually given priority in water allocation, and operate with many subsidies and a protected local market, the distinction betwen "public" and "private" becomes blurred. These days most private

large-scale irrigation schemes operate under close governmental supervision and are partly government owned. A strong case could be made for more exchange of experience between the better run "private" examples and some of the more inefficient "public" parastatals.

The label "small-scale" covers a greater diversity in project types. Generally, these are below 1,000 ha in size, where it becomes difficult to sustain the irrigation bureaucracy usually associated with the larger schemes. Best known are SAED's perimeters along the Senegal River (at Bakel, Matam and elsewhere). Here the parastatal agency (like ONAHA in Niger) works with farmers' associations by deliberate policy, giving them financial and technical assistance in return for acceptance of SAED's operating rules. As Adams' (1981) account indicates, such projects often have more of a "top-down" character than the sponsoring agency cares to admit. Similar physically, though organizationally more diverse, are the various NGO irrigation projects, such as Kortenhorst (1983) describes for Kenya, and Zimbabwe's Sabi Valley projects (Roder, 1965). However, Nelson-Richards' (1982) account of one such project near Lusaka, and our own of the Action Blé-Diré in Mali (1984:79-96) show there is no magic in being small. Small projects in Africa can be just as bureaucratically controlled as are large ones. They may have very high unit costs if one considers the few beneficiaries. And they encounter just as severe technical problems, sometimes beyond the competence of the sponsoring agency to solve (witness Keller's critique of Bakel's float-mounted pumping stations).

Traditional and nonformal "small-scale" irrigation takes still a different form in many countries (Tables 5 and 6).[1] Found across a range of ecological situations, these systems may be institutionalized at the community or clan level, but more typically are developed by individual farmers (here see Fleuret's depiction of furrow irrigation among the Taita of Kenya). Across the Sahel zone of West Africa are found traditional water lifting devices like the shaduf, these days as

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[1] Derived from the work of R. Carter, M. Kay and others at England's Silsoe College, who along with the Intermediate Technology Group in London, are providing the lead in technology development suited to small-scale production.

likely as not replaced by a farmer-purchased Honda pump. The spontaneous spread of small-scale pump systems for irrigated horticultural crops is a recent development, indicating that farmers found earlier labor-intensive methods (e.g., "calabash" irrigation such as one sees in Mali's Bandiagara Plateau) unsatisfactory. However, in oasis gardening or limited recharge situations over-pumping for irrigation from scarce supplies upon which people and livestock also depend is a genuine danger. So far, the very small field sizes--usually less than a hectare each--and the unreliability of pumps under field conditions have minimized this risk.

Least familiar to outsiders are the technologies in use for growing rice and other crops in "valley bottom" or "swamp" situations. Called bas fond cultivation in Francophone Africa, the technology was initially devised by farmers themselves (see Richards' important study, 1985). To use such "wetlands" (as they would be termed in the U.S.) requires a combination of drainage and supplemental irrigation techniques. These are of much greater potential importance in Arica than has been realized, a point we address later in our review of irrigation agronomy.

5. Engineering Aspects

To engineers assisting African irrigation, one of the first lessons is the problematic nature of the water supply itself--whether because of fluctuating levels, sediment loads, salinity, unreliable equipment or its complete absence when most needed. Projects must often be designed without adequate hydrologic data, but the engineers will carry the blame if a system fails. (Sometimes water cannot even be provided for construction crews at site.) It is obvious that when supply is in question, one does not worry too much about conveyance options--perhaps one reason for the predominance of civil over irrigation engineers in the past.

Within the drier lands where irrigation takes priority, potential evaporation (and hence, plant water losses to reduce heat stress) tends to be high during most of the year. High temperatures, low cloud cover and drying winds result in evaporation of the top two or more meters of

water storage over the season, greatly reducing the effectiveness of small or shallow reservoirs. This also explains why African landscapes receiving what would be ample rainfall in temperate zones still appear semi-arid in vegetation and character. The effect of high evaporation and limited groundwater recharge is that rivers flow only during the wet season, unless they tap large drainages (Ledger, 1969). During the rains, exposed areas of bare soil are particularly vulnerable to high intensity thunderstorms which are characteristic of the tropics. The removal of soil through wind and water erosion takes place rapidly. While some of Africa's large rivers (like the White Nile) have relatively low sedimentation because of inland swamps through which they flow, the same is not true of smaller rivers. These carry high sedimentation loads, sufficient to fill smaller reservoirs within 15 to 25 years. High rates of sedimentation should be allowed for in the design of storage reservoirs, the choice of canal gradients, planning of maintenance requirements and estimation of project life. All in all, the difference in relationships between runoff and reservoir capacity make small and medium-sized dams far less attractive as possible sources for irrigation water than might be the case in temperate zone conditions.

Another frequent supply problem is the failure of intake structures. Sometimes a dam simply washes out, a consequence of the size of the drainage needed to obtain an assured supply. On rivers, the inlets for pumps become clogged after floods or are left high-and-dry as water recedes--the main inpetus behind Senegal's experimentation with float-mounted pumps. It is not unusual for the whole riverbed to shift its location after a severe flood. In such circumstances, the entire irrigation system is put at risk. It is unlikely that engineering expertise involved at the construction phase can be called upon, especially if outside consultants do project design and construction supervision (as is typically the case). Another consequence is that design faults get repeated in project after project, since there is no feedback linkage from operators to the civil engineers who do the initial site design.

A second set of lessons relate to the changes needed in one's operating procedures to compensate for environmental conditions: shoddy

workmanship, mismatched parts, fuel shortages, high transport costs, etc. For example, canal lining can be very expensive in rural Africa, given the high foreign exchange content of imported cement in rural transport. Orphaned equipment which cannot be supported locally with spare parts or informed servicing is a perpetual problem within USAID-assisted projects (here, see in particular the Action Blé-Diré experience). Project deadlines will assume a timeliness and coordination which cannot be obtained within the local administration, creating predictable slippages which may invalidate the entire workplan. How does one offer pump-based irrigation to large numbers of smallholders if there is no place locally where either money or fuel can be stored? Very specific, mundane problems of this kind occur constantly within African field projects. Each specialist will regard them as somebody else's task, when in actuality the real issue is how to incorporate more realistic allowances into project designs from the very beginning. Because irrigation is a high input, high cost activity at the interface between physical, agronomic and economic systems, it is especially vulnerable to these kinds of systemic unreliability.

A particular problem these days is how to keep pump-based systems operating. A feature of pump-based systems is that when dislocations occur there will be an immediate shortfall in production. While gravity-fed systems allow farmers to postpone repairs or repayment--costs eventually paid when the scheme must be "rehabilitated"--in pump irrigation engines must be kept running and fuel bills paid on a daily basis. As the national economic situation deteriorates, it is common to find that spare parts can no longer be imported and fuel becomes scarce. Field engineers in Africa have never been enthusiastic about installing pumps (because the operator's understanding is so critical for long equipment life), but nowadays many pump systems have come to a complete standstill. For USAID, this is not a welcome message, since otherwise pumps offer an attractive point of entry into irrigation into smallholders (Stern, 1983; Brondolo, 1985).

A third area where difficulties have been experienced is in regard to what farmers are expected to contribute. African peasants are extremely reluctant to irrigate at night, in part because of worries

concerning personal security, but also because of poisonous snakes. It is common for systems to provide night storage of water, either through enlarged canals or separate storage reservoirs (thereby increasing construction costs). Again, schemes designed externally have sometimes left actual field leveling and the provision of field turnouts to farmers' initiative. Without mechanization, peasants find it difficult to level heavier soils, a skill not required in traditional irrigation which involved delivery of water into small "boxes" of a few meters square. Few farmers are familiar with the use of siphons, instead breaking the walls of tertiaries at points where water is desired. When donors supply expensive metal gates, these are soon stolen or lost.

The maintenance of physical works after they have been completed is seen as a major problem almost everywhere in Africa. In part, this appears to be a "common property resource" issue: unless all users do their part, an individual farmer's contribution will be wasted. To expect farmers to supply maintenance freely implies that the system will be highly organized. However, the failure to do maintenance when required may also reflect a situation where there are competing demands upon the farm labor force, as when its timing overlaps with the peak period of labor demand within rainfed cultivation. Also, to the extent that farmers have a part-time commitment to irrigation, or are alienated from the water delivery organization, maintenance is likely to suffer. Then there is the fact already commented upon above that poor design increases the need for maintenance, as does also vigorous weed growth and high rates of sedimentation.

What to do about drainage is a related issue. Because drainage is not essential for the initial operation of a scheme, designers may try to reduce construction costs by minimizing the drainage aspect. Often it will be stated that this, too, is the farmer's responsibility. The danger arises because even in dry environments, tropical thunderstorms do occur, which can quickly destroy an unprotected system. Without well designed drainage, weeds and health hazards increase, and over time there will be a salinity buildup. A further difficulty in West Africa is the extremely flat terrain along the major rivers (like the Niger),

so that to protect the main water delivery system may require extensive (and hence, costly) dikes.

To engineers, an annoying feature of African irrigation is the necessity of anticipating multiple uses of the field area and of water conveyed through the system. African peasants are often short of fuel, forage and staple foods. They will introduce banana plants, hedges, spice gardens, goats and cattle. Whole villages will draw their domestic water out of the irrigation canals during the dry periods. Livestock will trample the field bunds and contribute to erosion on the dikes. A priority area for exchange of experience is to learn how such multiple uses can be anticipated most cheaply within standard designs. Since the reasons for these disapproved practices are firmly anchored within the local economy--often there are no alternatives within farmers' reach--at a minimum, such uses could be planned for in advance.

6. Agronomy

Despite a substantial number of irrigation projects within Africa, irrigation technology is employed on only a few commercial crops--far fewer, for example, than would be the case in comparable U.S. situations. By a very large margin, the main irrigated crops in Africa are either rice, sugarcane or cotton--all three being ones which thrive on the heavy clay soils where most African irrigation is practiced. If the aim is to increase irrigation efficiency on Africa's larger schemes, only a few crops must be dealt with, and usually there is a backlog of tropical research to draw upon (see the summary of Humpal's paper in Appendix A).

While irrigated cotton production tends to be concentrated in the Sudan, Ethiopia and Zimbabwe, the cultivation of rice and sugarcane occurs widely throughout the continent. Relative to world production, Africa's contribution of rice and sugar is not large; the whole continent's production of rice, for example, is less than that produced in the Philippines (Swaminathan, 1984). Of the 6.45 million tons of rice produced in 1982, FAO estimates that 17 percent originated within Africa's modern irrigation; of the 41 million tons of sugarcane, about

half comes from estate irrigation (1985:36-37). While in both crops between 60 and 65 percent of total production is grown under irrigation, more than 5.1 million tons of rice comes from non-scheme, smallholder production (Table 7). Reflecting its southeastern Asia heritage, Madagascar is much the largest producer (600,000 tons), followed in distant second place by Nigeria and Mali. The contribution of Africa's best-known irrigation schemes such as the Office du Niger in Mali, SEMRY I and II in Cameroon, and Mwea in Kenya can be seen in the relatively high proportion of modern-sector rice production within those countries. Nevertheless, our point remains that (with the exception of Madagascar) most of Africa's food needs are not being met from these highly publicized and expensive schemes.

The key policy question for all African crops remains the extent to which moisture availability is the main constraint. If it is, then irrigation in some form--traditional or modern--will be necessary to achieve the production breakthrough desired. Humpal stresses (as already noted) that soil fertility may be even more limiting than water availability. Unfortunately, to rectify nutrient deficiencies by means of fertilizer application usually requires an adequate moisture regime, so that the two factors are interactive. What is needed from researchers are estimates of the cost-effectiveness at varying levels of water and nitrogen application. The optimal response typically requires their joint application, depending upon the particular climate in a given season. There is no mystery about how to obtain higher yields: the trick comes in finding cheap water application technologies and in screening varieties to obtain plants capable of bearing the heavier grain and resistant to insect pests and diseases. On north India's Punjab plain it was the triple combination of thick-stemmed, dwarf wheat varieties, nitrogen application and abundant irrigation water which made possible the sub-Continent's "green revolution" during the early 1970s.

Why, then, has Africa been unable to repeat the success of high yielding wheat and rice varieties in Asia? The most obvious reason is that the main staple foods in Africa are not rice and wheat, a fact illustrated by the striking contrast between Madagascar and the rest of sub-Saharan Africa. The traditional foods in the drier lands were

TABLE 7

IRRIGATED RICE PRODUCTION IN MAJOR PRODUCING COUNTRIES
(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

[a]Total production of rice in all sub-Saharan Africa is estimated to be 6.45 million tons.

Source: FAO Investment Centre, 1985. "Irrigation in Africa South of the Sahara," Table 16. Rome: FAO.

millets and sorghum, now largely displaced by maize, while in wetter regions they were root crops, particularly bananas and cassava (Leakey and Willis, 1977) and upland rice (an African domesticate). However, with the exception of part of the West African coast, the trend is toward ever-increasing reliance upon maize--and with it, an increased vulnerability to drought.

Wheat, too, is gaining in popularity (especially within the Sahel), but it remains largely the urban consumer's choice. In African conditions wheat production is comparatively expensive, has a high import content, suffers from many diseases and shows (with a few exceptions) low yields. Very few irrigation projects have been able to recover their production costs on irrigated African wheat (see the Action Blé-Diré case in Moris, Thom and Norman, 1984).

Irrigated sugarcane is an African success story (vide highly efficient irrigation complexes like Zimbabwe's Hippo Valley), but the collapse of international sugar prices has put the entire industry in jeopardy. Also, with a few exceptions like Swaziland's Vuvulane outgrower project (Tuckett, 1977), irrigated sugarcane is grown under "enclave" conditions with little participation by local farmers.

While maize production is highly sensitive to moisture deficits, the value obtained per hectare cannot justify installation of surface irrigation. In extreme conditions such as along the Somali coast, maize is sometimes irrigated, but this takes place on ex-Italian lands where irrigation was originally installed for horticultural purposes. It is now realized that variability at the start of the rains (affecting maize germination) and short dry periods within the growing season (affecting tasseling) are common over much of East and southern Africa, where maize is the staple crop. The extent of the problem was not adequately realized in the past, since it is masked when rainfall statistics are aggregated into monthly totals. More recent analysis according to pentades (5-day intervals) and employing computer programs to scan data for moisture shortfall in the immediately preceding and following periods makes it plain that moisture limitations exercise a very powerful effect on maize yields throughout tropical Africa. The problem is rather that there is no known low cost technology which might deliver

supplemental irrigation to smallholders' fields at the times when maize is under the greatest moisture stress.

Which brings us full circle to the prospects for introducing IRRI's "miracle rice" varieties to boost African production. The first limitation is obviously (with the exception of Madagascar) that the larger share of Africa's rice is grown under rainfed or valley bottom conditions, without full irrigation. However, it now appears that because of different pests and diseases, Asian rice varieties have not performed well. Iron toxicity has been a problem, as has also rice blast (Pyricularia oryzae). Yield reductions due to weeds are on the order of from 33 to 100 percent. As with maize, rice planted on well-drained upland soils is very sensitive to short dry spells, requiring varieties tolerant to drought. Breeding is continuing at ITTA in Ibadan and through WARDA in Monrovia (the main source for rice improvement in West Africa), but imminent breakthroughs are not anticipated (Zan et al., in Hawksworth, 1984:64-70; see also the summary of Humpal's paper; Are, 1975; and Buddenhagen and Persley, 1979).

Swamp cultivation of rice along the West African coast represents a special and interesting case (Owen, 1973; Richards, 1985; Pearson et al., 1981). Here marine incursion into former river valleys has created substantial areas of mangrove swamp. Farmers devised their own techniques for diking small fields into which fresh water was channeled, even though subsurface water was saline. More recently governments in Sierra Leone, Liberia and neighboring countries have instituted "swamp rice" projects based on conversion of mangrove swamps to wet rice cultivation. These projects have not been very successful, and the question naturally arises whether or not assistance to West Africa's upland "dry rice" might not be more cost-effective.

What most African irrigation schemes other than the private ones share is their concentration on heavier clay soils, or "vertisols" (as they are termed throughout the continent). The high clay content makes it difficult to work such soils without heavy equipment, but at the same time they retain moisture and thus prolong plant growth into the beginning of the long African dry season. Almost everywhere such lands are prized these days, though called variously "mares" or "bas fonds" in

Francophone Africa, "fadamas" in Nigeria, "mbugas" in East Africa, "dambos" in Zambia and "vleis" in Zimbabwe. Farmers mimic the recessional cultivation found on the larger rivers by cultivating downslope as the valley bottom dries out. Various techniques are applied such as mounding, tie-ridging, etc. to permit earlier planting of non "wet-foot" crops (e.g., yams and sweet potatoes) and also to trap residual moisture at the wet season's end. At present study of these indigenous technologies has hardly begun; it is another case where because the system differs from both full irrigation and rainfed arable farming, it is simply ignored by scientists.

It is also not sufficiently realized that Africa irrigation development accelerates the diffusion of weeds over the landscape. Humpal (personal communication) notes that when irrigation perimeters are built, frequently the land is not fully cropped. Weeds then rapidly colonize the disturbed soil. They out-compete introduced crops if irrigation water is poorly applied, and they thrive when maintenance is neglected. The weeds introduced in this fashion may constitute serious crop pests, e.g., the "red rice" observed by Keller and Weaver in a 1983 visit to Tanzania's Ruvu scheme. Once established, the weed seed gets incorporated into the harvested crop and is soon spread elsewhere (inspection of cereal grains is poor in many African countries). Furthermore, there are wild and indigenous varieties of both rice and sorghum which may cross with or out-compete the introduced ones (Harlan, 1975).

A critical agronomic issue is whether or not African schemes should aim to institute double-cycle irrigation, giving two crops per year instead of one. This transition has already been achieved in much of Asia, and seems relatively painless where communities depend mainly on wet-rice cultivation. It has the apparent attraction of spreading fixed investment costs over a larger volume of production. Once again, Africa differs from Asia. Adding a second irrigated cycle may mean that crops will be maturing under the drying Haramatan winds (in West Africa) or under cloudy skies (in East Africa). Service agencies typically use the break between seasons for restocking inputs and refueling. Farmers have rainfed cultivation uppermost in their minds, and will give it priority

over their irrigated plots. While several African schemes have attempted double-cycle cropping, it cannot be sustained until local farmers have made the transition into commerical production and the input delivery system functions reliably.

A final and welcome development to note is the coming to fruition of the first generation "farming system's research" projects in Africa (see Simmonds, 1985; Gilbert et al., 1980; Ruthenberg, 1980; and Shaner et al., 1982). FSR (as it is called) provides the framework which was missing for relating information on individual components into an overview of how tropical ecologies behave (Okogbo, 1984; Norman et al., 1982). Descriptive information about the African environment has greatly improved in recent years (here see Kowal and Kassam, 1978; Harris, 1980; Owen, 1973; and Richards, 1985). Even so, while some form of irrigation is seen in most ecotomes (Tables 5 and 6), attention to this aspect has been missing from the early farming system's analyses (though quite well covered in Ruthenberg, 1980 and Arnold, 1981). In Part III, we recommend the immediate inclusion of irrigation studies into ongoing FSR projects.

7. Environmental Impacts

In hot tropical climates, several of the most debilitating human diseases are water-linked. The linkage may be direct, through contamination and water conveyance (e.g., cholera); or it may be indirect, by providing a more favorable environment for parasite vectors (e.g., schistosomiasis, malaria, sleeping sickness and river blindness). Some of these health hazards are so extreme that areas of otherwise fertile land have been abandoned, e.g., because of river blindness (in West Africa) or human sleeping sickness (in East Africa). Other water-linked diseases are spreading into new environments, e.g., cholera and schistosomiasis within recent decades. The latter disease is so prevalent in African irrigation schemes that an increased incidence should be automatically entered into appraisal estimates as one of the costs associated with irrigation development. Belated efforts are now being made to modify the design of hydraulic structures,

taking into account the health risk factor. This remains a major area where further exchange of experience between countries and disciplines would be beneficial (Owen, 1983; McJunkin, 1975; Jewsbury, 1984; Mather, 1984).

Under tropical conditions, irrigation will usually be accompanied by vigorous weed growth--in water as well as on land. Rapid colonization of distribution channels can soon clog them, particularly if they are designed with a flat gradient. In fields, hardy tropical grasses may out-compete introduced rice, e.g., the "red rice" problem. Most damaging of all, the introduced water hyacinth (originally a native of Brazil) has spread in three decades from Zaire into Uganda, the Sudan, and even to Zimbabwe. In all these countries it has become a major pest, choking waterways, removing oxygen from the water and thereby eliminating fish, and even clogging power turbines and water control structures. As with the incidence of health risks, the incidence of weed growth is a dynamic factor which changes over time and is difficult to accurately anticipate in the initial design. Recourse to herbicides is not always feasible because of the large areas which are infested, the comparatively low value of localized production, foreign exchange limitations on imported inputs and unknown cumulative effects when introduced into complex food chains within relatively closed river systems (Obeid, 1975; University of Gezira, 1979).

8. Social Aspects

Because the creation of a water delivery system precedes the organization of farmers on larger irrigation systems, and because of a mutual lack of understanding of each other's disciplines, neither water management specialists nor social scientists have a clear idea how technical and social systems interface. The points where some coordination is necessary include:

- How land and water rights are acquired and allocated;
- The physical design of a system in relation to existing land use;

- Any activities where farmers participate in the planning and construction of the system;
- The timing of water releases, and thus of farmers' labor input;
- Constraints on irrigation generated by farmers' preferences and other enterprises;
- Arrangements for any common services provided by the scheme, e.g., puddling or transport;
- Systems for conflict resolution linked to water management;
- Any maintenance contributed by farmers;
- Organization of crop marketing if done jointly;
- Repayment by farmers of scheme costs and operating charges;
- Backward and forward linkages generated by irrigation on the larger economic and social system; and
- Increased health costs associated with irrigation.

While three of these are particularly important--water allocation, maintenance and conflict resolution--orderly implementation of scheme activities requires many other linkages with the social and economic lives of farmers. The complexity is such that neither the technical nor the social aspects can take automatic priority.

Two observations stand out clearly from our preliminary review. First, irrigation technologies differ greatly in what is expected from farmers and in the demands they impose on the economic system. Surface irrigation based on canals and flood basins will require far more modification of the physical environment than, say, a pressurized system employing portable piping and overhead sprinklers. Capable field engineers can usually provide water for crops in several ways. There is no intrinsic reason why social factors cannot be considered when choosing an irrigation technology.

Second, the popularity of small-scale pump irrigation systems (responsible for their rapid spread throughout much of the Sahel) is probably because such systems make minimal demands upon the farm household. A farmer buying a pump retains almost complete control over its use, subject only to fuel availability and access to repairs. At

the other extreme, a tenant who takes up an irrigation plot within one of Africa's larger schemes must usually accept many controls: on residence, inheritance, use of water, choice of crops, planting of trees, keeping of livestock, marketing of crops, and even (in some schemes) permission to use modern transport. To a considerable extent the negative features of large-scale irrigation in Africa are not dictated by the technology--as scheme managers sometimes claim--but instead grow out of the linkage of irrigation technology with organized human settlement. To civil servants, it has often seemed that the only reliable way for extracting cost repayment from subsistence-oriented farmers was if their residence and the marketing of the main "official" crop were tightly controlled. This is the "false lesson" which Palmer-Jones (1981) points out the Nigerian Government drew from its own early irrigation schemes. Of course, by instituting bureaucratic means for cost recovery, African countries find that irrigation development becomes still more expensive to pay for the infrastructural and overhead expenses associated with managing a large settlement scheme. In small-scale pump schemes farmers instead pay for their own fuel and spare parts, in effect a "water users' charge," and thereby avoid most of the complications associated with living on the territory controlled by a large bureaucratic agency.

Several features of indigenous African socioeconomic organization complicate farmers' likely response to the adoption of modern irrigation technologies. First, there is the constraint imposed by the tiny size, mixed cropping and non-contiguous pattern of many farmers' fields. Physically, this makes the design of a common system difficult; economically, it means farmers have insufficient cash flow to support major capital investments on their land. Second, over much of Africa a woman and her children constituted the basic food producing unit. Addition of an irrigated plot as a speculative investment by a husband does not necessarily guarantee the family labor it requires (here note that both rice and cotton are very labor-intensive), nor will it automatically benefit other members of the household. Third, the small-scale, incidental nature of traditional irrigation caused it to be viewed as a hedge against famine but not as a person's primary farm

investment. Fourth, until now most yield increases in Africa have occurred because of expansion into new lands rather than intensification within existing production. Specialized, mono-crop farming of the kind traditional in Asian "wet rice" communities has been rare in the African setting. And fifth, within the drier lands where irrigation is often proposed, it competes with livestock and trading enterprises for a farmer's capital. Depending on how it is planned, irrigation can hinder or support the keeping of livestock (see FAO, 1983).

The sphere where modern irrigation most immediately impinges upon farmers' livelihood is in respect to land and water rights. Construction of large schemes has usually meant moving existing cultivators off the land (creating a new category of ex-farmers, the "ousted"--or perhaps "evictee?"). If compensation payments are delayed (as has happened on Nigeria's schemes), those dispossessed may be left with no source of livelihood. This is not a "minor" problem. In a semi-arid environment, the lands flooded by a dam or required for its official irrigation will be densely settled bottomlands, nearest to existing water. Water retained in the reservoir will deny downstream "decrue" (or recessional) cultivators their livelihood as well--a point made by Mary Tiffen in her background paper for this study (see Appendix A). There are several horrifying case studies in the Adams and Grove volume (1984) as well as in Heyer et al. (1981) that illustrate this danger. Planned developments on the Niger River may in the future have the same negative impact on Mali's populous inland delta (Moris, Thom and Norman, 1984).

Analytically, aside from the question of what size plots farmers should be given, there are several dangers inherent in the process of transfer of rights into a new system linked to an irrigation scheme. At issue are:

- How to incorporate original rightholders and recruit new members;
- Whether traditional rights of easement are recognized;
- Which legal system to follow in regard to inheritance;
- What protection is afforded women and minors;

- Whether "functionaires" (scheme and agency staff) are allowed membership;
- What compensation is paid if a farmer is evicted;
- Whether to emphasize land or water rights;
- Whether houseplots are treated in the same way as irrigated fields;
- What restrictions upon use are attached; and
- Whether farmerrs can lease or rent their share to others.

The danger of an emergent landlordism is well known; less understood are the problems which occur when traditional easement is denied to pastoralists or when bureaucratic staff divert plots to their own relatives.

However arranged, land tenure provisions should give farmers enough security to encourage investment in their own holdings while insuring an orderly and fair transfer of assets when this is necessary. There is certainly room for further experimentation in the African context (see our Main Report where land tenure issues are explored at some length). Two possibilities come to mind: either to put greater focus on water rights (separating them from the complexities of indigenous land claims) or, alternatively, to divorce ownership of houseplots from field rights (making it easier for families to recover their investment by direct sales).

Uncertainty about how benefits will be distributed may explain why women's involvement in irrigation appears to grow more problematic as a scheme matures. On Mwea--widely regarded as Kenya's most "sucessful" irrigation scheme--there have been riots by women. Young men growing up within scheme villages have difficulty obtaining wives from outside because of the difficulties Mwea's households face (Chambers and Moris, 1983). Certain amenities are very important to peasant women nearly everywhere: clean water, adequate fuelwood, access to gardenplots, the opportunity to raise smallstock and freedom to market produce where they wish. Yet on official schemes designers may have eliminated many of these options--the very things which make an irrigation settlement livable. Eventually people will find their way around the bureaucracy;

almost everywhere in sub-Saharan Africa one ses illegal bananas planted on irrigation bunds, while cattle graze the ratoon growth in the fields.

Women and children are, indeed, the invisible partners who make successful irrigation possible. The great importance of timeliness in many irrigation operations means that for households without mechanization, members must be willing to substitute for each other when one falls sick or is absent. Women in the non-Islamic areas of sub-Saharan Africa do much of the fieldwork which in North Africa or Asia would be done by men. They spend hours transplanting, weeding and harvesting field crops, while their children are vital when bird-scaring is needed before harvest. However, as Dey (1984) and others have shown, it is common for household members to have separate plots. The assumption that African rural households operate as a "family firm" with unified management of labor and cash incomes is false--a significant difference from the pattern in much of Asia (and also in Madagascar). If the male household head is away looking for work--a frequent occurrence--the women left behind may have no authority to spend his money, or even to receive production credit. On the other hand, when family members fall sick it will be the woman who is expected to tend and feed them, a hidden loss of productive time which increases with the incidence of water-related diseases (like malaria) within irrigation areas.

A special case arises when women and children from nomadic, livestock-keeping tribes are left behind (either during drought or because the men are away fighting). Administrators of famine relief and refugee camps have often turned to localized irrigation as a partial solution to wean households from total dependency on outside aid. Kortenhorst (1983) and Schwarz (1983) describe several such settlements in northern Kenya. It is clear that stranded and destitute householders make poor irrigators, and yet this is a very widely encountered situation throughout much of the Sahel, Sudan, Ethiopia and Somalia.

Circumstances such as these may explain why many field engineers working in Africa feel most of the constraints limiting the application of standard technologies are of a sociological, administrative or political nature. Sociologists in turn argue that because of the separation in time between the design and construction phases and the

point when people are expected to operate irrigation systems, engineers can blame "social factors" for all low performance, even when basic design errors have existed from the beginning. Given the prominence in Africa of what everyone admits are "social" difficulties, it is noteworthy how little systematic study has been directed toward the social aspects of irrigation. With the exception of a few recent Ph.D. dissertations, detailed analysis of the key areas of interface between social and technical systems are missing. Instead, one encounters fragmentary and incidental references scattered through hundreds of sources oriented toward answering other theoretical questions. A sustained program of inquiry and research on this topic is long overdue.

9. Economics

The economic aspects of African irrigation are central, despite the general lack of cost data. The overriding policy question is whether the returns to rainfed agricultural investments would not be greater. Then there is the high cost of existing formal schemes--raising the possibility that assistance should go instead to the lower cost, nonformal sector--and the problem of a cost-price squeeze caused by a cap on output pricing (because of controlled prices, competition from synthetics, or world oversupply of certain crops). When irrigation is placed in remote sites, a country must face financing of infrastructural costs and the large transport cost component which somebody must absorb. Once schemes are in operation, they are likely to encounter a severe recurrent cost constraint. Most countries subsidize certain operations in an attempt to make commercialized irrigation more attractive to farmers; is this a wise policy? Farmers who are still at a subsistence level will have obvious difficulties repaying irrigation costs, making cost recovery a major problem almost everywhere on the continent. This, in turn, ought to influence the decision whether or not to seek external loan financing. When loans are obtained, they frequently assume either double-cropping or higher mean yields than the larger economic and managerial systems can currently sustain. And finally, as a country's balance-of-payments deteriorates, it may find

the high import content of modern irrigated production unsupportable. Add all these considerations into one column, and it becomes clear why these days issues related to irrigation economics overshadow all other aspects.[1]

The low ceiling on the sustainability of irrigation in Africa is set by farmers' dependence on hand labor and their limited entry into commercial production. In Kenya, for example, it is estimated that 54 percent of farmers in 1976/77 had holdings of less than one hectare (de Wilde, 1984:13). Where acreages are so small and farmers employ only hand tools, there is little scope for financing capital improvements of the kind associated with modern irrigation--unless, of course, farmers pool their resources within some form of cooperative or water users' association. Considered individually, African smallholders lack sufficient cash flow to support an expensive technology, both in regard to the initial investment and with respect to working capital. This explains why at present profitable irrigation is confined either to small-scale pump irrigation of higher value horticultural crops, or to large-scale commercial and parastatal production.

Assuming for the moment that irrigation will continue, there are at least eight strategies which would promote greater adoption. Many are already being employed in those countries where irrigation is established. The eight are:

1. Lowering costs by changing the form of the technology.
2. Subsidize major elements within irrigation development.
3. Do not charge infrastructural costs against projects.
4. Work with groups of farmers (pooled resources).
5. Insert surrogate managerial organizations (irrigation parastatals).

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[1] Starting references on irrigation economics include Bergmann and Boussard (1976); de Wilde (1984); Eicher and Baker (1982); Hazelwood and Livingstone (1982); Humphreys and Pearson (1979-80); and Pearson et al. (1981).

6. Encourage larger units by squeezing out smallholders.

7. Confine irrigation to high value crops.

8. Confine irrigation to sites where demand is high and transport costs are low.

From an external standpoint, it seems that some of the problems associated with African irrigation arise because inappropriate or expensive strategies have been employed to promote irrigation. In small economic systems characterized by such a high degree of dualism, it is unlikely that the choice of irrigation technology can be demand led. Instead, civil servants or outside consultants are frequently the ones who choose how irrigation is to be done and what policy adjustments it requires. Often, it would seem, they have not fully anticipated the economic impact of "solutions" which have been adopted to facilitate the spread of irrigated agriculture.

The deteriorating economic situation in sub-Saharan Africa has had a direct, immediate and strongly adverse impact on irrigation (see Pottan, 1984 on Madagascar). First, there is a cost-price squeeze affecting particularly sugar and cotton (and thereby threatening the entire irrigation sector in the Sudan). Second, borehole supplies ("tubewells" in Asian parlance) cannot survive without imported parts and fuel. In attempting to evade the parts' constraint, countries have become increasingly dependent on a large number of donors. This in turn has had the effect of diversifying equipment sources, but increasing local vulnerability because few of them are well represented by in-country suppliers. Third, shortages of fuel accentuate the riskiness of irrigated farming (as observed in Somalia in mid-1984) so that farmers may revert to what are essentially risk-minimizing, "rainfed" techniques even when farming within the irrigated perimeters. And fourth, many African countries are experiencing budgetary deficits such that they are reluctant to give field projects adequate recurrent finance (see the Club du Sahel, 1982; Finney, 1984; Gray and Martens, 1982; and Over, 1983). Managing a water conveyance system requires a continuing input of funds, so that large schemes with salaried staff are especially vulnerable when recurrent funds are curtailed.

While within Africa irrigation retains its magic association with "modern technology," donors have begun questioning the high unit costs typically encountered (Table 8). The costs outlined here for Sahel schemes are probably underestimated. Usually any larger scheme in Africa has expensive external management--though this is not necessarily true in those countries with an existing irrigation bureaucracy (e.g., Sudan, Kenya, Nigeria or Senegal). A single irrigated sugar estate may require 10 to 15 expatriate technical staff, employed at internationally competitive salaries. Then there are unavoidable infrastructural costs: staff housing, roads, crop storage, clinics, etc. A scheme placed in a remote setting like Kenya's Bura West settlement will cost about $25,000 per hectare in 1980 prices (Toksoz, 1981:13). When irrigation is so expensive and concentrated, it inevitably raises questions of basic equity; there is a high opportunity cost for other regions of the country which are denied foreign exchange and comparable levels of investment.

It is also puzzling why small-scale irrigation projects in Africa do not appear to show markedly lower unit costs than do large ones. The lack of a close association between the scale of technology and its unit costs suggests that the relationship is complex, and there are probably several intervening factors. Very expensive schemes can be found at all points across the spectrum, ranging from tiny installations serving a few families to quite large perimeters of several thousand hectares. Donors should not therefore assume that small-scale projects in Africa are inherently lower cost per unit of water delivered than large ones.

Appraisal documents have often contained strong assumptions about the system being evaluated. Possibly the single largest source of error has arisen when the costs of farm labor have been heavily discounted. The standard argument is that farmers enjoy free family labor, and have few remunerative options for their own effort. Even without irrigation, this is seldom the case within present African farming systems where seasonal labor bottlenecks are very pronounced. Recognizing the preference farmers show for long distance trading and their labor input into high priority livestock enterprises, we can be virtually certain that the work devoted to irrigation will be perceived as having a high

TABLE 8

ESTIMATED CONSTRUCTION COSTS FOR SAHEL IRRIGATION SYSTEMS
(1985)

Type	Earthworks	Concrete Structures	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	1,000	5,800[b]
•large schemes, river terraces	2,400	800	1,200	4,800[c]
•large schemes, lowlands	4,600	1,200	1,000	8,400[d]

[a]Plus labor by beneficiaries.

[b]Plus labor by beneficiaries, but includes leveling (US$400/ha).

[c]Includes leveling at US$400/ha (favorable site).

[d]Includes leveling at US$1,600/ha (complete control).

Source: FAO Investment Centre, 1985. "Irrigation in Africa South of the Sahara," p. 41. Rome: FAO.

opportunity cost. These facts are well known in the literature (Wallace, 1981). It seems farm labor costs have been eliminated from benefit-cost calculations because this was the only way appraisers could make benefits look sufficiently attractive to justify the high investment costs. The artificiality of such appraisal estimates will increase over time, since labor costs are likely to rise substantially once the area as a whole begins to develop economically.

Locational and pricing issues emerge as key considerations influencing the success or failure of individual projects. Often, water and land availability have been allowed to dictate where schemes are placed. Afterwards, it will be realized that high transport costs make production uneconomic even if schemes are being efficiently run. Again, imported inputs become very expensive by the time they are trucked to the scheme. To offset these disadvantages, many African countries have tried to set uniform prices throughout the country, absorbing the transport differential through national subsidies (de Wilde, 1984:6). Such policies favor irrigation, but the costs (with a large foreign exchange component) remain to be paid somewhere in the system.

There is a large literature on food policy and marketing in Africa (see Bates, 1981; Club du Sahel, 1977; de Wilde, 1984; Eicher and Baker, 1982; Humphreys and Pearson, 1979-80; McIntire, 1981; Maiga, 1976; Pearson et al., 1981; Singh, 1983; and Wilcock, 1978). The general picture is that many African countries have tried to intervene, smoothing out price fluctuations by establishing price controls and inserting bureaucratic marketing boards between the producer and the retailer. And, as noted above, input prices and transport costs may be subject to control, also receiving a subsidy. At the same time, the political leadership may wish to subsidize urban food prices on basic staples. The outcome is to put all stages in the production-marketing chain under administered prices, except for what the farmer pays to keep in operation. The temptation to pass rising production costs on to the farmer is nearly irresistable, since scheme managers cannot readily change nationally-fixed prices. At the same time as overhead expenses in the marketing chain balloon out of control, the national leadership fights to retain cheap urban food. As a high-cost technology, irrigated

food production is particularly vulnerable to the resulting cost-price squeeze. During times of drought, concessionary food imports relieve the pressure on the leadership to adjust prices upwards. The "failure" of a scheme in this situation may simply reflect the impossibility of commercial operation under contradictory economic policies.

Surprisingly, the one strategy most African countries have not fully explored (unless pressured to do so by donors) is to lower costs by changing the form of the technology. Table 9 gives FAO's estimates of the incremental paddy output required to justify costs under alternative investment options. By far the easiest interventions to repay in terms of incremental output are minor repairs to existing schemes or assistance to swamp rice. (Note that the costs given for "full control" projects are one-third those evidenced in Kenya's Bura scheme.) The implication is that "modern" irrigation in the form usually seen within Africa to date is probably the least cost-effective option. To make it pay requires realizing high yields from the beginning while enjoying protected markets to keep out cheap imported rice.

10. Institutional Aspects

An important difference between African regions is the extent to which irrigation engineering has become institutionalized within the local system. Professional "irrigation engineers" are a novelty almost everywhere. However, a fairly close equivalent exists in the "genie rural" corps established within most Francophone countries. In Egypt and the Sudan, salaried engineers are attached to Ministries of Irrigation and there is already substantial local competence. Elsewhere, this need has been met by the temporary assignment of civil engineers brought in for project planning and supervision. Once constructed, the irrigation perimeter was usually put under agronomic advice. Africa's agronomists were initially colonial officers, replaced in recent years by local graduates or perhaps FAO and World Bank staff. Thus, attention to the managerial integration of irrigation perimeters as systems has been lacking, except insofar as scheme managers choose to make it their special concern.

TABLE 9

INCREMENTAL PADDY OUTPUT REQUIRED TO JUSTIFY TYPICAL IRRIGATION INVESTMENT COSTS[a]

Rice Price (US$/t)		Desired Rate of Return			
		12%		7%	
		180	300	180	300
		---------t paddy/ha/yr----------			
New Irrigation					
• 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[b]					
• 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]Assuming 68 percent milling efficiency and operating costs equal 30 percent of gross output value.

[b]This case assumes works over three years and full benefits in year six.

Source: FAO Investment Centre, 1985. "Irrigation in Africa South of the Sahara," p. 60. Rome: FAO.

Few African countries know what their manpower situation is with regard to potential irrigation development. Wright and his colleagues at Silsoe (1982) prepared a detailed estimate of manpower requirements for the development of Nigerian irrigation, including identification of technical cadres and the skills required of each. To our knowledge, this is the only such study on the continent. In some countries where irrigation is quite important, such as Somalia, the sections concerned at the Ministry level have no systematic information available on the overall manpower situation for the sector as a whole. Most interventions which AID might consider will require such information, and in any case, it is badly needed for internal planning within the country.

There is a general perception among external technicians working within Africa, irrespective of their discipline, that management has been weak on many African schemes. A partial explanation is provided by a review of African management studies, which found that while universal management principles explain internal agency functioning quite well, local agencies experience difficulties in their relationships to the sociopolitical environment (Kiggundu et al., 1983). Since irrigation necessarily involves linkages which tie production activities into the larger environment at many points, it could be predicted its management will be problematic.

There are seven separate levels where management must be supplied in order to insure the long run success of an irrigation system. First, somebody must undertake macro planning and supervision at a sectorwide or river basin level--a neglected component in many countries. Second, there must be managerial input during the construction phase (generally supplied on larger projects by the contractor and/or outside consultants). Third, when operational, a given irrigation system is often put under some kind of scheme management. This may be a formally organized settlement scheme, a parastatal farm, or simply a small PVO unit attached to the perimeter. Scheme managers are responsible for coordinating the financial, agronomic and farmer inputs into the irrigation system. Fourth, there is usually a need for hydraulic (or "main system") management of the water supply itself. At this level,

the focus will be upon the pumping or intake facility, the distribution system and the scheduling of water delivery to the point where farmers take charge of it. Fifth--though this element has often been missing--there may be a user organization linking farmers who receive irrigation water. Water user organizations can be specialized associations, or simply a part of a larger community system. If they provide allocative, scheduling, repayment, maintenance and dispute resolution functions they, too, require leadership and coordination. Sixth, we must not forget on-farm water management, which is basically how farmers utilize water to grow their crops. And seventh, over time there may emerge a need to manage the socioeconomic and environmental impacts of irrigation.

American analysts coming to Africa from a technical background are likely to perceive the managerial input in relation to only three of these seven levels. They will understand the need for sectorwide and river basin management, for "main system" management of a basically hydraulic nature and for "on-farm" water management, which is largely a question of irrigation agronomy. Approached from this standpoint, the "problems" of African irrigation will usually appear to lie at the interface with other systems--typically either economic, social, institutional or agronomic--and little modification will seem necessary within standard procedures for irrigation management as already developed in other parts of the world.[1]

To date most African countries have relied upon outside assistance when undertaking major irrigation projects (Sudan being the principal exception). Just as each colonial power developed its own approaches, so today each donor injects its own technological preferences into the schemes it finances. The Dutch may build polder-type units, the Chinese make flood-basins for paddy rice and the World Bank perhaps finances dikes for floating rice (e.g., in Mali). Confusions become exacerbated on large, multi-donor projects where one country may supply the extension component, a second the construction financing and a third the

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[1] Two non-U.S. sources which take a wider view of irrigation management are Sagardoy (1982) and Walker (1984).

design and technical supervision. Multiple reporting and accounting systems greatly increase the effort required of scheme management. (We note that FAO's financial year ends in December, the World Bank's in June and USAID's in September.) Dealing with so many donors at the national level will also divert the attention of a country's few engineers, depriving scheme managers of the specialized assistance they need (Haddon, 1980).

Recognizing these problems, African countries have tried to establish their own planning organizations. One set of initiatives were triggered by the 1973-74 drought, which brought into being a consortium of donor nations (the Club du Sahel) matched by a committee of recipient countries, the CILSS organization. The joint Club/CILSS reports outline medium- and long-term considerations influencing irrigation development, and cover most of the topics we reviewed in this report, though only for the Sahel. (An annotated listing of the key Club/CILSS studies is available in Gellar, 1981.)

Another organizational framework has been the river basin authority (or RBA), obviously modeled on the United States' TVA. The initial impetus for RBAs was at the international level, to provide for planning and coordination of development where a river was shared between several states. Most advanced is the OMVS (an interstate organization for the Senegal River linking Senegal, Mauritania and Mali). Other rivers for which authorities or commissions have been created include the Niger, the Volta, the Gambia, the Kagera and the Nile, as well as the Chad Basin (see a 1983 United Nations report for a description of each of these). USAID became closely involved with several of these RBAs through the establishment of a separate office concerned with the Sahel as a region (see Lateef, 1980; Derman, 1984; Joyce, 1978; USAID, 1976; and Brondolo, 1985). In more recent years several countries have also begun to implement RBAs on internal drainages. For example, Kenya has three such authorities, Tanzania at least two and Nigeria no less than eleven. To the exent that there has been systematic planning for irrigation within individual African countries, most of it has been linked to RBAs. However, as Siann (1981) notes for Nigeria, such organizations overlap existing water boards and there can be numerous

conflicts if an RBA begins to take on executive responsibilities for actually implementing projects. Scudder (1980) provides an excellent overview of the social aspects of river basin development, which has been the focus of a separate AID-financed study under his leadership. Given that such organizations already exist, they offer a logical point of attachment for future irrigation studies (see Part III).

Even where RBAs exist, it is common to find operational responsibilities shared between numerous other government organizations. Construction is likely to be vested with the Ministry of Works, main system management under a Ministry of Water Development and Power or a Water Board, agronomic aspects under Agriculture and perhaps social aspects under a Settlement Commission. To give greater central coordination, many African countries have established separate irrigation parastatals at the national level. Best known and documented are probably Senegal's SAED, Niger's ONAHA, Sudan's Gezira Board and Kenya's National Irrigation Board. (Other countries lack such agencies entirely, e.g., Tanzania and Somalia.) While there are obvious differences in scale, in their structure and mode of operations, irrigation parastatals have much in common. They can be reasonably effective if they keep tight control over their costs and staffing, if they monitor individual scheme performance closely and if the agency retains sufficient technical expertise to support field programs. On the other hand, in some countries they face pressure to add unnecessary staff and have been unable to retain their best technical personnel. We consider the need for some executive body at the national level which can implement schemes is so great that irrigation parastatals will persist, despite their faults. We do not see, however, that RBAs and irrigation parastatals are <u>both</u> necessary.

Much less familiar to Americans is the widespread African innovation of a scheme organization. With large farmers, of course, a scheme is unnecessary. The operator may do many managerial tasks directly, and calls upon an external agency only when arranging the water delivery schedule. However, when hundreds of peasant farmers participate in an irrigation system, an intervening level of organization is usually required. Actions taken at the scheme level

encompass many functions which farmers cannot arrange individually: scheduling of water releases in the main system, purchase and replacement of equipment, repayment of project loans, arranging import approval, formulating budgets, paying staff, providing transport, etc. In all these activities the scheme management acts as a surrogate for farm-level decision-making; it exercises the powers which in a large-scale farming system would be vested in individual farmers. It becomes obvious that at present the scheme level is the critical arena to examine if one is interested in issues of irrigation management.

Our earlier discussion of existing systems made the point that large-scale, formal irrigation projects in Africa have developed a paternalistic, "top-down" style of dealing with individual farmers. Almost everywhere in such schemes farmers' participation is regarded as a privilege extended by management (see Chambers and Moris, 1973). We do not think it is coincidental that such schemes are also characterized by high costs, overstaffing, inflexibility and alienation of farmers. The logical question is, then, whether some alternative organizational framework might be devised which could act on farmers' behalf but would be more responsive to their needs.

A U.S.-style "irrigation company" would be one possibility. We consider the more likely candidate would be some form of a water users' association, perhaps structured along the lines of a producers' cooperative--an institutional form already well represented in most African countries. An excellent starting reference discussing this option is Underhill's FAO study, supplemented by Montgomery (1983), Silsoe (1985) and the 1984 Zimbabwe conference (Blackie, 1984). Water users' associations already exist along the Senegal River (see our earlier listing of references), and in Niger. We expect they will constitute the focus for institutional innovation as Africa's irrigation projects learn how to pay more attention to their clients rather than their masters.

11. Lessons for Field Projects

In summary, we have tried to distill what we have learned into a few rules-of-thumb for potential project designers and field staff. No

individual guideline is applicable under all circumstances. We warn these preliminary observations have not been scrutinized by experienced field engineers. Those involved in small-scale irrigation are urged to consult Kortenhort's excellent presentation of the Kenyan experience (1983:28-51).

1. Assume there will be existing right holders, seasonal as well as permanent. If all interested parties stand to gain something, a project is much more likely to succeed.

2. Do not proceed in locations where land or water rights are already contested.

3. Devote extra effort to securing a reliable water supply. Do not depend on small dams unless there is ample local experience to draw upon.

4. Check out hydrological estimates of high and low water levels by actual field interviews with farmers.

5. Use involvement of farmers at the planning and construction phases to create a pool of local skills and to compensate them for disruption of their own activities.

6. Anticipate training and assistance to farmers in doing field leveling.

7. Avoid unnecessary pumping. If pumps must be incorporated, choose them to take into account fluctuating water levels and available support services.

8. Never include "orphan" equipment which is not already supportable within the country and region.

9. Allow double the planned time for establishing the project if it has a major element of construction and is in a remote location.

10. Other things being equal, the project design with the lowest recurrent costs is to be preferred.

11. Avoid loan financing for infrastructural costs. Intensive preparatory work with farmers can often generate simple structures from their own resources.

12. Include subsistence security within irrigation plans, since this will be uppermost in farmers' minds.

13. Incorporate at least one high value "cash crop" to serve as an income generator in the initial years.

14. Pay particular attention to transport costs unless the project is already within a center of demand or will be part of an already operational marketing chain.

15. Make allowance for regular use of irrigation water by households and livestock during dry periods.

16. Assume farmers with only hand labor cannot cultivate more than about 1 to 2 hectares of irrigated cropland.

17. Assume that there will be competition for labor at peak periods and that labor costs will rise over time.

18. Involve local women in the planning and implementation of the project, and obtain their views on all organizational and procedural aspects.

19. Do not expect farmers to maintain structures at their own initiative if these are not located on their land.

20. Avoid plans for double-cycle cropping until farmers are experienced and a commercial input and marketing system has evolved.

21. Minimize paid employment and channel any employment opportunities toward the children of project participants.

22. Expect that cost recovery will be difficult and painful to all concerned. Recovery devices should be preplanned to coincide with times when farm families have access to ready cash.

23. If the scheme design assumes that either money or fuel must be kept within the community, be sure institutional arrangements for this purpose are already effective.

24. Locate the potential sources of health hazard and investigate the alternatives for minimizing them.

25. Avoid becoming a settlement agent. Keep it simple!

12. For Further Study

Some users of this report may not have access to the other two volumes, which expand upon these conclusions. For this reason, a fairly extensive listing of references is included as Appendix B. Several excellent reviews of tropical agriculture with good coverage of irrigation are now in print: Arnon (1981); Ruthenberg (1980); Richards (1985); Okigbo (1984); and Leakey and Willis (1977) are especially

recommended. On the African irrigation experience, Brondolo (1985); Adams and Grover (1984); Rydzewski (1974); chapters in Heyer et al. (1981); Blackie (1984); and FAO (1985) are all useful. The Gellar bibliography (1981) is an excellent guide to other sources, supplemented by Hawksworth (1984). The listing of countries covered in some depth by sources in Appendix B include Kenya, Nigeria, Sudan, Senegal and Mali/Niger.

PART III
IMPLICATIONS FOR DONORS

Issues

The literature already contains three useful listings of the main issues donors should weigh when appraising irrigation development. Two come from AID-financed studies (Berry et al., 1980; Steinberg, 1983: 35-65) and one from the OECD (Carruthers, 1983:68-75). Drawing most heavily on Carruthers, we suggest 15 points on which policy decisions are required in African irrigation:

1. Where and when to subsidize?
2. New projects or rehabilitation?
3. Drainage or more irrigation?
4. Large- or small-scale irrigation?
5. Direct investment or price support?
6. Public or private development?
7. Hydro-power versus irrigation?
8. Hardware or management?
9. Conjunctive use of groundwater?
10. River basin authorities versus individual schemes?
11. Scope for alternate energy sources?
12. Swamp-rice versus rainfed rice?
13. Rightholders versus cultivators?
14. Full Control versus supplemental irrigation?
15. Technology transfer or technology development?

Familiarity with the general arguments advanced by Steinberg and Carruthers is here assumed. We have emphasized instead the special features which may alter standard prescriptions when one is dealing with African irrigation. It will also become apparent that there are not many continent-wide prescriptions. On most issues, each country has peculiarities which will require extra attention in choosing an appropriate strategy.

1. Where and When to Subsidize?

The first issue to consider in regard to irrigation investment is, according to Steinberg, "Who pays?" (1983:43). By now, the relevance of criteria for cost allocation should be obvious. We have seen that African irrigation tends to become inordinately expensive, that smallholders cannot afford major capital improvements, that the typical peasant farm is "energy starved," and that African governments cannot assume increased recurrent cost burdens. Furthermore, well-intentioned plans for double cycle cropping -- introduced primarily to boost farmers' cash flow as a means of enhancing repayment capacity -- are not technically advisable under typical African conditions.

Thus, deciding "who pays" is a core issue which must precede consideration of all others on our list. It is fairly clear that under typical African circumstances irrigation simply cannot pay its own way until the accompanying farming system has reached a fairly advanced stage of commercialization, e.g., supplemental irrigation for Kenyan coffee farms or valley-bottom irrigation on Zimbabwe's large farms. The implication for donors is, therefore, that some element of subsidy is inevitable if a country intends to proceed in developing irrigation. The operational question is then not whether to subsidize, but where, when and with what consequences? If so, a financial appraisal is not enough: a country must also look at the economic costs and returns, both at the enterprise level and for the sector as a whole.[1] Questions to weigh include whether to finance initial construction on a grant basis, leaving the host country to concentrate on financing recurrent costs?[2] Can the nation afford to exempt its irrigation schemes from duty on imported inputs? Should an irrigated cereal crop enjoy a

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[1] An excellent study which does distinguish between financial and economic considerations, private versus social profitability, and marketing as well as production costs is the five nation Stanford comparison of rice in West Africa (Pearson et al., 1981).

[2] Grant-financed initial construction may, in fact, leave countries in a worsened situation because of their acute recurrent cost constraints. Here see Finney (1984) and the whole literature on this topic.

protected local market? What about concessionary food imports? Would rainfed agriculture give higher or more reliable returns from a similar level of subsidy? What aspects can be left for on-farm financing, given that irrigation as presently encountered tends to be highly risky?

2. New Projects or Rehabilitation?

Obviously, in those countries like Niger or Tanzania where the rate at which already developed irrigable land is going out of production exceeds the development of new irrigation, rehabilitaion should take first priority. In recent years, this has indeed been the emphasis among most donors. However, experience with attempted rehabilitation shows the issue is not so clearcut:

- Engineering considerations tend to predominate during rehabilitation, when in fact the greatest need may be for "O&M" modifications.
- The need for rehabilitation is usually linked to a lack of adequate maintenance procedures. Unless these can be instituted within the local system, physical reconstruction will effect only a temporary improvement.
- Where the main system has been allowed to badly deteriorate, the costs of reconstruction can be just as high as for the building of new schemes.
- The pyramiding of new loans on top of old ones creates a crushing financial burden beyond the support capacity of many schemes.
- If the root cause for failure to do maintenance is a tight recurrent cost constraint influencing the whole system, this situation needs to be diagnosed and dealt with at a policy level first.

Thus, while the balance of effort in Africa probably should be directed towards improvement of existing irrigation, it does not necessarily follow that physical reconstruction of these schemes under external loan financing is what is needed. A carefully done, case-by-case comparative analysis of "O&M" deficiencies which makes rehabilitation necessary within existing schemes would appear to be precondition before effective remedial measures can be instituted.

3. Drainage or More Irrigation?

This report has argued that rainfall intensities are such in tropical Africa that drainage must be provided alongside any water supply improvements if these are fairly substantial in size. Farmers' lack of equipment and resource constraints make it unlikely they can add drainage works by local effort. A particular technical problem is how to achieve adequate drainage on the very flat alluvial plains in parts of the Sahel, e.g., along the Niger River or near Lake Chad. Elsewhere for the most part existing schemes can utilize the topography for drainage (provided that care is taken in the initial design). Health hazards and removal of weeds from drainlines must also be considered. For all these reasons, drainage and irrigation must be jointly provided and the drainage component may require careful planning.

4. Large- or Small-Scale Projects?

If in Africa small-scale projects are not necessarily cheaper to build, they are nevertheless easier to withdraw from; managerial assistance by an NGO rather than the government is more feasible; they represent a smaller financial commitment; field layouts can be more adapted to farmers' needs; and there is at least a theoretical possibility farmers will be more involved and consequently more committed. We recommend, therefore, a bias towards assisting small-scale projects and technologies, traditional as well as modern.

This recommendation is qualified by reservations outlined in earlier chapters, and also touched upon by Carruthers (1983:70-71). It ignores the fact that schemes requiring large reservoirs or major canals are bound to be large-scale in nature. It also conflicts with a pervasive opinion within AID/Washington that small projects are just as demanding of supervision and management as are large ones. While this may be true, the consultants drawn upon in this study were nearly unanimous that in Africa smaller, flexible projects on average outperform the larger ones. One final point: these arguments do not rule out experimentation <u>within</u> large systems to decentralize scheme

functions and increase farmer participation, e.g., as the Dutch have attempted in the Office du Niger.

5. Direct Investment or Price Support?

Carruthers warns that for irrigation to succeed, agriculture must be profitable (1983:71): "There is clearly no point trying to enforce water charges or other taxes if farmers do not have a reasonable income." He outlines a downward spiral where governments try to maintain low food prices while maintaining over-valued exchange rates and imposing inefficient bureaucratic controls on agricultural production. When production stagnates, the availability of cheap food aid on concessionary terms removes the pressure to allow a raise in farmgate prices. The dangers of this situation are by now well recognized (World Bank, 1981; Bates, 1981), particularly within USAID. (However, if we accept this argument at the farm level we must also recognize its validity at the country level, where adverse terms of trade vis-a-vis the industrial nations have a great deal to do with the current difficulties of African commodity procedures.)

The central economic issue remains how to introduce irrigation technologies in systems where because of very small farm sizes and low productivity farmers cannot individually afford expensive capital improvements. This explains why so many countries have introduced intermediary institutions whose service charges in turn depress farm prices. While better prices might raise the ceiling on affordable investment slightly, the gap between smallholders' existing technology and what outsiders might recommend continues to be very wide.

6. Public or Private Development?

Carruthers is probably correct in insisting that irrigation development is one sphere of economic activity where both public and private initiatives are required (1983:72-73). This message will not satisfy either side in the continuing debate over "privatization," incentives and bureaucratic reform. The situation is further

complicated because in Africa here "private" does not describe a unimodal cluster of firms. Instead, as a rule the "private sector" in African countries is sharply bi-modal, being split between traditional small-scale farming (and trading) and large-scale, export-oriented "plantation" agriculture, as often as not owned by outsiders. A third group are the missionaries and other NGOs, oriented toward smallholders rather than the plantation crop sector.

While large-scale operators may cooperate with public agencies in sharing experience (something we recommend), their scale of operations is so much larger that on vital managerial aspects they have little that is suited to the smallholder. As noted above, this disparity explains why many African governments of all ideological complexions have been forced to establish intermediary service organizations to assist irrigated smallholder farming. Furthermore, most activities needed for developing irrigation -- testing of materials, design of new systems, modeling of aquifers, integrated planning of groundwater and surface supplies, controlling of saline intrusions -- are not activities the private sector will underwrite (Carruthers, 1983:72). Nor are the individual African regimes eager to see non-national firms play a larger role by being given privileged access to credit or preferential donor assistance. Thus, AID/Washington's policy mandate to give greater assistance to the private sector runs directly counter to local political realities in many ex-colonial African nations. To the extent that "aiding the private sector" will mean giving assistance to outsiders (e.g., Lebanese in West Africa or Asians in East Africa) or even to tribal elites, it often cannot become a stated policy. A possible resolution would be to encourage activities which deepen institutional resources (training, research and extension) available to the whole irrigation subsector.

In regard to small-scale operators, AID has much greater flexibility for rendering support, but comparatively less to offer because such systems are so different from our own. There appears to be a genuine "technological gap" at the micro-irrigation end of the spectrum, where farmers are irrigating market gardens from very limited supplies. As a donor, AID could also underwrite credit for small-scale

operators -- though this should be linked to training because of high risks and frequent failures. AID could do much more to insure technical backstopping for various NGO, PVO and Peace Corps projects active in small-scale irrigation. An assessment of "technology backstopping" needs for small-scale NGO projects might be a suitable topic for an all-Africa workshop.[1]

7. Hydro-Power versus Irrigation?

Hydro-power generation and irrigation needs can come into competition in several ways. If irrigation is developed upstream from power generation, the loss of water can necessitate a significant reduction in hydro-power generation -- as, for example, Tanzania's irrigation schemes in Mbeya Region above the Mtera and Kidatu dams on the Ruaha River. Where power generation lies on the upstream side, the need to maintain flow even in the rainy season will reduce water storage available for dry season irrigation. But much the most important interrelationship concerns the cessation of annual flooding on rivers where this may have been significant to farmers, e.g., the Aswan High Dam on the Nile (Waterbury, 1979). In West Africa, on the Senegal and Niger Rivers, farmers practiced "decrue" (or "recession") farming, planting their crops on river terraces as the floodwaters receded. While not "irrigation" in the strict sense, this tradition made maximum use of scarce moisture and existing clay soils in an otherwise barren environment. It is sufficiently important that the new upstream dam on the Bafing River (a major source of the Senegal's fow) has been designed to provide an artificial "flood" through controlled water releases. For similar reasons, some have proposed that Tanzania's Steigler's Gorge Dam (not yet financed) should also allow for controlled downstream flooding in the Rufiji Delta (Sandberg, 1974). In either case, the artificial "flood" will lack the sediments which are mainly deposited in the reservoir's upper end.

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[1] AID policy on the public versus private issue is discussed at some length in Steinberg (1983:57-60).

One might question spending time on this issue when throughout this report large projects have been downplayed. However, three added facts are relevant. First, the tradeoffs between hydro-power, dry season irrigation and "decrue" (or equivalent, downstream pump) farming are a significant issue in three countries high on USAID's priority list (Egypt, Sudan and Senegal) and also in systems which derive their water from neighboring countries, e.g., Somalia and Mozambique. Second, Africa has tremendous though underdeveloped hydro-power potential. It would be very helpful to have worked out in detail the interrelationships between power generation and agriculture before further large schemes are launched. Third and perhaps most appropos to this report, it is discouraging to see high voltage transmission lines passing right over irrigable lands in countries where water pumping still depends on diesel engines. Hydro-power in Africa has largely been used for industrial development, not irrigation. Since the continent does have such large reserves of untapped hydro-power potential, the present energy constraints within irrigation ought to be viewed as an inheritance from the past and not a constraint upon future development.

8. Hardware or Management?

Many think this is the overriding question to be addressed in African irrigation. It is difficult to answer, because the usual means donors employ to gain influence over project management is through financing increments to "hardware." Without building new schemes, would donors be allowed to assist on "O&M" issues? In Africa, the answer might well be "yes" for the simple reason that Ministries of Agriculture find themselves hard pressed to plan and supervise irrigation development.

In the section on irrigation management, seven types of "software" were identified as potentially contributing to the effectiveness of irrigation in Africa. Not all are operational at the moment -- which partly explains glaring gaps and weaknesses in many of Africa's present schemes. Let us recapitulate what the seven types of management include:

1. Sector planning and supervision;
2. The construction stage;
3. Scheme management;
4. Main system management of the water supply;
5. Supervision and liaison with water users;
6. On-farm water management; and
7. Environmental impact management.

Of these seven levels, some type of "software" (i.e., organizational routines) is definitely required at each level. Nonetheless, few authorities on irrigation recognize more than three or four. Because of the particular problems encountered in Africa, irrigation advisors need to become cognizant with all seven.

A principal message of this report has been that these levels are rarely considered jointly. Each managerial unit concentrates on its phase in the project cycle in the hope that ultimately crops will be grown and farmers benefit. Indeed, one cannot even tell from the literature on most schemes what managerial practices are in general use. One suspects that as currently implemented, project "management" concentrates on physical construction -- always a particularly demanding task in Africa -- with "scheme" management coming in once a perimeter is "handed over." Enough is known about field difficulties to suggest that there is very little margin for error.

Field operations under typical African conditions encourages an opportunistic, day-by-day management style which differs greatly from the procedurally complex routines outsiders often recommend. In stating Africa's need for better "software," we are not implying that the "high technology" routines coming into voque among U.S. irrigation engineers represent a good, or even workable, solution. Instead, the argument is that the managerial sphere must be where attention is concentrated in an effort to lern how and why existing systems "go wrong." Only then can one select among "software" options and design more effective forms of training.

9. Conjunctive Use of Groundwater?

Where water supply from flowing rivers is so difficult, the question naturally arises whether instead irrigation should not draw upon "tubewells" (or "boreholes," as they are called in Africa). At a policy level, the answer obviously must be "yes" -- but strongly qualified by recognition that pumping has a particularly bad record in Africa and that there may be large areas where the low yield from wells cannot support anything beyond a very small patch of irrigation. However, donors could promote the exchange of experience between those working on household and community supplies, often based on pumping, and the irrigation sector in the same country. European donors such as SIDA and the Dutch have put heavy investments into development of community supplies in Africa, and have accumulated valuable experience.

10. River Basin Authorities versus Individual Schemes?

We have noted that many African countries have created river basin authorities responsible for planning water resource development. The degree of executive involvement varies, ranging from those like Senegal's SAED, carrying direct operationalresponsibilities for small-scale projects, to those with purely planning functions like Tanzania's RUBADA (for the Rifiji Basin) or Kenya's TARDA (for the Tana and Athi River Basins). The prior existence of such agencies gives an additional option to donors interested in assisting African irrigation. In many countries, donors have three basic possibilities: (a) assistance to individual field projects; (b) support to the irrigation section in the Ministry of Agriculture; or (c) support to one or more river basin authorities (RBAs). The policy issue then becomes to determine under which circumstances irrigation agencies, ministry units, river basin authorities, or individual projects merit which kinds of assistance? No general answer applicable to all of Africa is possible. The priority placed on irrigation differs from country to country, as do the levels of performance shown by outwardly similar organizations. One can,

however, identify the advantages and disadvantages of assisting the RBA-type units.

The principal advantage is the fact already noted that RBAs are often the only administrative units which already possess a rudimentary irrigation planning capability. If an aim of assistance is to deepen in-country technical capabilities, then the TBAs constitute a feasible starting point. Most are parastatals, and as such, have better chances to attract and retain specialized staff. Irrigation planning is usually already within their formal scope of operations, so that complicated negotiations and new legislation are unnecessary.

The RBA orientation towards planning can also become an obstacle, if it becomes an end in itself or if inappropriate methodologies are adopted. Vincent (1948:28) warns that American concepts of river basin planning can be quite detrimental in an African context. And, one might add, very expensive: development agencies can develop an enormous appetite for an interminable series of "preliminary investigations."

In view of the latter danger -- which African experience indicates is quite real -- we suggest that AID might concentrate on developing more appropriate and cost-effective training and research methods for RBAs. Among these might be:

- Training at a Master's level in irrigation-related fields;
- Regional or Africa-wide seminars to direct attention to new concepts, procedures and resources (e.g., farmer participation, remote sensing applications); and
- Derivation of simplified planning and monitoring techniques which would be more cost-effective under African conditions.

11. Scope for Alternate Energy Sources?

If African peasant farmers depend mainly on human or animal power, and if irrigation agencies have such difficulty obtaining fuel, why cannot other forms of renewable energy be employed? Each of the alternative source -- methane, windpower, solar power, photovoltaics, and even new domesticates like water buffalo -- has its adherents. The record so far, however, suggests once again that caution be exercised.

Any alternate energy source which itself requires complicated technology is likely to malfunction in the harsh African environment. Similarly, any "appropriate" technology which is vulnerable to neglect or misuse is likely to fail.

In the longer run, it may be feasible to power small-scale equipment from photovoltaics (provided the vandalism problem can be overcome), just as the inclusion of lucinae stands within a surface irrigation system could provide the raw material for biogas generation. A more risky and still longer-run option would be to copy Brazil in using sugar byproducts (ethanol or alcohol) derived from irrigated production for powering scheme equipment. All three options are techically feasible today, but represent fairly high risk possibilities in the more remote parts of Africa (primarily for managerial and environmental reasons). What is clear is that energy costs are problemmatic, while farm operations remain energy-starved for want of a cheap and readily accessible fuel. Thus, further experimentation is warranted, and meanwhile the calculation of energy budgets (both in the ecological and in the financial sense) ought to accompany any in-depth analysis of proposed irrigation developments.

12. Swamp-Rice versus Rainfed Rice?

Africa has its own traditional varieties of "upland" rice, which appear to have been domesticated within West Africa itself (Harlan, 1985). In recent decades, flood-basin types from Asia have been replacing upland rice in the coastal, West African countries even though proportionately rainfed rice production is still far more significant. Nevertheless, by draining valley bottom lands ("swamps") and switching to wet rice varieties, per hectare yields can be greatly increased. Most state-sponsored schemes have been of the "swamp rice" or valley improvement kind. Since, as we have seen, seasonally waterlogged lands are widely found throughout tropical Africa, the issue arises whether or not valley improvement schemes are as cost-effective as equivalent investment in "rainfed" upland production. At the country level, several USAID analyses have addressed this question -- usually in the

form of a crude contrast between "irrigated" versus "rainfed" development -- with the usual result being to recommend concentration on rainfed production.

In reality, it is not quite so simple. The valley-bottom "vertisols" represent some of the best agricultural land available provided they are intelligently used with suitable technologies. The division between "irrigation" and rainfed" cultivation is here also arbitrary, since what usually occurs is not full irrigation, but rather a combination of drainage, impoundment (for "wet" rice), and some supplemental water to extend the soil moisture regime. Within individual countries of West Africa one finds a diversity of rice production systems extending along a continuum of gradually increasing investment intensity. While some "polder" type swamp schemes can be extremely expensive, others based on slight modification of farmers' existing technology are not. The Stanford comparison of rice production in five West African nations gave different results for each country and for individual systems (Pearson et al., 1981). We therefore recommend an updating of the Stanford analysis employing present prices and incorporating additional crops (wheat, sorghum and cotton), while focusing more agricultural engineering attention on the technological issues inherent in valley-bottom improvement.

13. Rightholders versus Cultivators?

Tenure problems arise as an issue because in Africa those controlling plot rights -- whether they are bureaucratically appointed managers or male kinsmen in charge of a compound -- often cannot provide the labor irrigated production requires. Since this is also true for much of Asia's irrigation, observers may have been slow to recognize its ramifications in the African context. The "problem" exists because in either of the two contexts -- scheme or compound -- those recognized administratively and socially as rightholders are under minimal pressure to acknowledge cultivators' claims over irrigated land and its production. For example, when irrigation schemes insist upon retaining rights of eviction over tenants, they create a psychological climate

wherein the individual farmers will be unwilling to invest in long-term improvement, or sometimes even in canal maintenance. Similarly, if household bonds are weak and a woman anticipates being dispossessed (of either her home or her share of crop returns), she is unlikely to provide the substantial labor input which irrigated rice or cotton requires. There is ample evidence that those doing field work are not utilizing irrigation to the full extent which is technically feasible. While one can guess at their reasons, such guesses constitute an insufficient base for policy formulation.

We recommend, then, that research targeted on this topic be undertaken under various social and technical systems. Furthermore, donors who finance irrigation projects are in a position to insist that procedural changes are made which give greater security to cultivators. It is a strange situation indeed that in rural systems where women had quite strong traditional rights to irrigated food crops, under "modern" bureaucratic schemes they lose these safeguards. Some fairly simple procedural improvements are usually feasible. One could insist, for example, that daughters as well as sons could inherit plotrights; that whoever is in day-to-day charge of the crop can be issued credit; and that houseplots can be owned by families outright (thus safeguarding the value of house improvements). Some countries have already implemented such changes; exchanges of operational experience might facilitate the diffusion of better procedures aimed at increasing household security and intra-household equity.

14. Full Control versus Supplemental Irrigation?

It will be noted that the question usually posed, whether to stress irrigated versus rainfed agricultural development, has not received as much emphasis in this report. Here we suggest an intermediate position makes the most sense. We note that commercial farmers in East and Southern Africa have usually found it necessary to develop supplemental irrigation in order to achieve reliable crop yields. If so, the same need probably exists within smallholder farming. Regularization of rainfed crop returns by stabilizing planting dates and eliminating the

within season dry spells might represent a more desirable (and water conserving) objective than "full" irrigation with its heavy water demands. The main problem is, of course, the high cost of present technologies for achieving this objective. Generally, the large-scale farmers in Africa employ movable piping and overhead sprinklers, requiring heavy initial investment. Some suggest that drip irrigation represents an ideal compromise where water is scarce, but here, too, practical difficulties -- termites and impure water -- are encountered. Perhaps the answer is to incorporate water harvesting during the rainy season; or else to add a rainfed, supplemented crop grown alongside the area used for "full" dry season irrigation. We do not yet have answers, but the need to pay more attention to partial irrigation seems obvious (repeating a point made vis-a-vis "swamp" systems).

15. Technology Transfer or Technology Development?

The final issue is one which underlies many aspects of this review: the selection, adaptation and support of irrigation technologies. Questions which come under this rubric have surfaced again and again in this review. For example, it is clear that some irrigation techniques must be accompanied by certain technological capabilities (e.g., freedom to import parts or access to streamflow data) before they can be used effectively. But which ones depend upon which "upstream" support capabilities? Again, when should African governments accept "orphaned" equipment imported at donor insistence? (This has been a frequent issue in irrigation because rapid repair is usually essential.) Which aspects of U.S., Egyptian or Asian irrigation experience can be transposed directly into African practice? Are there "miracle" technologies (like drip irrigation) which might dramatically improve output within African irrigation? Can systemic weaknesses at the local level be offset technologically by increased investment? Why are even simple technologies like pump-set operation so problemmatic in rural Africa? Can given technological packages such as Dutch polder techniques be disaggregated and employed selectively? When and where should donors

sponsor technologies which are new to Africa, such as overhead sprinkler irrigation or satellite-based "early warning" systems?

Whatever one might conclude theoretically, such questions are at present answered largely by default. Particular donors almost invariably stress the kinds of technology already in use at "home" or developed in their former colonies (e.g., the "Gezira" system). It is clear that for the large-scale commercial producers who enjoy exemption from currency restrictions, the standard "off-the-shelf" solutions from advanced nations usually can be made to work under highly standardized, plantation crop situations. However, as soon as one must deal with typical smallholder situations in the more remote communities, technologies tend to become quite problemmatic unless carefully adapted to circumvent local constraints. The adaptation and support elements are often overlooked in programs aimed at direct technology transfer. Since irrigation is essentially a repetitive activity, involving a network of support institutions, we recommend that donors put greater stress on deepening local technological capabilities.

Gaps

The scope of work for this overview specified that it should identify priority areas needing further attention -- the "gaps" within present research or within the existing distribution of institutional effort. What are, then, the most significant missing elements whose lack contributes to the present low efficiency of Africa's irrigation?

1. Irrigation Engineering

At several points in this report it has been pointed out that irrigation engineering in the American sense is absent from black Africa, except perhaps in the Sudan and Sahel. When tasks requiring irrigation expertise arise, decisions tend to be made either by civil engineers (at the design and construction phases) or by agronomists (in scheme operation and water management). Few of the civil servants who staff Africa's river basin authorities and ministry-linked irrigation

units are actually professional irrigation engineers. Most come to their assignments from other professions, and see themselves more as employees of the agency than as irrigation managers per se. As a consequence, the handful of qualified irrigation engineers in each country will be preoccupied in dealing with donors and reviewing new projects. While the manpower gap is being gradually closed by recruitment of newly trained professionals, "irrigation engineering" does not yet exist as an integrated field combining elements of design, construction, water management and agronomy within a single discipline.

On the one hand, this situation leaves room to shape the emerging discipline in ways more suited to Africa's needs.[1] On the other hand, it also explains the technical void encountered in most countries on matters related to water management. Without enough trained professonal staff, African irrigation agencies rely heavily on outside consultants and on accidents of bureaucratic precedent to determine their managerial systems.

2. Manpower and Sector Planning

Few African countries have in hand systematic plans for the strengthening of manpower support for irrigation development. Most have never analyzed staff needs in the irrigation subsector, nor do they have accurate or even up-to-date statistics describing the sector. Sometimes, as in Kenya, individual units have good documentation, but the overall effort is badly fragmented. More typically, as in Somalia, the necessary information for irrigation planning is simply not available and no realistic program for staff preparation exists. Of course, staffing weaknesses go hand-in-hand with an absence of sector planning. As a consequence, in most countries technical design and even field supervision depend on donor-financed, expatriate staff who leave

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[1] In-country programs for training irrigation engineers constitute an obvious area where fairly modest donor commitment might have major long-run impacts. If we look at numbers being trained, Egypt is at present by far the largest source for African professional manpower in relation to engineering and irrigation (FAO, 1984).

when their contracts terminate. We have pointed out that this situation greatly reduces the possibility of organizational learning taking place within local agencies officially responsible for irrigation. Even after two decades of external assistance, many African countries have surprisingly little institutional capacity for planning and managing their irrigation subsectors.

3. Project Documentation

For African irrigation, the "literature" such as it is consists mostly of project documentation:[1] preliminary reviews, appraisal reports, design specification documents, donors' performance audits, a sprinkling of trip reports, terminal reports and project evaluations. For most larger projects, several consultancy firms will have been involved. Their reports are user-commissioned. Sometimes individual authors rework their data for academic publication, but much more commonly the reports can only be found in the firm's headquarters or stacked against the back wall of some minor official's office in the recipient agency. Officials receiving this documentation have no incentive to integrate the information into a larger picture; and, indeed, the site and project-specific format makes synthesis difficult. In many African countries, the only general collections of such technical materials occur in donor's offices, particularly within USAID and the World Bank.

This background accounts for the thinness of U.S. documentation on African irrigation. The two principal exceptions are U.S. theses based on African field research and the World Bank's home office collections (to which access is usually restricted). For the bulk of materials on African irrigation, one must travel to company offices in England and on the continent or to library collections in Germany, Holland, London, Paris and Rome where the larger volume of donor-financed activity has originated. In particular, we suggest that there is a need for an

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[1] For an annotated bibliography of recent sources, see Volume III of this report.

inside review of documentation held in the United Kingdom, since British consulting firms have been especially active in Africa.

4. Vertisol Management

Vertisols -- what a lay person calls "black cotton clay soils" -- are found throughout the tropics, wherever soil formation occurs under circumstances of impeded drainage. Such soils constitute an important resource because of their moisture retaining capacity and their differential fertility, not only in Africa but also in India and Brazil (where they are also significant). In the review of technical aspects, it was pointed out that while these soils are difficult to work with light equipment, they are nonetheless the site for most flood basin irrigation of rice in Africa. Depending on the situation, they may be either acidic (highland swamps and coastal mangrove swamps) or alkaline (saline "pans" in closed drainages). The main point is that they react to moisture very differently from the sandy loams prized by plough farmers. With vertisols, canal lining may be unnecessary -- a significant advantage in Africa -- but water control structures must be specially constructed. Also, their high moisture retention may permit preirrigation and the growing of a subsequent, "ratoon" crop. For all these reasons, while vertisols constitute a key resource, they require distinctive engineering and agronomic management. Individual African countries are rarely in a position to tap the continent-wide experience with such soils. We suggest that donor support for exchange of managerial experience, coupled with further research to identify the most cost-effective crop and equipment combinations, would be something AID should consider. Any such exchanges of experience should also draw in irrigation engineers from Egypt, India and Brazil.

5. Weed Control

An unexpected finding has been that control of weeds -- terrestrial as well as aquatic -- is a major difficulty within African irrigation. Terrestrial weeds are, of course, usually treated as a farm-level

problem, whereas aquatic weeds are seen as a threat to the water management system as a whole. Nonetheless, both types pose a high level of threat to irrigated production. Without repeating the technical arguments about "red rice" and other common weeds, we note simply that the partial completion of scheme works which often occurs provides ideal circumstances for rapid weed growth, just as tropical canal systems do for aquatic weeds. More attention to this aspect is imperative, since there are good reasons for suspecting that under typical conditions for smallholder production the degree of weed challenge may be far greater than is commonly acknowledged.

6. Maintenance

If, as earlier WMS II studies suggest, physical rehabilitation is in effect the provision of "deferred maintenance," then it seems plain that maintenance has been the weak link in many African irrigation schemes. The resulting deterioration is evidenced by inoperable equipment, by weed-choked canals, and by the erosion and failure of physical works. To the outsider, it seems poignant that expensive irrigation works should be allowed to deteriorate so rapidly in such poor countries. Tractors and pumps which could have served for ten years may have an average working life of two to three years. Some schemes now require rehabilitation before their original loan financing is half repaid. Observations of this nature explain the nearly unanimous agreement that poor maintenance constitutes the single most important unresolved problem in African irrigation. Of course, it is linked to many other issues: recurrent cost constraints, the impact of currency and import restrictions, farmers' alienation or insecurity, improper design, seasonal bottlenecks in labor supply, etc. We reiterate, therefore, a plea made in last year's review of Sahelian irrigation: that this topic should receive top priority within any field research that donors might finance (Moris, Thom and Norman, 1984).

7. Irrigation Extension

As a rule, either irrigation "extension" is derivative from scheme requirements and confined to the project/scheme environment (as in

Gezira, the Office du Niger, or Kenya's National Irrigation Board's schemes) or it is totally absent, leaving a void between the water supply section and the usual, rainfed farming orientation of the general extension service (as in Somalia). To irrigate successfully in Africa, farmers require a number of specialized skills: knowledge of how to level their fields, the signs of moisture stress in plants, when to stop watering, control of salinization, interactions between watering and fertilizer use, how to avoid waterlogging and unnecessary erosion, synchronizing irrigation activities with rainfed farming, how and when to do maintenance, the rotation system (if practiced), signs of nematode buildup, and how to recognize and control weed growth. This incomplete listing is sufficient to indicate that there is a fairly large element of skill and local experience needed.

Farmers who have grown up within an irrigated farming system (such as in Gezira or Madagascar) probably acquire most of the necessary skills informally. Elsewhere on the continent, to the contrary, adult farmers who in other respects know a great deal about plant husbandry may nonetheless lack these special skills. Where initial extension and training has been weak, farmers become entirely dependent on scheme management for advice, and they are likely to perform certain key operations (like field leveling) so poorly that yields are greatly depressed. This situation in turn reinforces stereotypes held by managers and staff about farmers' low motivation and interest, setting in motion the issuance of unexplained directives which further depress farmers' performance. The need for advance instruction is particularly great when irrigators are former pastoralists, whose traditional way of life differs at almost every point from what is required in irrigated farming.

Hardly anything is known about the actual content of "irrigation extension" as it occurs in Africa. There is an urgent need for comparative data of this nature, since the World Bank is wily-nily imposing its India-derived "training and visit" system on most African countries which accept its financial assistance in the irrigation sector.

8. Intra-Household Economics

Identification of household economics as a "gap" may strike African specialists as strange, since there is a huge literature on the continent's systems of production and exchange. There are even a number of detailed sources on the role of women in African peasant farming. The "gap" is not, therefore, a lack of basic sources, but refers instead to failure to integrate and apply this knowledge within analyses of irrigated farming. In part, there is a gap if we are interested in detailed economic analysis of the irrigated subcomponents within larger arable farming systems. However, there also appears to have been deliberate blindness towards likely production costs, since to have accepted realistic estimates would have wiped out the apparent benefits which were being claimed for irrigation projects. Incorporation of more realistic figures on likely yields, labor costs, time scheduling, etc. would have made it clear that most African irrigation projects have been problematic right from the start.

To understand future irrigation performance, donors must become willing to incorporate actual field data reflecting typical conditions into project appraisals and evaluation. In systems where households are only loosely integrated, allowance must be made for the possibility that returns within the household unit may be insufficient to guarantee the necessary commitment by women and other farm laborers. Analyses must also take into account the opportunity cost of farm labor during the peak bottlenecks so characteristic of African hoe cultivation. Planners must recognize women's strong commitment to achieving food security, and their limited access to credit which forces them to give priority to low input, rainfed cultivation even under conditions of high risk. In short, there are a bundle of agricultural economic issues which require knowledge of patterns of internal household organization within African farming systems. While many of these relate specifically to the woman's sphere, there are also other aspects of a more general nature requiring similar data. Estimation of farm investment potential, labor costs, livestock economics, locational economics and intra-household

distribution requires a type of applied household economics which is not yet available for most settings where irrigation might be considered.

9. U.S.-Based Irrigation Expertise

The thinness of U.S. documentation on African irrigation is matched by equivalent weakness in regard to irrigation expertise. There are only a handful of practitioners in the U.S.A. with professional interests in the various aspects of African irrigation. It was anticipated that there might be few U.S. irrigation engineers interested in Africa, but in fact, irrigation economists are just as scarce. Yet, paradoxically, one finds numbers of younger scholars eager to work on applied aspects of irrigation development -- individuals with the necessary field acquaintance and language skills, but usually lacking technical training in irrigation or sufficient support to maintain an active involvement.

Given the lack of senior specialists, it is apparent that AID's future programs will depend upon expanding the numbers of younger professionals in irrigation-related fields. We strongly endorse the concept of "tag-along" assignments, whereby younger workers are funded to accompany the few senior experts on applied assignments in Africa. Another option might be to initiate an exchange program, wherein U.S. graduate students lacking field experience might "fill in" at the host-country level for nationals who come to the U.S.A. under long-term training arrangements. Still another need is for establishment of two or three U.S. centers where there is adequate documentation and staff background to provide relevant short and longer term training oriented towards African water management.

The difficulties we have encountered in assembling this report from (mainly) U.S. sources will also apply when efforts are made to train African nationals within the U.S.A. It is clear that U.S. institutions have not paid much attention to African irrigation, and have relatively little to offer when it comes to an integrated, relevant perspective. To give adequate managerial training always requires having at hand a wealth of materials related to the problem: case studies, exercises,

description of field constraints, etc. At present this context relevant to African circumstances is missing within U.S. technical training, which instead perpetuates a bias toward further specialization and "high technology" solutions.

AID Strategy

The message our review holds for AID/Washington may at first glance seem contradictory. African countries face increased reliance on irrigation in the future, and -- in view of the low levels of present performance -- have an urgent need to learn how to use irrigation technologies more cost-effectively. Nevertheless, because in most African countries USAID has become a minor donor, we cannot recommend any dramatic increases in AID's direct financial support to underwrite new irrigation projects. Existing African irrigation projects are simply too expensive to warrant receiving scarce investment funds from a small donor. This conclusion is strongly supported by the background papers prepared independently by Vincent, Humpal and Sparling. It also echoes the World Bank's "Berg Report" (1981:78), and Carruthers' OECD review (1983:15), both of which recommend an initial concentration on improving output from present schemes rather than upon starting new ones.

Instead, the consensus among nearly all expert observers is that first priority within the irrigation subsector should be to strengthen its institutional capacities. As a general strategy, this has the advantage of providing a base for future project funding while also assisting countries to get higher returns from already committed projects. In a few instances where a country is heavily dependent on its irrigation sector (as in Sudan and Somalia), the U.S. Government may find it politically desirable to intervene at the production level, but even in these cases we recommend AID moves cautiously. At present, the USAID system in Africa, both at regional levels and within country missions, simply does not have enough qualified irrigation engineers to plan and supervise an expanded portfolio of irrigation projects. An immediate area for attention should be to expand U.S. technical

capabilities for dealing with irrigation and water management issues in African contexts. Thus, improvements in "institutionalization" are needed in the U.S.A. itself as well as in recipient nations.

By "institutionalization," what is meant? Basically, "institutional" measures are those which increase the capacity of national, regional and local systems to use irrigation more intelligently. More effective irrigation planning, based on actual field information and realistic premises, is one obvious requisite. Ways must be found to stimulate feedback from the farm and scheme levels. Decision-making procedures themselves need revision, so that once problems are identified they receive prompt and effective remedial attention. An organized capability to provide specialized assistance when individual schemes need help must be created. And, of course, projects must be institutionalized at the local level so that scheme users -- the farmers themselves -- understand what is required and participate to insure the success of their own irrigation.

In reviewing how AID might best render such assistance, we have kept two limitations in mind. First, over the past two decades USAID in Africa has paid little systematic attention to support for irrigation. Very little of value can be found in AID's Washington-based documentation service on African irrigation. When US firms have been active implementing irrigation-related activities (mostly in the Sahel), they have as likely as not employed French Canadians or European engineering staff on those aspects requiring detailed African experience. For East and Southern Africa, USAID has neither the engineers nor the documents required for an upgraded program of institutional support. We must therefore be realistic in assessing which are the areas of comparative US advantage, recognizing that on some desirable topics the US has little to offer. Second, except in a few countries, it is quite unlikely USAID will ever serve as the major donor assisting irrigation. Among other donors, the Dutch, Germans and Japanese are already far ahead and will likely remain so. This situation makes it desirable that AID coordinates its input to take into account what other donors are already doing within the continent. It

also suggests we cannot rely upon "spin-off" benefits (participant training, etc.) from USAID's present projects to meet the main need for institutional strengthening. If this becomes AID's goal for the irrigation subsector, it must be addressed directly.

Taking the above limitations into account, we propose nine options as suitable areas for immediate AID support:

1. Cooperation with Other Donors
2. Incorporation of Irrigation into FSR Projects
3. Systemic Malfunctioning and Rehabilitation
4. RBAs and Irrigation Planning
5. Remote Sensing Applications
6. Women-in-Irrigation-Development
7. Small-Scale Systems
8. NGOs and the Private Sector
9. Deepening of U.S. capacity

1. Cooperation with Other Donors

In the short run, AID needs to incorporate the experience of other donors which have been active in assisting African irrigation. In saying this, we do not imply that these countries necessarily have better water management expertise than does the USA. The point is simply that documentation on irrigation consists largely of project reports of one kind or another: appraisal estimates, site surveys, trip reports, managerial audits and terminal evaluations. Such materials are usually commissioned, and rarely find their way into academic collections outside the country where they occur. In Africa, the main donors have been the World Bank, FAO, France and England; supplemented in recent years by the various development banks and funds and newer donors such as the Dutch and Germans. To consolidate Africa's present experience with irrigation, one must start with the agencies and donors who have been doing actual irrigation projects -- and that means going outside the USA (with the World Bank's Washington headquarters being

the one notable exception).[1]

Beyond talking to those who have implemented irrigation in Africa, AID should reach a policy decision to participate vigorously in various low level, multilateral activities which are already under way. For instance, FAO and the Dutch have strongly supported small-scale irrigation in Africa (Underhill, 1984), and FAO is taking the lead also in analyzing women's participation (Dey, 1984). Both kinds of activity merit additional support, and would constitute excellent starting points for a collaborative effort. AID should strengthen its representation at the various regional conferences on irrigation, which have become more important as the number of donors and potential recipient nations have increased. Assistance might also be given to ODI's irrigation network, which has reached a size where to remain effective it must have additional resources. None of these initiatives seem very glamorous, but they have the advantage of bringing U.S. technical personnel into contact with those involved on a day-to-day basis in the planning and field implementation of African irrigation projects. Another source closer to home is the World Bank, which despite its policy pronouncements, remains closely tied to a number of large investments in African irrigation. While liaison between the Bank and AID in Washington has been smooth, for irrigation expertise the Bank has generally drawn on non-U.S. sources. One way or another, AID and its associated contractors must develop direct access to an experiential base on African irrigation before other forms of institutional support become feasible.

2. Incorporation of Irrigation into FSR Projects

Currently AID has under way several farming systems research (FSR) projects in Africa (in Sudan, Tanzania, Malawi, Ruanda, Burundi and Botswana, among others). The rationale for these projects has been the need to identify existing constraints and to describe the needs of

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[1] Our inability in this study to tap these other sources -- except for those in France, which were visited -- was a serious limitation, which probably reduces the general applicability and validity of our conclusions.

various farming systems. Similarly, ILCA has sponsored several in-depth investigations of the role of livestock enterprises within the larger farming systems (with regional centers in Kenya and Mali as well as in Ethiopia itself). Then, under AID funding CIMMYT has its East and Southern Africa program, based in Nairobi, but conducting farm-level diagnostic surveys and seminars throughout the region.

Irrigated production exists as a significant option in many of the countries where FSR research is being done. The failure of researchers to give it explicit consideration probably stems from the fact already noted that irrigated enterprises are often only a subcomponent within larger, non-irrigated systems. Also, early FSR research was preoccupied with rainfed, arable farming to the extent even of ignoring livestock enterprises which were also often present. We suggest that there is no defensible reason for arbitrarily excluding irrigation and livestock aspects from FSR, even in systems where these various enterprises are not tightly integrated.

Adding an irrigation component would thus complement existing FSR activities. From AID's standpoint, since these are already funded projects, some finance might already exist which could be tapped; or, alternatively, a minimal startup period would be needed if it were decided to broaden their objectives by additional funding for attention to irrigation and water management aspects. Several specific changes might be instituted along with such modifications: (a) incorporation of more attention to farm decision-making and intra-household aspects; (b) careful attention to competition between rainfed and irrigated enterprises; (c) analysis of the institutional risk which farmers incur when attempting irrigation; (d) analysis of on-farm labor costs and returns, between enterprises and throughout the season; and (e) estimation of returns from different potential innovations. The value of such information for understanding why irrigation has not been popular is obvious.

3. Systemic Malfunctioning and Rehabilitation

A broad review such as this one, based mainly on a literature

search, can only provide rough estimates of systemic performance. Numerous examples could be given in earlier chapters to support the conclusion that Africa's irrigation performance is generally far below its design potential. Suggestions were also reviewed as to why irrigation has been so problemmatic, but here the findings are of necessity more tentative. Only a handful of field visits were permitted; field practitioners were, with a few exceptions, not interviewed; and the engineering component is very poorly covered in the available US literature. It would seen essential, then, for AID to further refine the broad conclusions within this report.

Three possibilities for doing so suggest themselves. First, better coverage of individual scheme experience would seem imperative. There are whole countries not covered in this report (e.g., Angola and Mozambique, as well as most of central Africa), just as there are many interesting schemes where the documentation is not available within the USA. Second, it might be fruitful to look at irrigation systems region by region -- a task fairly well in hand for the Sahel, but barely begun for Africa's other regions. There are pronouced regional differences which are bound to have direct policy implications; and, in any event, AID's own approach to project monitoring makes use of regional REDSO units. Third, it would be productive to look at particular technologies or situations (lakeside pumping; flood rice cultivation; swamp improvement, etc.) comparatively. (Since these constitute a very large agenda for potential action, we stress the need once again to avoid duplicating what other donors may have already begun.)

However obtained, more precise knowledge of the causes of scheme and systemic malfunctioning must be in hand before investments of the usual "institutional building" variety are launched. Public agencies have such an insatiable appetite for conferences, courses, training modules, publications, and the like that we cannot recommend the customary "shotgun" approach to deepening institutional capacity. First, let it become clear what the real reasons for poor performance have been, and then begin packaging remedial interventions.

Of course, gaining such information on schemes which are not USAID-funded will be difficult. Descriptions of main system management

and present irrigation procedures are almost entirely missing, and must be created from scratch. In the process, it ought to be possible to learn why maintenance is so poor, what skills farmers lack, and the reasons why they are excluded from meaningful participation. Informaton will also be required on the bureaucratic aspects of agency operation, and on the performance of necessary support institutions in the external environment.

4. RBAs and Irrigation Planning

As already noted in this chapter, AID could focus assistance for irrigation planning within the existing river basin authorities. Here the danger to avoid is to merely duplicate the present pre-investment planning which is already under way for the larger, multinational RBAs like the OMVS. Such projects simply substitute outside planners for local ones; they can become very expensive; and the large number of RBAs opens the door for a never-ending stream of requests. Instead, we recommend AID focus on improving existing methodologies and in-country capacities to do integrated water management planning. Topical attention (conveyed by means of short courses, regional workshops, etc.) might address needs such as development of rapid reconnaissance methods, better integration of soils information, exchanges of experience with regard to vertisols, identification of labor constraints and comparisons between technologies. RBAs might also benefit from manpower analysis and provision of externally assisted training to fill certain priority needs. They are strategically located to monitor environmental impacts, and might welcome assistance to facilitate this important function. In some countries where agricultural engineering has been established within higher level agricultural training, USAID might encourage linkages between training and river basin institutions. Another priority area would be to assist RBAs in evaluating and (where appropriate) organizing technology support to the irrigation subsector. Finally, RBAs should devise their own rating system for measuring scheme and project performance -- a development which might serve as a potent stimulus towards better performance.

In all instances, the goal should be to demonstrate an integrated, multidisciplinary approach in practice. Perhaps AID/Washington could select one or two river basins to serve as pilot areas for the application of more flexible, field oriented approaches -- maybe the Gambia and Juba basins? (We assume further details about how such a program should be implemented will be forthcoming from AID's parallel review of four African river basins.)

5. Remote Sensing Applications

Until recently, the U.S.A. has enjoyed a technological advantage in providing high quality LANDSAT imagery for African natural resource planning. Assuming that the non-military U.S. remote sensing capability remains in the public sector, it offers substantial promise for documenting rainfall coverage, and hence, irrigation demand. Weather satellite imagery has been drawn upon to provide relatively quick overall estimates of moisture and vegetative growth conditions. No other source can provide equivalent information for such large areas of the continent. We suggest such data should be integrated into a continent-wide "early warning" system, whose forecasts of impending drought would be shared with the countries concerned. In several key countries (from the perspective of US interests) this information, if provided promptly, could trigger a shift towards increased cereal food production in the irrigation sector, e.g., as happened in the Sudan in 1984. There are undoubtedly other applications which also merit further refinement, carried out by collaborative teams of U.S. scientisits and host country nationals. One suspects, for example, that spatial and trend analysis of the degree of environmental degradation taking place on the continent will continue to command policy-makers' attention. There is no reason why measurement of broad environmental trends cannot be combined with specific attention to hydrologic aspects. It would be a pity if at just the point where we are learning how to make these technologies genuinely useful, further financial assistance is withdrawn.

The above arguments constitute strong reasons why the U.S. should

maintain its present comparative advantage in applying remote sensing to the assessment and planning of natural resources. Of course, should Washington's proposals to "privatize" these publicly funded services be implemented, most LDCs will turn to other non-American sources which are already under development. If, for strategic reasons, the US government must fund such uses of remote sensing anyway, we consider it far preferable that this work is conducted in public where the countries being analyzed can participate and learn from the experience.

6. Women-in-Irrigation-Development

It seems that ultimately many issues in African irrigation revolve around gender-linked differences in farmers' commitment and access to resources. The role of women in African farming is already an academic area where U.S. researchers have a comparative advantage. (One thinks immediately of Simmons, Fortmann, Staudt, Peters, Atherton, Jones and Spring, among others.) We recommend that AID funds a modest "add-on" program targeted specifically at learning how African women participate in and benefit from irrigation. A topical focus on irrigation would give greater practical thrust to AID's present WID commitment, and might constitute justification for added support. The individual studies required would be mostly small-scale, to insure that intra-household aspects receive scrutiny.[1]

7. Small-Scale Systems

The transfer of experience with small-scale irrigation systems also constitutes an attractive possibility for donor support (though one already receiving attention within Europe). USAID has been closely involved with small-scale systems in several Asian countries (notably Sri Lanka, Indonesia and the Philippines). It seems likely that the

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[1] Perhaps the FAO office working on this topic or the two African REDSO units could provide an organizational base, to which researchers might be attached under a rotating post-doctoral fellowship.

lessons from such experiences may also apply within parts of Africa. The theoretical arguments in favor of small-scale systems have already been reviewed, but still it would be useful to determine to what extent these can be realized in actual practice.

Issues which might be examined under AID funding include:

1. Factors related to the survival of some traditional systems and technologies;

2. Existing institutions for water allocation, maintenance, dispute resolution and cost recovery;

3. Types of perimeter organization already in use;

4. Kinds of technical "backstopping" required in small-scale systems;

5. The choice and support of pumps in African environments;

6. Impact of the spontaneous spread of small pump systems; and

7. Options for providing external aid to small-scale systems.

8. NGOs and the Private Sector

Another option for AID support would be to concentrate on helping the NGOs and PVOs active in African small-scale irrigation. For example, Kenya's small, PVO-assisted schemes reviewed by Kortenhorst (1983) have experienced many technical problems. (Weber's background paper for this study cites numerous further examples from other parts of Africa.) These suggest that small schemes can be just as problemmatic as large ones if designs are faulty or technologies inappropriate. Given that PVO staff are usually motivated and willing to experiment, helping them resolve technological and organizational problems might give AID access to a wide spectrum of African field experiences at comparatively low cost. There are individuals who have accumulated an in-depth understanding of particular aspects of irrigation development, but one usually finds they focus on only one or two elements of the larger process, and they are not free to advise beyond their own limited

circle of projects. Outside assistance could help in pooling this valuable experience and making it more widely available.

In regards to private sector irrigation within African countries, there is an equivalent need to stimulate sharing of technological experience between large-scale, commercial operators and PVOs or public agencies working with smallholder farmers.

9. Deepening of U.S. Capacity

The eagerness of U.S. institutions for federal funds sometimes disguises the true situation vis-a-vis availability of manpower and resources to undertake requested technical tasks. This seems to be the case in regard to African development. While there are many American specialists with African experience, most are social scientists without in-depth understanding of the technical side of irrigation. Others lack the French or Arabic or Portuguese needed to undertake field assignments. And still others will find the deteriorating security and supply situation daunting. For all three reasons, we have identified the thinness of U.S. capacity as a major constraint limiting AID's scope of action in the short-run.

Remedial interventions should address both staffing and institutional resources. On the staffing side, we have suggested more use of "tag-along" assignments to bring in young professionals who will acquire broadened field experience. This is particularly necessary in regard to the technical specialties (agronomy, irrigation engineering, hydrology, soil science, etc.) but it also applies to irrigation economics and settlement organization. (French and Arabic capability are also crucially important in certain countries, but many potential candidates already have the necessary languages from their initial field assignments.)

In regard to institutional resources, we propose greater use by Americans of London's ODI irrigation network rather than attempting to duplicate this listing of field practitioners. Close liaison with the International Irrigation Management Institute's (IIMI) program for Africa should also be established. Access to field reports and theses

on Africa needs to be improved at the major U.S. institutions which AID intends to involve. Many of the needed resources do exist within the U.S., but are scattered within institutions which do not have an irrigation emphasis.

Bridging the Gap

This study has aimed to fill a gap in the literature by providing a continent-wide overview of African irrigation experience to date. Our contributors discovered the task sometimes exceeded the means within their reach. Not only is there a major gap between academic sources -- which generally can be located within the U.S.A. -- and the many user-commissioned project reports filed away overseas, there is also a chasm separating engineers who design and construct Africa's schemes from the agronomists and administrators who try to make them work. The first gap was expected, but the second one was not. We close this study, then, by identifying several areas where at present effective inter-communication often breaks down:

- Between civil engineers and agronomists (design versus operation);
- Between scheme managers and farmers;
- Between technology suppliers and technology users;
- Between plot-holders and field workers; and
- Between scheme members and surrounding communities.

The WMS II project originated because of concern that field programs would benefit from an integrated perspective, utilizing water management as a unifying device to highlight interconnections between sectors (and hence, between analytic disciplines). The "synthesis" element expressed AID's belief that field projects should not keep repeating each other's mistakes. This review makes it abundantly clear that both concerns are especially relevant within African irrigation. Present organizational structures virtually guarantee a fragmented approach to irrigation, leaving each set of actors in a position to

blame others for the obvious faults which abound on every side. And, as a consequence, learning from past experience does not occur. We hope the views expressed in this report will constitute a first step towards a comprehensive understanding, enabling all those involved to assume collective responsibility and, eventually, to devise more effective solutions.

WATER MANAGEMENT SYNTHESIS PROJECT REPORTS

WMS 1 Irrigation Projects Document Review

Executive Summary
Appendix A: The Indian Subcontinent
Appendix B: East Asia
Appendix C: Near East and Africa
Appendix D: Central and South America

WMS 2 Nepal/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 3 Bangladesh/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 4 Pakistan/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 5 Thailand/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 6 India/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 7 General Asian Overview

WMS 8 Command Area Development Authorities for Improved Water Management

WMS 9 Senegal/USAID: Project Review for Bakel Small Irrigated Perimeters Project No. 685-0208

WMS 10 Sri Lanka/USAID: Evaluation Review of the Water Management Project No. 383-0057

WMS 11 Sri Lanka/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 12 Ecuador/USAID: Irrigation Sector Review

WMS 13 Maintenance Plan for the Lam Nam Oon Irrigation System in Northeast Thailand

WMS 14 Peru/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 15 Diagnostic Analysis of Five Deep Tubewell Irrigation Systems in Joydebpur, Bangladesh

WMS 16 System H of the Mahaweli Development Project, Sri Lanka: 1980 Diagnostic Analysis

WMS 17 Diagnostic Analysis of Farm Irrigation Sysems on the Gambhiri Irrigation Project, Rajasthan, India: Volumes I-V

WMS 18 Diagnostic Analysis of Farm Irrigation in the Mahi-Kadana Irrigation Project, Gujarat, India

WMS 19 The Rajangana Irrigation Scheme, Sri Lanka: 1982 Diagnostic Analysis

WMS 20 System H of the Mahaweli Development Project, Sri Lanka: 1983 Diagnostic Analysis

WMS 21 Haiti/USAID: Evaluation of the Irrigation Component of the Integrated Agricultural Development Project No. 521-0078

WMS 22 Synthesis of Lessons Learned for Rapid Appraisal of Irrigation Strategies

WMS 23 Tanzania/USAID: Rapid Mini Appraisal of Irrigation Development Options and Investment Strategies

WMS 24 Tanzania/USAID: Assessment of Rift Valley Pilot Rice Project and Recommendations for Follow-On Activities

WMS 25 Interdisciplinary Diagnostic Analysis of a Work Plan for the Dahod Tank Irrigation Project, Madhya Pradesh, India

WMS 26 Prospects for Small-Scale Irrigation Development in the Sahel

WMS 27 Improving Policies and Programs for the Development of Small-Scale Irrigation Systems

WMS 28 Selected Alternatives for Irrigated Agricultural Development in Azua Valley, Dominican Republic

WMS 29 Evaluation of Project No. 519-0184 USAID/El Salvador, Office of Small-Scale Irrigation - Small Farm Irrigation Systems Project

WMS 30 Review of Irrigation Facilities, Operation and Maintenance for Jordan Valley Authority

WMS 31 Training Consultancy Report: Irrigation Management and Training Program

WMS 32 Small-Scale Development: Indonesia/USAID

WMS 33 Irrigation Systems Management Project Design Report: Sri Lanka

WMS 34 Community Participation and Local Organization for Small-Scale Irrigation

WMS 35 Irrigation Sector Strategy Review: USAID/India; with Appendices, Volumes I and II (3 volumes)

WMS 36 Irrigation Sector Assessment: USAID/Haiti

WMS 37 African Irrigation Overview: Summary, Main Report, An Annotated Bibliography (3 volumes)

APPENDIX A

SUMMARY OF WORKING PAPERS

A REVIEW OF IRRIGATION TECHNOLOGY IN TROPICAL AFRICA

by

Peter H. Stern

This working paper briefly reviews the historical development of irrigation from earliest times to the present when modern irrigation technology was introduced into Africa through the Gezira Scheme in 1910. From a scheme of 2500ha in 1910, Gezira had developed over 400,000ha by 1952 and represented over 50 percent of all irrigated land in tropical Africa. Four trends have been identified in the development of irrigation in Africa since 1952.

1. The expansion of surface irrigation to the river basins of Africa.
2. Introduction of Asian techniques for controlled paddy rice irrigation, especially in West Africa.
3. The development of pressurized overhead irrigation beginning in South Africa.
4. More recently greater attention has focused on small-scale irrigation of food crops.

Stern subdivides the continent into four regions--the Sahel, Equatorial West, Equatorial Central and East, and Southern Africa. Irrigation activities are reviewed country by country. Following this discussion, the technology of irrigation is reviewed under the following headings--geographical considerations, water source development, water extraction and major engineering works.

1. Geographical Considerations -- A distinction is made between countries where crops cannot be grown without irrigation and where irrigation is used to supplement rainfall. In the wetter areas where the dry season may be short weed growth becomes a formidable problem.

2. Water Source Development - Many of the rivers of Africa are international in that their catchment areas and courses lie in several neighboring countries. The failure to regulate apportionment of water by international agreement can create several problems for integrated river basin development.

3. Water Extraction - Larger irrigation schemes in Africa are provided water from reservoirs or diversion and thence by gravity to a canal system. Where gravity flow is unfeasible, water is lifted by pump. Gravity systems are more cost-effective because of the energy and maintenance costs involved in pump schemes.

4. Major Engineering Works - Large irrigation schemes require skills in planning, designing and constructing the major hydraulic works. Dams, reservoirs, barrages, pumping stations, arterial canals and complex control and distribution systems are essential to major river basin development. It may be advisable to question rather more carefully the ultimate value of a major dam and reservoir on a river which carries a heavy silt load. Sound engineering is important in the planning and designing of small irrigation schemes, and it is often the absence of this which has led to the failure of small-scale development.

   (a) In large-scale schemes faulty design has been attributed to the failure of providing sufficient water to complete irrigating within a specified time period. Stern suggests that perhaps rather than being a design problem it may be a maintenance problem because weed growth and silt laden canals severely reduce flow. Another point emphasized by Stern is that systems which have worked tolerably well in Sudan have not been as successful when exported to other parts of Africa.

   (b) In most instances overhead irrigation is not a viable method of irrigation in Africa. Emphasis on surface irrigation will continue because of the problems inherent in operating and maintaining machinery. Soil salinity and health hazards are two other factors that need close attention in irrigation development in Africa.

   (c) Emphasis on small-scale development has been relatively recent and usually is more successful when the initiative has originated with the farmers. Small-scale irrigation has been most actively promoted in Mauritania, Senegal, Mali, Niger, The Gambia, Guinea, Sierra Leone, Ivory Coast, Kenya and Tanzania.

      (i) There is the widely held view that small-scale schemes do not need the same degree of investigation, planning and design that is undertaken for the

large schemes.

(ii) In fact a properly designed small scheme is likely to cost more per hectare in capital investment than a large scheme.

(iii) With regard to technology of small-scale irrigation, emphasis must be on low cost but feasible. Solar energy for pumping may become economically viable.

(d) Wherever machinery and equipment are used in rural Africa, operation and maintenance cause problems. This is not always because operators are inexperienced or lack motivation. More often than not failure arises from difficulties in getting supplies. In many countries pump operators manage to keep their machinery running under conditions which would defeat a more sophisticated attendant.

From this overview Stern draws the following conclusions:

1. General -

(a) Although traditional irrigation has been known in parts of Africa for a very long time, modern irrigation technology has spread across the continent very rapidly.

(b) Of the 4.6 million ha of irrigation in Tropical Africa, 93 percent is to be found in 10 countries: Sudan, Madagascar, Nigeria, Senegal, Tanzania, Zimbabwe, Ethiopia, Mali, Somalia and Mozambique.

(c) The principal irrigated crop in Tropical Africa is rice, representing about 30 percent of the total area, followed by cotton (13 percent) and sugar cane (8 percent).

(d) Traditional flood and simple lift irrigation are practised extensively throughout the Northern semi-arid parts of Africa.

(e) Modern irrigation in Tropical Africa started in Sudan in the second decade of the twentieth century, and was developed initially for the commercial cultivation of cotton.

2. Planning and Design -

(a) All over the continent time schedules and costs for development have been drastically underestimated.

(b) The causes of cost and time escalation are complex, but are related more to world economics and social and political situations than to the technology of irrigation.

c) However some of the failures can be attributed to the over-hasty introduction of inappropriate technology.

3. Water Source Development -

(a) Most major African rivers are international, but only a few are subject to comprehensive international agreement over the use of their waters. The lack of proper agreement causes problems in some countries.

(b) Some major river dam storages are giving concern on account of unexpectedly premature silting.

(c) On the whole, and where feasible, gravity irrigation supplies are preferable to pumped supplies.

(d) In some situations, e.g. Sierra Leone, tidal irrigation can be practised. In coastal and estuarine areas this could be further developed.

(e) Solar pumping for irrigation may soon be economically viable if the capital cost of photo-voltaic units can be further reduced. What is not so certain is how these pumping units will stand up to permanent use in remote rural situations.

4. Irrigation Applications -

(a) Surface irrigation still seems to be the most common method of water application in Tropical Africa. Of the 4.6 million ha under irrigation, 95 percent are under surface irrigation.

(b) Overhead irrigation is mainly used on a large scale for sugar cane in Tropical Africa. It is also used for the intensive cultivation of cash crops by "capital" farmers (i.e., farmers with large capital resources).

(c) More than half of the overhead irrigated areas are in Southern Africa.

(d) It is relatively easy to grow poor quality flood rice (padi) under irrigation, but it is difficult in Africa to maintain the husbandry and water control needed to maintain high yields.

5. Large Scale Irrigation -

(a) Large-scale irrigation developments are attractive because they are spectacular.

(b) Large-scale projects inevitably call for sophisticated technology in both their construction and operation.

(c) The operation of large schemes inevitably requires centralised management.

(d) Standards of operation and maintenance of large schemes in countries like Sudan or Somalia are low because of (a) acute professional and technical staff shortage, (b) shortage of funds and (c) exhausted equipment and machinery.

(e) Better training is often held to be the solution for better management for large irrigation projects. In fact the attractions of city life, or lucrative jobs in the private sector or in Middle East oil countries drain rural projects of the staff they need, and training in the normally accepted sense will not reverse this.

6. Small-Scale Irrigation -

(a) Many attempts to introduce small-scale irrigation in Tropical Africa have met with the same problems as large projects.

(b) Many small schemes have failed because of inadequate investigation, survey, planning and design.

(c) Small-scale irrigation using traditional practice is generally successful and has been on the increase, particularly with recent drought conditions. Promoted small-scale irrigation heavily supported from outside can succeed as has been demonstrated in some West African countries, but this has been achieved at very considerable cost.

(d) Small-scale irrigation seems to have had more success in West Africa than in East Africa. In

Kenya it has been found that small-scale irrigation has a better chance of succeeding if supported by a Non-Government Organisation rather than by a Government agency.

(e) Full local acceptance and co-operation is essential to a small-scale irrigation development.

7. Operation and Maintenance -

(a) The costs of fuel, maintenance, repairs of machinery and general operation seem to be a burden on all but the most highly commercial undertakings.

(b) In most countries in Tropical Africa the breakdown of machinery such as pumps and engines is due more to causes such as the shortage of foreign exchange, restricted imports, bureaucracy and unreliable channels of supply, than to the failings of mechanics and pump attendants in the field.

(c) The spread of schistosomiasis through large irrigation schemes is a matter of great concern to health authorities and considerable resources are being devoted to research on this. Control measures are feasible but they have been found to be uneconomic.

LAND TENURE ISSUES IN IRRIGATION PLANNING DESIGN AND MANAGEMENT IN SUB-SAHARAN AFRICA

by

Mary Tiffen

Overseas Development Institute

This working paper summarizes the problem of land tenure in Africa, water rights, tenure and management issues arising during planning and implementation, tenure, and management on settlement and extension schemes.

1. Land Tenure in Africa -

   (a) Customary law is still the basis on which the African farmer acts and decides his economic strategy.

      (i) Communal systems are most common where land is owned by a lineage or a village.

      (ii) Rights to use of land are based on the claim of first clearance for cultivation and these rights are heritable.

      (iii) A second group of customs derive from right of conquest.

   (b) Colonial powers, through conquest claimed all land was state land on which farmers had customary rights of usufruct.

      (i) Concept of State Land, Crown Land, Regime Domainial for unclaimed or unused land was created.

      (ii) Emphasized States' national control through local authorities.

   (c) According to customary law improvements such as crops and buildings belong to the farmer.

      (i) Raises issue on settlement schemes and the problem of ejecting a tenant who has

made improvements in housing.

(ii) Moslem law has gradually changed customary inheritance laws and prescribes land division with 2 shares for a son and one share for a daughter and widow's portion.

(iii) Tension currently arising between farmers who have moved to a position where he feels land belongs to him and the politician's view of state control through new national legislation.

2. Water Rights -

(a) Many African countries have no legislation or judicial principles on areas control to good water resource and irrigation planning.

(i) In Francophone countries all waters belong to the public domain by law except wells and cisterns built by individuals on their own land.

(ii) In Anglophone countries British common law generally prevails.

(iii) The United States "prior appropriation" doctrine giving priority to first constructors does not apply in Africa.

(iv) For many countries water law is vague.

(b) Priority between uses--especially urban vs. agricultural needs is vital to river basin planning yet it is not among the tasks of development authorities.

(c) Irrigation priorities--only a few countries have established systems for monitoring existing irrigation uses and establishing priority rights as between upstream/downstream irrigators.

(d) Very few countries have monitoring and licensing systems either for groundwater extraction or river water extraction.

3. Tenure and Management in Farmer-Initiated Systems -

(a) Partial Control Systems--are most common in Africa and include flood recession land, swamps, polders and valley bottom land where

there is no control over quantity or timing of the flow of water.

(i) Wet lands often used for grazing; however, under customary law use of these lands for cultivation takes precedence.

(ii) Conflicts arise when governments take over these lands for state purposes.

(iii) Usually the wet land plot is only a part of the family's total activities.

(b) Total Control Systems--three types are identified.

(i) Individually owned--quite common in West Africa. Small-scale, traditionally shaduf, more recently small pump and wells.

(ii) Capitalist Systems--covers a larger area than a normal African farmer can manage; consequently uses hired laborers, share croppers or tenants.

(iii) Communal or Cooperative Systems--control and ownership of irrigation are in a corporate body (clan or village institutions).

(c) Issues for Consideration.

(i) Further investigation on the rights and productivity of flood recession land users and groundwater users, especially when affected by dams for irrigation schemes.

(ii) In communal schemes where dams, canals, etc., have been created there is a need for a clear definition of the ownership and control of the assets, agreements over diversion of water and clarity over tenurial status of irrigated land.

4. <u>Tenure Issues Arising During Planning</u> -

(a) At the planning and implementation stage, it is necessary to establishing existing situation.

(b) Issues needing attention at feasibility study stage:

(i) Consideration of land use in the

with/without project situation taking into account down-river effects and the reservoir area.

(ii) Incorporate provision for compensation and cost of resettlement in the initial financial plan.

(iii) Undertake necessary socio-economic and cadastral surveys. Ascertain whether the population to farm the irrigated areas will retain land and assets off-scheme which may affect labor availability.

(iv) Pastoralists' rights have often been neglected. Compensation either by an offer of tenancy or monetary payment for loss of grazing rights needs to be considered.

(c) The typical African irrigation scheme will have either bought out or ignored local rights and then must make decisions on tenancy selection criterion, tenancy size, and housing and infrastructure provision.

5. Tenure and Management on Settlement Schemes -

(a) Justification for Settlement Schemes. Settlement schemes are those where land as well as water resources are owned or controlled by the scheme authority and on which the farmers have the status of tenants.

(i) Justified in that the State or commercial company is providing important and expensive assets and must ensure a good economic return.

(ii) Enables rules on cropping patterns, irrigation practices, rotations and cultural methods, timing of operations, etc., to be enforced.

(iii) Facilitates marketing procedures and enables the authority to recover costs and charges.

(iv) Easier to entrust functions of water delivery, maintenance, repair, cost recovery, etc. to a new state agency than to assist farmers to create their own institutions.

(v) Plot layout can be decided by technical requirements; size can be controlled and tenants can also prevent fragmentation and unwisely mortgaging land and losing it to indebtedness.

(b) Rights and duties of tenants.

(i) In Anglophone countries the literature is rarely clear on how the terms of the lease were conveyed to the tenant and whether or not he had an individual written agreement, and what occurred if changes were made in the conditions of the tenancy.

(ii) In some Francophone countries the legal contracts are with cooperatives. The tenant is commonly obliged to become a member of a cooperative.

(iii) Functions of the management authority include the delivery of water. In some cases management is also responsible for mechanized operations.

(iv) Sanction for non-performance is eviction but is difficult to accomplish.

(v) Methods of charging tenants for management services varies from scheme to scheme.

(c) Issues for consideration.

(i) A disadvantage of settlement schemes is the complexity of functions imposed on often inexperienced management staff.

(ii) A serious social disadvantage in cramping innovation and personal development.

(iii) Tenant status has been thought to instruct inexperienced farmers. Literature suggests better yields reported where supervision is minimized.

(iv) If it is decided to give farmers more freedom and responsibility, the stages and methods by which this can be done need consideration.

(v) The provision of housing, social

services and the relationship to ministries and local governments.

6. Tenure and Management on Extension Style Schemes -

(a) On extension style schemes farmers retain their original holdings and changes in tenure are either not made or are agreed.

(b) On the whole, the record of extension, when tried, seems successful provided the technique offered was genuinely profitable.

(i) Often a slow start, with only a few individuals or groups accepting the experiment initially.

(ii) After three or four years adoption accelerates.

7. Areas Where Further Research is Needed -

(a) Francophone scholars have given more attention to land use and legal issues than Anglophone ones.

(b) Issues connected with water rights, water use licensing, water use monitoring, existing water use in partial control systems.

(c) Virtually no information on tenure and management of large state farms, commercial estates, large private or small private farms which are introducing new irrigation technology.

(d) The connection between tenancy and a dependency complex needs further investigation.

(i) The methods by which management can withdraw after an initial learning phase have not been considered.

(ii) Investment patterns of farmers on settlement schemes seem only to have been researched in the Sudan.

(iii) The issues of the relationships of a resettlement scheme to authorities responsible for normal government services warrants investigation.

PROSPECTS FOR IRRIGATION DEVELOPMENT IN HYDROLOGICAL ENVIRONMENTS OF AFRICA

by

Linden Vincent

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University of East Anglia

I. INTRODUCTION

A. Objectives

1. Analyze prospects for irrigation in the hydrological environments of Africa.

2. Review aid to irrigation.

3. Review the different hydrological environments.

II. RAINFED VS. IRRIGATION STRATEGIES

A. Aid for Irrigation

1. Prevailing view that irrigation is the answer to Africa's food problems.

   (a) The validity of this assumption is questioned because of energy and recurring costs.

   (b) Disruption of existing agricultural production may in effect worsen food shortage situation.

2. In many large-scale schemes the primary objective is not agriculture but power, flood control, navigation or domestic water supply.

   (a) Double cropping with the development of a permanent water environment increases the disease hazard.

(b) Disruption of individual farmers' livelihood during the construction phase of irrigation development often results in indebtedness.

(c) High labor inputs decrease food diversity.

3. Suggests that the highest priority should be for rehabilitation and improvement of existing schemes.

(a) Need an appraisal for prospects of traditional African crops to provide urban stables--need to halt automatic promotion of wheat and rice, the basis of most large-scale irrigation.

B. Prospects for Irrigated Crops

1. Commercial crops rather than cereal crops are the most cost-effective irrigated crops.

(a) It is suggested that more attention should be given to rainfed staples such as maize, sorghum and millet thereby reducing the need for irrigated wheat and rice.

(b) Rice and wheat prices are fixed artificially low.

(c) Fruit and vegetables respond more to market forces.

2. Rhetoric of aid organizations focuses on involving the small farmer, evidence suggests that an increasing number of schemes are not involving the poorest groups.

3. Conclusions

(a) The "need" for irrigated crops has been distorted by some poor thinking about prospects of rainfed crops or existing rice varieties to supply the urban food requirements of Africa.

(b) The evidence of potential dynamism in traditional production of rice, maize and sorghum suggests it may be poor attention to marketing and production constraints that are the main problems, not their inherently limited prospects under the vagaries of climate.

(c) There is a need for development of projects to supply vegetables, fruits and some staple cereals.

C. Irrigation vs. Rainfed Farming

1. Virtually every analysis of irrigation schemes in Africa shows the way small farmers will try to protect their subsistence crops.

   (a) Because they retain their traditional rainfed plots there develops a labor constraint.

2. There is a need to resolve a number of population-resource imbalances.

   (a) Where there are high population densities, there is usually a labor surplus. Irrigation development is a way of utilizing the labor surplus.

   (b) In low rainfall zones where the rainfall is too low for crop production, irrigated crop production is an alternative where goods can be marketed.

   (c) The growing urban centers and their demand for food often leads to assumption that irrigation is the only alternative to increase food production. Vincent suggests considerably more work needs to be done on rainfed crops.

D. Improving Economic Performance

1. Profitability is of central importance--farmers will not participate if it increases indebtedness and does not provide subsistence security.

2. Labor availability is crucial--need to understand labor demands of family and that the working hours per day are realistic.

3. Size of farm needs to be realistic given labor constraints and level of profitability.

4. Social facilities are an important consideration and incentive to settlement schemes.

5. Adequate credit facilities, marketing, and provision of inputs are vital. Cooperatives play a useful role.

6. Inputs and mechanization should be assured by management.

7. Sound technical advice, drainage and levelling are essential for success.

E. Pastoralism and Fodder Production

1. Experiments have been promoting irrigated grass zones on which nomads could graze herds under management control.

   (a) Prospects for dairy farming based on irrigated pastureland have been investigated--not very cost-effective.

2. Conclusions

   (a) Pastoral groups show a willingness to be involved in schemes that add security to their production.

   (b) Success will come only if it can bolster and extend subsistence activity.

   (c) Irrigation can be a technique for "settling" nomads if it recognizes the continuation of grazing activities together with irrigated production and can overcome economic difficulties in producing irrigated pasture or forage crops.

III. CLIMATIC RESOURCES

A. Introduction

1. We know a great deal about the characteristics of African weather even if we are uncertain of the overall atmospheric mechanisms that control it.

2. Increased interest in agricultural development has resulted in several new classifications based on agroclimatic zones which used to:

   (a) define areas of similar problems;

   (b) see possibilities for new crops; and

   (c) identify similar regions for transfer of local varieties.

3. FAO has developed agroecological zones based

on techniques of matching water balance, temperature and day length requirements, soils and levels of inputs to examine the feasibility of certain staple rainfed foodstuffs.

B. Climate, Climatic Change and Agriculture

1. Prevailing wisdom of many climatologists is that the climate of Africa has not changed substantially within this century or recent centuries.

2. Where there is instability in food production it is more the result of increased population settling land that is marginal for crop production.

C. Climatic Data Analysis

1. There are three main areas of current research.

   (a) Problem of collecting representative spatial and temporal data to use for monitoring rainfall variability.

   (b) Appreciation of the range of environmental variables that can influence the definition of agroecological zones and growing periods.

   (c) Improving calculation of crop water requirements.

2. Recent progress in the definition of agroecological zones has given a much wider appreciation of the prospects for rainfed agricultural production in Africa.

   (a) Irrigation may provide water for a dry period, but it is also important to understand day length and temperature regimes of the dry period.

   (b) There is evidence that frequent water applications that keep soil near capacity is an important influence on yields.

      (i) Most irrigation schemes do not allow for this frequent irrigation.

      (ii) Schemes are designed to apply water at intervals which optimize the number of irrigators using water against any crop yield reductions

produced by water stress.

D. Climate vs. Rivers

1. Most African river basins show a very complex relationship with the climate of the areas the drain. River basins are influenced by three features:

   (a) inputs of water (primarily rainfall but also groundwater);

   (b) physiographic characteristics of the catchment area; and

   (c) vegetation.

2. The long-time scale over which most African drainage systems have developed has resulted in the development of vast complex, low-gradient systems.

IV. SURFACE WATER RESOURCES

A. Relevance of the River Basin Concept in Africa

1. There are 15 main drainage systems in Africa, some of them draining enormous areas and geomorphically they are very different from the smaller, younger rivers of the temperate world.

2. The way people use these drainage systems is also very different.

   (a) From the local perspective (people who use the diverse hydrological environments of Africa) flooding is regarded as a resource, although extreme floods or drought can cause food deficits.

   (b) Floodwater is not wasted--it actually forms the basis for food production and high population density.

   (c) It is water in combination with good soils and people that creates irrigation potential.

   (d) Frequently the pedological and social data are the weakest aspects of irrigation surveys.

   (e) Hydrological literature is littered with surveys of irrigation potential based

solely on water availability with no real economic presentation of their practicality.

3. The river basin concept is useful in organizing international cooperation in Africa.

   (a) Western concept of assessing a river basin as a means to assess the entire amount of available water that should be apportioned out for the most essential uses is likely to have disastrous consequences for many African rivers.

   (b) Vincent suggests keeping the river basin as an essential planning unit, but need to stress the diversity of environments within the river basin.

   (c) Far too few African dams are multipurpose. Need to include irrigation component more often. Also have to think of irrigation in terms of impact on traditional uses downstream.

B. Classification of Hydrological Environments

1. Western hydrological methodology has emphasized water inputs but the key problems in modeling African hydrological environments come from a lack of understanding of the physiography and vegetation of the catchment area.

2. Vincent classifies African hydrological environments as follows:

   (a) rivers and flood plains;

   (b) ephemeral streams and pans;

   (c) lakes, lakeside marshes and inland deltas;

   (d) wet coast environments and deltas;

   (e) swamps; and

   (f) dambos, i.e., intermittent swamps.

C. Problems with Irrigation Surveys and Implementation

1. The gap between potential and realized benefits on irrigation schemes has been investigated by several workers.

(a) Need to improve calculations of water requirements and losses in the distribution of water.

(b) Some of the worst technical problems stem from poor soil survey assessment.

(c) Failure to execute levelling requirements, inadequate drainage in order to cut costs.

2. Poor initial survey before farmers are settled can be compounded by limited research on crop yields on various soils.

(a) Few field trials are developed to establish optimum water application techniques.

3. Another key problem is the disruption to farmers of major land use changes introduced through irrigation.

(a) Often land levelling, drainage and canal excavation interrupts cropping three to four years, yet governments rarely take responsibility for this problem.

(b) Many farmers are forced to mortgage land becoming tenant farmers.

D. Rivers and Floodplains

1. Complexity of Africa's river basins need to recognize importance of geomorphic agents and agricultural foci rather than just water.

(a) Because of the amount of water and sediments vast floodplains have developed.

(b) Floodplain zones are also important areas for groundwater recharge.

2. Vincent identifies three catchment types:

(a) Complex--Remote catchments: low population density, few interventions except for power.

(b) Complex-Populous: large rivers draining hydrologically complex catchments, high rural population densities.

(c) Conventional-Populous: Smaller rivers or tributaries following more conventional

geomorphic profiles, high population density along rivers. Areas of greatest intervention, smaller flow more easily controlled.

3. Vincent is critical of foreign consultants using inappropriate concepts of water resource mobilization.

   (a) Often the new area irrigated does not produce an equal amount of food as the habitat it disrupts.

   (b) Cautions against the rapid resource mobilization of African rivers.

AGRONOMY AND IRRIGATION IN SUB-SAHARAN AFRICA

by

Donald S. Humpal

This working paper provides an excellent overview and synthesis of agronomic aspects of irrigation in Africa. The focus is upon the broader context of the place of agronomic technology for irrigation rather than upon individual schemes or countries. The paper is divided into five sections. The first section provides some general considerations on water and agriculture. Section two outlines the diverse irrigation and drainage methods used. The remaining sections discuss the agronomic issues of rice, sugar cane and cotton production in Africa.

I. WATER AND AGRICULTURE IN AFRICA--GENERAL CONSIDERATIONS

A. Assumptions

1. Generally held that the limiting factor to crop production in Africa is rainfall.
2. Recent work by Dutch researchers indicates that for important areas of the Sahel, major limiting factor to primary productivity is soil fertility rather than water.
   (a) Supplemental irrigation doubled production.
   (b) Nitrogen and Phosphate additions almost quadrupled production.

B. Factors Affecting Irrigation Development

1. Variable Climatic conditions especially as it affects rainfall, surface flows, temperature, and wind velocity.
2. Soil variability across the project site.
3. Increasing weed infestation.
4. Changes in pests, disease and viruses caused by improved conditions for pest multiplication.
5. Creation of attractive feeding sites for vertebrate pests.
6. Unexpected or ignored problems of salinity.
7. Exacerbation of problems by poor main system management, operations and maintenance.

C. Irrigation vs. Rainfed Agriculture

1. Arguments have been made that greater efforts should be devoted to rainfed agriculture because of the myriad of problems associated with irrigation.

2. Some areas in Africa where improved water control has resulted in fairly impressive production increases.
3. Might conclude that future emphasis in the irrigation sector should be on improvements to the performance and stability of production from existing schemes.

II. IRRIGATION METHODS AND AGRONOMIC PRODUCTION ALTERNATIVES

In this section Humpal identifies and classifies irrigation according to water source. The data on source of water, means of water control, drainage provisons and chief crops are presented in table form.

A. Irrigation and Drainage Systems
1. Class I - Groundwater Use with Drainage and Minor Extraction.
2. Class II - Groundwater Use with Intensive Extraction.
3. Class III - Rainwater Harvesting.
4. Class IV - Capture of Seasonal Surface Flows.
5. Class V - Supply from perennial flows, Run-of-the-River.
6. Class VI - Dam and Reservoir River Regulation.
7. Class VII - Coastal Mangrove Swamps.
8. Class VIII - Riverine Grasslands.
9. Class IX - Inland Valleys and Swamps.
10. Class X - Surface Flow Exclusion.

III. RICE AGRONOMY IN AFRICA SOUTH OF THE SAHARA

A. Classification of Rice Productions Systems
1. Two major divisions generally recognized
   (a) Irrigated with full water control.
   (b) Rainfed.
2. Such a two-fold classification overlooks natural flood irrigation systems such as in the Inland Delta of Mali.
   (a) These systems have proven more reliable than pumping schemes along the Niger and Senegal river that have been engineered to provide full water control.
3. Humpal makes a comparison between the IITA, IRAT, WARDA, IRRI and Moorman and Van Breemen rice production system classifications.
4. Important differences between Africa and Asian rice productions systems include
   (a) Dominance of rainfed production over 80% of the rice surface area of Africa compared to a more balanced distribution in Asia.
   (b) Over 30% of total rice area of Africa is dryland compared to 8% for Asia.
   (c) Higher proportion of strongly leached and weathered soils in Africa.

(d) Lack of Highland mountain zones in Africa compared to Asia which sustains stronger perennial flows.
(e) Different weed, insect, and disease complexes have evolved in Africa.
(f) Technological level of rice production in Africa is generally much lower than Asia.
(g) Remoteness and lack of transportation networks more of a problem in Africa.
(h) Lowland African environment often disease and parasite infested.
(i) There are few truly rice-based cultures in Africa.

B. Rice Production in Africa

1. Rice is a rainfed upland crop in much of Africa, grown under rainfed freely draining conditions--except in river flood plains, deltas, valleys, and coastal swamps.
   (a) Farmers have adapted production to a wide range of sites.
   (b) Average yields in major producing countries has doubled over past two decades.
   (c) Progress slow compared to increasing consumption, due to rapid population and urbanization changing the eating habits.
2. Factors involved in failure to match demand.
   (a) Research and development of rice based on a major transformation of productions systems to full water control and an organizational, management capability not present in Africa.
   (b) Effects of Green Revolution in Asia has made African rice production non-competitive.
   (c) Political and organizational shifts have disrupted research and development efforts.

C. The Agronomics of Rice Production

1. This section discusses rice production systems in Africa from the agronomic perspective. Special emphasis is placed on the research strategies employed to improve rice productivity. These include:
   (a) Varietal Improvement.
   (b) Water Management.
   (c) Weed Control.
   (d) Pest Control.
2. Research programs and development projects have addressed most of the above with site-specific strategies emphasizing one or more.
   (a) Focus of cultivar improvement, water control and tillage in the Delta area of the Niger River.
   (b) Main emphasis of cultivar improvement, soil management and pest control in the Casamance Basin of Senegal.

(c) Wholescale transformation of farming systems to full water control, mechanization and high input use in the Lower Senegal River Basin in Senegal, Office du Niger (Mali) and SEMRY in Cameroon.
(d) Management of soil salinity, acidity and fertility, and cultivar improvement in coastal mangrove swamps.

3. Varietal Improvements in Africa are summarized and discussed under the heading:
   (a) Floating and Deepwater Rice in Mali.
   (b) Flooded and Pluvial Rice.
   (c) Mangrove Swamps.
   (d) Shallow Swamp and Irrigated Rice.
   (e) Water Stress Tolerance: Upland vs. Lowland Types.
   (f) Insect Pest Resistance.
   (g) Disease Resistance.
   (h) High and Low Temperature Tolerance.
   (i) Regional Coordination.
4. Water Management - in Africa flooding is generally preferred because water stress is eliminated, weed control is easier and it induces a reduced soil environment which increases availability of some nutrients as pH approaches neutrality. Improved water management for rice is much more costly and difficult to sustain in Africa. Traditionally, rice has been of localized importance relying on high rainfall, floods or advantageous topography. Approaches to water control and their problems are discussed under the following.
   (a) Floating Rice.
   (b) Deepwater Rice.
   (c) Mangrove Swamps.
   (d) Shallow Water Rice.
   (e) Full Control Irrigation.
5. Soil management--the author discusses soil management practices as it relates to water availability and soil fertility in rice production systems.
   (a) Soil Management during Rainfed Periods.
   (b) Fertility Management.
6. Weed Control--methods of weed control proposed include:
   (a) Use of early varieties which flower and mature before red rice sets seed.
   (b) Use of cultivated fallows.
   (c) Rotation with sorghum, maize and wheat.
   (d) Pre-Irrigation followed by harrowing.
   (e) Seed cleaning to eliminate red rice.
   (f) Rotation with perennial forage plants.
   (g) Grazing of native stands and fallow fields.
   (h) Herbicide use with antidotes for cultivated rice.
7. Insect pest control--evident that the economic

behavior of most insect pests of rice are not well understood in Africa. Suggests that in absence of information need to:

(a) Determine economic threshold of damage.
(b) Determine the economic feasibility of treatment.
(c) A treatment calendar based on susceptible periods during insect life cycles.
(d) Minimize the risks.

IV. SUGAR CANE

A. Introduction

1. Humpal reviews origins of sugar cane production to its introductions into West Africa by the 15th Century.
2. The drive to produce sugar in Africa was spurred by WWII and colonial investment to develop cheaper sources of sugar.
3. Major new sugar projects in Africa:
   (a) Have been designed and implemented to provide import substitution for rapidly growing sugar consumption (Nigeria, Ivory Coast).
   (b) To obtain some foreign exchange from exports (Burkina Faso, Malawi, Kenya, Zimbabwe).
   (c) To determine the economics of sugar cane as a basis for ethanol production as a fuel substitute (Zimbabwe).
4. History and the agronomy of sugar cane development are focused on large-scale production and closely linked to processing operations to avoid post harvest losses of sucrose conversion.

B. Irrigated and Rainfed Production

1. Irrigation and/or drainage works are key features of many sugar cane plantations.
   (a) Sugar yields and crop management tend to be highest when there is a cool dry period to permit maturation--allowing accumulation of sucrose in the cane.
   (b) Environments which have distinct dry periods may also have low reliability of rainfall at times when rapid growth of cane is desired.
2. Both rainfed and irrigated sugar cane production exists in Africa. The author discusses case studies from Mozambique, Ivory Coast, Zaire, and Niger, and concludes:
   (a) That site and crop management can be combined in many ways to maximize sugar production.
   (b) The crop can be grown for one year, two years, or eighteen months before harvesting.
   (c) Ratoon crops can be varied in number and duration.
   (d) Mechanization can be nearly total or selectively employed.

(e) The combinations and permutations of agronomic management are many.
(f) Water supplies a key role in manipulating growth rates and maturation periods within certain limits set by environment and variety.

C. Varietal Decline and Improvement
1. Sugar cane is subject to varietal decline i.e. varieties tend to decline in their yielding ability over a period of two decades.
2. Varieties differ in their susceptibility based upon genetic makeup; bacterial, fungal and viral disease; insect pests, nematodes; and environmental stress.

D. Pest and Weed Management
1. Termites, root grubs, stem borers, and nematodes are the four major pests of sugar cane in Africa.
2. Cultural practices to minimize problems include:
   (a) Selection of uninfested seed pieces.
   (b) Selection of seed pieces from 9-10 month old cane.
   (c) Dieldrin treatment of seed pieces to protect against termite attack while reducing destruction of beneficial insects.
   (d) Sprinkler irrigation for crop establishments emerging borer larvae are drowned.
   (e) Harvest the first cane crop at a maximum age of 12-13 months.
   (f) Destruction of stools of the previous cane stand after the last ratoon crop.
3. There is generally not a problem with weed control during first crop which undergoes several tillage operations up to full cover.
   (a) Succeeding ratoon crops usually develop a strong weed challenge, especially after field firing.

E. The Large-Scale Nature of Sugar Cane Production and Smallholder Isolation from Technological Advances.
1. Sugar cane is an industrial crop, economic optimization of production, harvesting and milling are important.
   (a) Price fluctuations of world market prices require periodic adjustments at all levels of production.
   (b) As a result all large schemes have research and development programs.
2. Smallholders of Africa are generally outside the sugar cane research and development circles.
   (a) Varieties, growing practices, input use, maturation techniques and harvest technologies lag a decade or more behind the main plantations.
   (b) There are apparently no programs in Africa

which work on sugar cane or sugar-cane based cropping systems for smallholder conditions.

V. COTTON

A. Introduction

1. Cotton yields in Africa are about half of other areas--reason being that most cotton in Africa is grown under rainfed conditions.
   (a) Notable exception is the Gezira Scheme of the Sudan.
   (b) Irrigated cotton is also produced in Mali, Kenya, Tanzania, Mozambique, and Zimbabwe.
   (c) Recessional cotton is grown in Chad and Madagascar.

B. Irrigated Cotton Yields

1. Cotton yields in the Sudan have been stagnant or declining for the past ten years.
   (a) Inadequate pest and weed management, drainage problems, poorly mechanized practices, lack of harvest labor and poor farmer management and disincentives are the cited reasons.
   (b) Overuse of pesticides, government policies, management and disincentives have also been cited.
2. Research on long-term cotton yields in U.S. suggest that yields tend to level out and decline despite steady improvements of new higher yielding varieties.
   (a) Suggests that irrigated cotton production problems in Sudan may not be remedied when irrigation schemes are rehabilitated and reorganized.
   (b) Problems may have increased when Gezira switched from an eight-year fallow and fodder intensive rotation to a four-year cotton-wheat-peanut-fallow rotation.
3. In new areas cotton production obtains high yields.

C. Pest Control

1. Production severely constrained by insects, weeds, disease, fertility, and soil moisture.
2. Currently numerous projects in Africa, financed by IBRD and the European Development Fund have been launched with strong components in improved insecticide and herbicide programs.

D. Weed Control

1. Hand weeding is still dominant in Africa--labor requirement considerable and is often neglected in cotton areas with priority given to food production.
2. As a rule good land preparation, a pre-emergence herbicide or early mechanical or hand weeding, and a well-timed second and third weeding will provide a reasonable level of control.

(a) No work on biological control of weeds in Africa is underway.

E. Disease Control

1. A variety of diseases are found in Africa.
2. Recommended procedures for minimization of disease include:
   (a) Selection of seed for high vigor.
   (b) Careful control of nitrogen fertilization to avoid aggravation of wilt severity.
   (c) Potassium fertilization to avoid potassium deficiencies favoring wilt.
   (d) Adequate irrigation rotations.
   (e) Clean tillage.
3. Chemical control of cotton disease is seldom economic.

F. Fertility Management

1. Research into fertilization of irrigated cotton produced under arid conditions emphasizes:
   (a) Nitrogen should be at adequate level from the beginning of growth.
   (b) An ample supply is needed near bloom.
   (c) Best yields and quality are obtained if soil nitrogen is depleted after maturity.
   (d) The deep roots of cotton enable the plant to take up leached nitrates form the lower soil horizons.
2. Normally complete NPK fertilization is carried out with additives of boron and sulfur to produce a "cotton fertilizer."

APPENDIX B

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