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INVESTMENTS IN LARGE SCALE INFRASTRUCTURE: IRRIGATION AND RIVER MANAGEMENT IN THE ~~SHAEL~~ SAHEL

by

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EXECUTIVE SUMMARY

This report investigates the ways in which large-scale infrastructure investment in irrigation and river management in the Sahelian countries of West Africa is consistent with the Congressional mandate of 1973 to aid the poor majority in developing countries. The report examines the legislative history surrounding the establishment of the mandate and concludes that the U.S. Congress is in general willing to finance large-scale infrastructure in the Sahel as long as it can be demonstrated (1) that there are no better alternatives and (2) that the majority of benefits accrue to small producers with secure land tenure. After establishing the need for large-scale infrastructure investment in the Sahel the rest of the report examines the conditions under which these requirements are likely to be satisfied.

To aid in exploring this question, two surveys were undertaken the results of which are reported in detail in the appendices and summarized in the text. The first survey included A.I.D. financed irrigation projects all over the world; the second covered irrigation projects financed by all donors in the Sahelian countries. In addition, the experiences of the two largest irrigation projects in sub-Saharan Africa -- the Gezira scheme in Sudan and the Office du Niger in Mali -- were examined to see what additional light they might shed. From these data, a typology of irrigation projects was developed which indicates the project characteristics which contribute most to aiding the poor.

The conclusions of this analysis suggest that development of irrigation on a large scale in the Sahel is likely to be costly and to contribute relatively little to the well-being of the poor if it is carried out using capital-intensive techniques of construction and cultivation. Fortunately, experience also suggests that it should be possible to develop an alternative production system which would not only be technically and economically viable but would also provide substantial benefits to the poor without being socially disruptive. This system would involve total water control and at least two crops per year, labor-intensive as well as mechanized technologies of construction and cultivation, farmer organizations consistent with traditional social structures, and commercial as well as food crop production.

Investment in river basin infrastructure, however, goes far beyond the construction of irrigation systems. Sooner or later river flows must also be regulated, and this generally involves large, lumpy expenditures on upstream storage dams. Associated construction of downstream irrigation systems must also usually be accomplished relatively quickly for financial reasons, resulting in very large total capital requirements as well as assurance of subsequent recurrent cost financing for operation and maintenance of the whole system.

The current situation regarding irrigation and the need for river flow regulation is examined in this report for each country and major river basin in the Sahel. This is done using a rudimentary systems approach which takes into consideration the existing potential for developing rainfed agriculture and small-scale irrigation. The results suggest that there are marked differences in the need for major river basin development. At one extreme, Chad, Mali and Upper Volta are able to concentrate for the rest of this century on rainfed cultivation and small-scale irrigation without having to be concerned about regulating the flows of their major rivers. At the other end of the spectrum, Mauritania and Niger have little potential for developing rainfed agriculture and their scope for expanding small-scale irrigation is likely to be constrained fairly soon by the quantity of water available for a second crop (though this will depend for Mauritania on the rate at which Senegal uses the water in the Senegal River). The Gambia and Senegal occupy an intermediate position. They have some possibilities for developing rainfed agriculture and small-scale irrigation but will probably have to initiate major river basin development before the end of this century if they are to avoid increasing food imports.

Regardless of the current situation facing each country, there is a need to initiate action now if the Sahelian river basins are to be rationaly developed in the future. The following recommendations are offered in the concluding section of this report:

1. That A.I.D. participate actively in the development of a prototype irrigation and production system along the lines described above. This will involve studying past experience as well as investing in a variety of types of infrastructure. The justification in terms of ultimate benefits to the poor could be very high.

2. That A.I.D. promote agricultural development, including irrigation, in the higher rainfall areas of the Sahelian countries and, in particular, experiment with various ways of facilitiating immigration into these areas from those with lower rainfall. Attention should be focused on finding an approach somewhere between very expensive land resettlement programs and spontaneous migration, which can sometimes be rather disruptive. The approach should probably be closer to the latter than to the former method, however, if significant numbers of people are to be involved. A survey of the existing literature on migration and land resettlement in West Africa, as well as a number of micro-level field surveys in key areas, should be undertaken.

3. That A.I.D. encourage a thorough examination of marketing possibilities for irrigated crops. This should include not only outlets for cash crops such as cotton, which might feed into domestic textile industries, but also the implications of expanding the production of food with respect to both import substitution and its effects on local prices of non-traded cereals.

4. That A.I.D. promote research and development for potential irrigated cash crops as a means of financially sustaining the river basin development programs

5. That A.I.D. participate in the training of the specialists, planners, and managers who will be required for major river basin development.

6. That A.I.D. incorporate into the infrastructure projects which it finances a systematic means of evaluating both the primary and secondary costs and benefits of those projects.

7. That A.I.D. promote the use of a systems approach to river basin planning along the lines discussed earlier in this report. Quantification of this system should help to identify information gaps and to evaluate alternatives concerning the timing and direction of development. It would be useful in this respect to consider the methodology suggested by the U.S. Water Resources Council, which is consistent with the Club du Sahel's suggested multi-objective approach to planning and project analysis.

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INVESTMENTS IN LARGE SCALE INFRASTRUCTURE: IRRIGATION AND RIVER MANAGEMENT IN THE SAHEL

INTRODUCTION

In recent years, there has been considerable reluctance to have U.S. aid programs involved in large-scale infrastructure projects such as dams, irrigation systems, roads, ports, and power generation facilities. The shift away from this type of investment, which accounted for the major portion of development assistance in the early 1960s, occurred for two reasons. First, the general increase in economic activity resulting from infrastructure projects tended to benefit most families that were already well established. Poor families, on the other hand, usually did not have the resources required for them to take full advantage of the newly created opportunities.

A second hesitation about large-scale infrastructure projects stemmed from the Agency's experience with implementing such activities. Low rates of return and numerous cost overruns too often created painful budget constraints and curtailed program flexibility. Not only was the distributive impact of infrastructure adverse but also the efficiency with which large-scale projects used investment funds was low.

As a result, A.I.D. programs have been reoriented toward projects which directly benefit the poor by enabling them to grow more food and to have access to improved education and health facilities. A major component of this new orientation is the creation of the capacity to develop more scientific knowledge about agriculture and to disseminate the improved technology among small farmers. This continues to have a high payoff in many parts of the world. Indeed, it would be hard to conceive of a more effective use of foreign aid than the assistance given developing countries to obtain improved seeds, to acquire adequate stocks of fertilizer, to generate additional water supplies from tubewells and pumps, etc. Moreover, despite numerous fears and predictions to the contrary, the divisibility of inputs such as seeds and fertilizer has resulted in relatively broad participation in the benefits of increased agricultural productivity.

Important as this strategy shift has been, however, there is increasing evidence that it is not a panacea. Certain preconditions appear to be necessary for its successful implementation. Most obvious, perhaps, is the crucial role of controlled water supplies in implementing the high yielding varieties (HYV) technology.[1] But other infrastructure

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[1] Uberto Colombo, D. Gale Johnson, Toshido Shishido, "Expanding Food Production in Developing Countries: Rice Production in South and Southeast Asia," Report of the Trilateral Food Task Force, 1977.

investments, such as transportation, power, and processing facilities, are also necessary conditions for the introduction of more productive farming systems. It is no accident that the areas in which progress in increasing output has been most rapid, e.g., Taiwan, Korea, the Punjab in India and Pakistan, are also areas in which major investments in dams, canals, and roads antedated the "green revolution" by several decades.

In countries where at least some minimum infrastructure exists, opportunities for expanding output by increasing productivity in the existing system continue to be available. Regions in which little or no infrastructure is found, however, present a more difficult challenge. Here the scale of capital investment required not only for creation of infrastructure but also for complementary projects which benefit the poor can be very large indeed. In addition, there may be considerable lumpiness in the sense that investment in the entire package must be made within a fairly short period to avoid excessive interest costs and to ensure that the poor benefit relatively soon.

Decision makers concerned with U.S. foreign assistance are thus faced with a dilemma. The "new directions" mandated by the Congress in 1973 call for A.I.D. "to help the poor majority in developing countries raise their living standards beyond subsistence levels."[2] This has recently been interpreted in terms of "a 'basic human needs' strategy of development as an extension and refinement of the 'equitable growth' strategies underlying the 'new directions'."[3] There is a growing feeling, however, that continued pursuit of these strategies will ultimately require decisions to be made concerning Agency participation in the financing of large-scale infrastructure projects -- a type of investment which has been thought in the past to have contributed little to the well-being of the poor.

This report examines the issue of infrastructure investment in irrigation and river management programs envisioned for the Sahelian countries of West Africa. The next section deals with a number of conceptual issues related to the new directions mandate and to investment in large-scale infrastructure. Subsequently, material drawn from a worldwide survey of current and past A.I.D. irrigation projects, as well as from the general development literature, is used to provide concrete illustrations of these issues. A preliminary typology of irrigation schemes is also proposed. Following this, some preliminary conclusions from the first part of the report are drawn and the stage is set for the subsequent

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[2] Agency for International Development, Implementation of "New Directions" in Development Assistance, Report to the Committee on International Relations on Implementation of Legislative Reforms in the Foreign Assistance Act of 1973, Washington: U.S. Government Printing Office, 1975, p. 64.

[3] AIDTO CIRCA-168 of April 6, 1978, "Program Guidance for FY 1980," p. 2. The basic human needs strategy is further explained in Agency for International Development, A Strategy for a More Effective Bilateral Development Assistance Program: An A.I.D. Policy Paper, March 1978.

discussion of irrigation and river management in the Sahel. This begins with a brief review of the current agricultural situation in the Sahelian countries, an examination of the potential for irrigation, a discussion of past experience with irrigation, and an outline of plans for its future expansion. Next, existing irrigation projects are classified into six categories, following the typology proposed earlier, and these are discussed with respect to their differential impact on the well-being of the poor. Some lessons are then drawn from the history of the Gezira Scheme in Sudan and the Office du Niger in Mali, the only two truly large-scale irrigation projects in this area of the world. The next section briefly examines each of the major river basins with respect to the need for and timing of river flow management as related to overall rural development. Finally, some general conclusions are presented and recommendations made.

CONCEPTUAL ISSUES SURROUNDING INVESTMENTS IN LARGE-SCALE INFRASTRUCTURE

The New Direction of U.S. Foreign Aid

During the 1950s and 1960s, capital transfers and technical assistance from the United States were directed toward a variety of physical infrastructure projects as well as the support of national institutions concerned with various aspects of development. In the rural sector this included the construction of fertilizer plants, the establishment of irrigation systems, the building of roads and power distribution networks, and the promotion of agricultural research and extension programs. By the end of the 1960s, however, there was an awareness that even in countries with impressive growth records the benefits from development were frequently very unevenly distributed. Direct measures of well-being related to nutrition, education, and health frequently showed little or no progress insofar as the poor were concerned.[4]

The major cause of this failure was held to be the inability of samller farmers with low levels of income and wealth to take advantage of the opportunities presented by new feeder roads, irrigation systems, agricultural technology, and extension and credit schemes. Instead, it was larger farmers with greater access to capital who were better able to exploit these new services. In addition, government policies often favored larger over smaller farmers, and political realities did not permit this situation to be easily changed.

One result was the "new directions" mandate, appearing in the Foreign Assistance Act of 1973, which directed A.I.D. to be more responsive to the needs of the poor majority by focusing less on large-scale capital transfers and more on food production, rural development, nutrition, population planning, health, education, public administration, and human resource development.[5] Special emphasis was placed on enhancing the capacity of the poor for self-help and involving them more as active participants in the development process.[6] To this was later added "the explicit objective of making it possible for as many people as possible to achieve a minimally acceptable standard of living on a sustainable basis within a reasonable period of time."[7]

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[4] Agency for International Development, Agricultural Development Policy Paper, Washington: June 1978, p. 5.

[5] Public Law 93-189, 93rd Congress, S. 1443, December 17, 1973.

[6] Agency for International Development, Implementation of "New Directions"..., p. 3.

[7] AIDTO CIRCA - 168, p. 5.

Although the later "basic human needs" objective was seen as a logical extension of the new directions mandate, it did shift attention away from the importance of developing a productive base required in the long run to support a "minimally acceptable standard of living on a sustainable basis." Rural development project proposals to strengthen agricultural research institutions or to invest in major physical infrastructure such as irrigation, rural roads, and electric power became controversial because of their high capital cost and technical assistance demands and because of their failure to directly benefit the poor. "Yet, these kinds of projects, appropriately designed and implemented, can be a vital step in bringing cost-reducing and production-increasing technology to farmers, and hence higher incomes to the rural poor and more abundant and lower cost food to consumers," many of whom are also very poor.[8] Furthermore, an expanding production, and hence tax, base is essential if national governments are going to be able to meet the recurrent expenditure requirements implicit in public programs designed to meet "basic human needs." "In other words, to be substainable, a development strategy in support of the provision of basic human needs requires broad-based economic growth in which the widespread productive participation and benefit of the poor is an essential feature."[9]

Thus there clearly is a case for infrastructure investment, and the main question is on what scale. This is recognized by the Congress. The following quotation is illuminating:

> Mr. BUCHANAN. Mr. Chairman. I fully support this amendment. I, too, would like to make a little legislative history. Unfortunately, we do not have a clear definition of "infra-structure" in the law and, therefore, we had quite a discussion at the subcommittee level as to what we meant by the definition of "funds for major infrastructure projects." And we agreed we were talking about things like dams, major roads. We were not talking of buildings for a health clinic or a group of such buildings in different villages. We were not talking about village schools to implement educational programs. We were talking about things like dams, major roadways, really major public works projects. I would like that legislative history to get into the record as well.[10]

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[8] Agency for International Development, Agricultural Development Policy Paper, pp. 7-8. This document, as well as the one cited in the following footnote, indicate the substantial rethinking on this issue which occurred later within the Agency.

[9] Agency for International Development, A Strategy for a More Effective Bilateral Development Assistance Program..., p. 10.

[10] U. S. Congress, Foreign Assistance Legislation for Fiscal Year 1978 (Part 9), Mark-up Sessions before the Committee on International Relations, House of Representatives, Ninety-fifth Congress, First Session, Washington: U.S. Government Printing Office, 1977, p. 162.

The same interpretation appears to exist within the Agency:

> Financing of small-scale rural infrastructure is specifically authorized in Section 103(c) of the Foreign Assistance Act which refers to activities "to increase the productivity and income of the rural poor, through such means as... expansion of local or small-scale infrastructure and utilities such as farm to market roads, land improvement, energy and storage facilities." A.I.D. interprets this section to permit development of rural physical infrastructure that may be crucial to improvement of the material well-being of the poor.
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> The existing legislation and legislative history clearly discourage A.I.D. funding of large infrastructure projects such as power plants, high dams, super highways, major port facilities, etc., especially insofar as they are intended to serve modern industry and major petroleum areas rather than the rural poor. Within that overall restriction, however, the kinds of infrastructure mentioned in Section 103(c) are not intended to be an exclusive and exhaustive list to which the Agency must be strictly held (for example, the creation, expansion and improvement of water delivery systems through irrigation, drainage, management and other water control efforts are often vital to increasing the productivity and incomes of low-income agricultural producers).
>
> Legislative history makes it clear that Congress considers infrastructure aimed at the well being of the poor an essential element of the new directions approach. In general, therefore, it is our view that the legislation not only permits but encourages us to finance the kinds of infrastructure that are most necessary to increase the productivity and income of the rural poor.[11]

Thus A.I.D. has continued to finance "the construction and renovation of such small scale infrastructure as irrigation systems, rural electricity distribution systems, and rural road systems." These investments, in fact, constitute about 40 percent of A.I.D.'s total agricultural and rural development program.[12]

It is only with respect to large-scale infrastructure, therefore, that the U.S. aid program may be restricted by the new directions mandate. Even here there appears to be some flexibility since A.I.D. has proposed a Congressional amendment which would permit financing of major infrastructure, preferably within a multilateral framework, where sufficient

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[11] AIDTO CIRCA - 168, p. 7.

[12] Agency for International Development, <u>Agricultural Development Policy Paper</u>, p. 42.

financing is not available from other sources and the infrastructure is "important to broad-based development and is complemented by other measures to assure that the benefits reach the poor."[13]

It also appears that the Congress is prepared to make exceptions to its restriction on large-scale infrastructure in the case of the Sahelian countries as long as a number of conditions are met. The General Accounting Office's recent report to the Congress on the Sahel Development Program notes, for example, that:

> AID's General Counsel analyzed the legislative history of the Sahel legislation, including the language contained in the fiscal year 1978 Conference Report. It concluded that while there were some problems of interpretation, the authorizing legislation can be construed as granting authority for the United States to participate in financing a "fair share" of SDP infrastructure....[14]

Furthermore, the report of the House Committee on Appropriations concerning the Foreign Assistance and Related Programs Appropriation Bill of 1979 states that:

> In recognition of the low level of development in the Sahel region, there is a special need for developing an effective infrastructure.... If funds are requested for large-scale infrastructure projects, such as large dams and irrigation projects, AID should be prepared to demonstrate to the Committee:
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> - that large-scale projects have been compared to alternatives, such as small dams and small irrigation perimeters, and that the choice of large dams is justified by the evidence;

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[13] AIDTO CIRCA - 168, p. 8. The question of scale is, of course, rather arbitrary. Peter Cook has proposed the following useful definitions:

major project: development impact on a regional scale, e.g., large dam or trunk road;
intermediate project: development impact over a zone including several villages or towns, e.g., large irrigation canal or irrigation perimeter or a secondary road improvement;
minor project: development impact over a small group of farms or a single village, e.g., small dam, irrigation ditches, or farm to market roads.

(Peter D. Cook, "Issues Paper on AID Infrastructure Policy With Reference to the Sahel"). The definition of large-scale infrastructure used in this report includes both major and intermediate projects as defined by Cook.

[14] Comptroller General of the United States, Report to the Congress: The Sahel Development Program - Progress and Constraints, Washington: March 29, 1978, p. 52.

- that the majority of benefits of river basin development projects will accrue to small producers with secure land tenure;

- that river basin development projects will not lead to the further spread of schistosomiasis or other health problems; and

- that the full potential of small-scale, decentralized, energy technologies - such as mini-hydropower generators, windmills, methane generation plants and direct solar devices - will be utilized.[15]

Thus the way seems open for the United States to finance large-scale infrastructure investment in the Sahel provided that the projects can meet these requirements.

Justification of Large-Scale Infrastructure

The major justification of large-scale infrastructure is that it can improve the effectiveness of projects designed to directly increase production and the well-being of the poor. Without infrastructure, returns to other forms of investment tend to decrease as more of these investments are made.[16] With infrastructure, on the other hand, even though initial investment in social overhead capital may yield no direct benefit, returns to subsequent investment in productive projects are at first higher and thereafter decline more slowly as the total magnitude of investment is increased.

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[15] U.S. Congress Foreign Assistance and Related Programs Appropriation Bill, 1979, Report together with Minority and Additional Views of the Committee on Appropriations, House of Representatives, Ninety-fifth Congress, Second Session, Washington: U.S. Government Printing Office, 1978, pp. 31-32.

[16] The use of the word "returns" is broader here than in the usual benefit/cost analysis in that it refers to all the goals, including benefitting the poor, taken into account by decision makers and not just that of economic efficiency. Possible conflicts between these goals are ignored for now but are discussed later in the report.

This is illustrated in Figure 1, which shows a possible relationship between cumulative past investment and the return to that investment with and without infrastructure. Although investment in infrastructure may yield no return up to point C, the return to directly productive investment is so great with infrastructure that the total rate of return soon exceeds (after point D) that which exists in the absence of infrastructure. This suggests that infrastructure investment is a necessary, if not a sufficient, condition for continuing development.

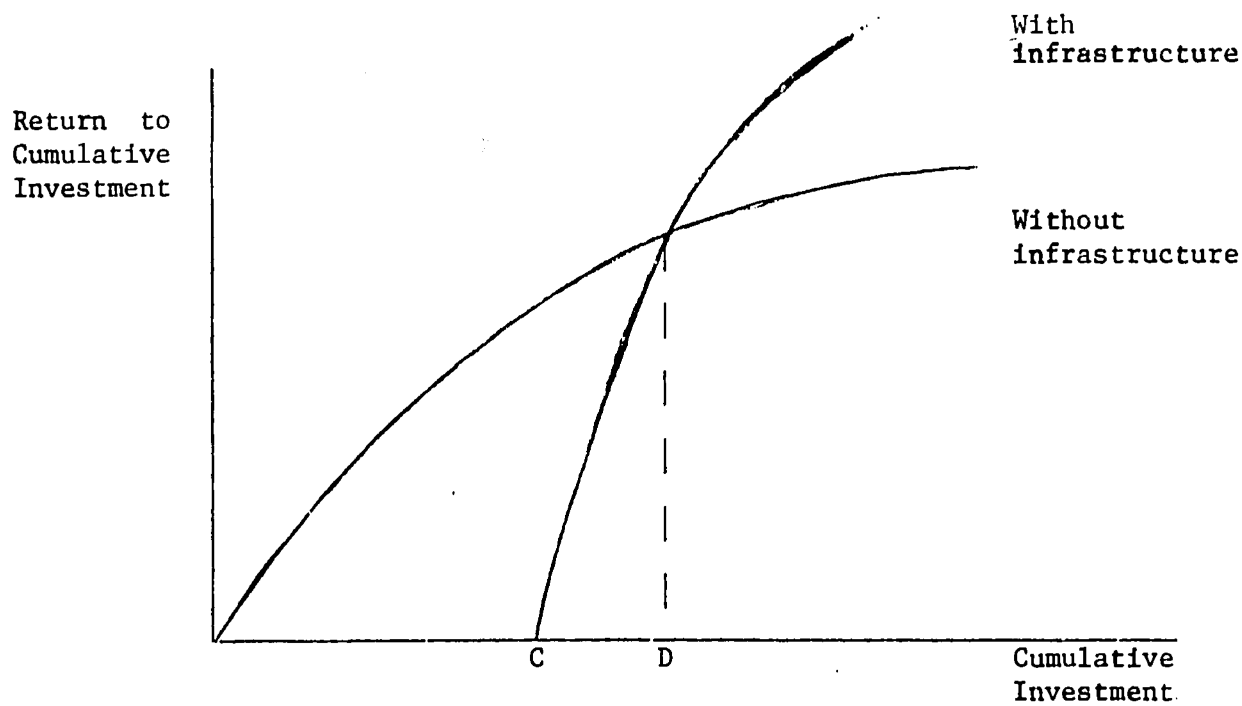

Figure 1

There are a number of specific ways in which the failure to invest in infrastructure frustrates the development process. One of the most obvious of these is the difficulty of improving people's lives in outlying regions not served by roads or other forms of transport. Lack of transportation facilities to other countries also prevents a nation from benefitting fully from its potential for international specialization and trade. Communications systems and administrative infrastructure which are inadequate in the countryside make it more difficult and costly for the government to provide services in these areas. Lack of agricultural research seriously undermines efforts to improve productivity in agriculture. The list goes on and on.

With respect to large-scale infrastructure for irrigation and river regulation, it is clear that with present technology the largest part of the world's future increases in food production must eventually come from irrigated agriculture.[17] This is particularly so for the rice economies of Asia, but it will also become increasingly true in other areas of the world since land is ultimately limited in supply and expansion of production increasingly must come from raising yields. But rainfall everywhere is uncertain, and in many regions, such as the Sahelian countries, it is also in short supply even in normal years. As a result, there are important physical limitations on the extent to which yields in rainfed cultivation can ultimately be raised, particularly in lower rainfall areas.

Because of generally low population density, the bringing into cultivation of unused land in the Sahel may continue for some time, especially in higher rainfall areas when these are cleared of onchocerciasis and trypanosomiasis. In addition, the most profitable investments in the rural sectors of the Sahelian countries are probably still in rainfed agriculture because current yields are so low. As these yields are increased, however, diminishing returns to further investment will increasingly be felt in the absence of irrigation. Furthermore, there are already pockets of higher population density where pressure on the land is being felt, and these will become more numerous in the future.

Aside from its role in permitting greater yields to be obtained, irrigation is also desirable as a way of making production more secure. This is especially important in the Sahelian countries, which are subject to high variation in rainfall. The cost of stabilizing production in this way should be compared, however, with the cost of other methods of assuring adequate food supplies, such as grain storage.[18]

The general need for irrigation does not necessarily imply a need for large-scale irrigation. All over West Africa there are small-scale efforts to control water. These involve bunding, the building of low protection dikes, the construction of small canals and drainage ditches, the use of low-lift pumps, and numerous other measures. These are important innovations that need to be studied carefully to see the extent to which they can be replicated, but they are unlikely to tap more than a small part of the Sahelian region's water resources. Full exploitation of these will require investment in large-scale infrastructure such as diversionary dams, salt water barrages, and extensive irrigation systems.

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[17] Colombo, Johnson, and Shishido, "Expanding Food Production in Developing Countries...."

[18] For further discussion of this see J. Dirck Stryker, "Food Security, Self-Sufficiency, and Economic Growth in the Sahelian Countries of West Africa," Food Research Institute, Stanford University, February 1978.

Even when these large-scale investments are made, a substantial area of land in the Sahelian countries can still be irrigated without regulating river flows through expensive upstream storage. This results, however, in several problems. Large-scale irrigation facilities are costly to construct and to maintain. To offset these costs, it is desirable that the facilities be used to the maximum extent. But this implies double cropping, which is difficult because of seasonal variation in river flows. As the total land area under irrigation increases, the supply of water during the dry season will become increasingly inadequate to supply all competing needs without storage dams to even out river flows over the year.

In addition to seasonal variation, there are substantial fluctuations in flows from year to year. Some irrigation systems can function only if there is adequate natural flooding and in dry years part of the land may yield no crop at all. In other systems, water may be obtained by pumping or a diversion dam, but the small amount in the river in some years may not be sufficient to meet competing demands. Eventually, interannual upstream storage will be required if the full potential of the region is to be realized.

There is, of course, always the possibility that technological advances will permit the achievement of greater yield increases in rainfed farming. Historical experience so far, however, indicates that irrigation is required to obtain maximum advantage from the use of HYVs and their complementary inputs. As long as population in West Africa continues to grow, therefore, the question seems to be not whether investment in large-scale infrastructure for irrigation and river management will ultimately be necessary but rather what should be its timing relative to the development of rainfed agriculture and small-scale irrigation. This question cannot be answered a priori but depends on factors such as the distribution and growth of population, the rate at which higher rainfall areas can be cleared of disease, the willingness of people to move from areas of high to those of low population density, and the speed with which diminishing returns to investment in rainfed cultivation is reached. Only when quantitative estimates have been made for these variables and they have been combined together in a comprehensive planning system can this question of timing be adequately addressed.

Large-scale infrastructure has a very long gestation period. In addition, if this infrastructure is to be properly designed, preliminary experience should be gained from pilot projects which simulate as closely as possible conditions which will exist when the infrastructure is in place. Thus even if large-scale irrigation and river management can be postponed for a number of years, the time for planning is now.

How Large-Scale Infrastructure Benefits the Poor

The new directions approach implies that U.S. foreign assistance directed toward investment in large-scale infrastructure must benefit the poor majority. This requires some definition of who these intended beneficiaries are, a question which was discussed at some length in A.I.D.'s report to Congress in 1975 outlining how the new directions approach was to be implemented. There it was suggested that the following benchmarks be used to define the poor majority:

(a) Per capita income below $150 per year (in 1969 prices);

(b) Daily diet of less than 2,160 to 2,670 calories (depending on the country); and

(c) Several health indicators: life expectancy at birth of below 55 years, infant mortality over 33 per 1,000 children aged 0 to 1, birthrates over 25 per 1,000 population, or access to broadly defined health services for under 40 percent of the population.[19]

By these standards all the Sahelian countries would easily qualify. The report makes clear, however, that..."these indicators are intended to apply to varying proportions of country populations, not to countries as a whole"[20] Even in the absence of disaggregated statistical data, it is quite apparent that most people in the Sahelian countries meet these requirements for being included in the poor majority.

The Congressional legislative history indicates quite clearly that projects must meet the criterion of improving the absolute levels of living of the poor rather than of necessarily raising their standards relative to those of others who are better off. The basic human needs strategy also implies that it is absolute deprivation which is of foremost importance.[21] This is fortunate because there is evidence to indicate that growth and development are frequently accompanied, at least in the early years, by increasing inequality of relative income distribution even if incomes of those at the bottom of the distribution scale rise absolutely.[22]

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19 Agency for International Development, Implementation of "New Directions"..., p. 6.

20 Agency for International Development, Implementation of "New Directions...," p. 6.

21 Agency for International Development, A Strategy..., p. 14; Paul Streeten and Shahed Javed Burki, "Basic Needs: Some Issues," World Development, 6(3), 1978, p. 414. Using somewhat different criteria than those suggested by A.I.D., Streeten and Burki estimate that approximately 500 to 800 million people throughout the world fall below the absolute minimum standard. This compares with over 800 million people estimated by A.I.D. to be in this category.

22 Montek S. Ahluwalia, "Inequality, Poverty, and Development," Journal of Development Economics, 3(4), December 1976, pp. 307-42.

The new directions mandate thus calls for improving absolute standards of living of the poor majority, where these standards are defined so as to include not only per capita income but also a number of other objective indicators related to nutrition and health. The next question is how large-scale infrastructure investment can contribute to the improved well-being of the poor.

Cynthia Cook, in a recent paper, has made a useful distinction between the direct and indirect impact of infrastructure investment.[23] The direct impact involves events over which the individual has little control. An example might be the resettlement required by those who live in an area flooded by the construction of a storage dam. The indirect impact, on the other hand, occurs because of a change in the opportunities faced by an individual and depends on his behavioral response to this change. Farmers usually have a choice, for example, as to whether or not they will participate in an irrigation scheme. The first type of impact is fairly easy to anticipate as long as there is a thorough understanding of the technical and environmental aspects of the project; the second is more difficult because of the need to predict human behavior.

In addition, there may also be secondary effects which occur as a consequence of the primary direct and indirect effects of the investment. The production of more food by farmers involved in an irrigation scheme, for instance, will usually benefit consumers by causing the price of food to fall. Some have even argued that it is the secondary effects of infrastructure investment which are most important in benefitting the poor since it is usually the larger farmers who can more easily capture the primary gains.[24] Nevertheless, there has generally been considerable disillusionment with these secondary, "trickle down" benefits.[25] Partly this may be because of the difficulty of accurately measuring them.

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23 Cynthia C. Cook, "Impact Evaluation for Infrastructure Projects in Developing Countries," Louis Berger International, Inc.

24 Hans P. Binswanger, "Income Distribution Effects of Technical Change: Some Analytical Issues," Center Discussion Paper No. 281, Economic Growth Center, Yale University, May 1978, makes this observation with respect to technical change in agriculture, and the same conclusion could easily apply to investment in infrastructure.

25 The report of the House Committee on Foreign Affairs concerning the Mutual Development and Cooperation Act of 1973 states, for example, that "Projects which aim at development through a 'trickle down' approach should be left to multilateral international financial institutions and private investment." (U.S. Congress, Mutual Development and Cooperation Act of 1973, Report of the Committee on Foreign Affairs, House of Representatives, Ninety-third Congress, First Session, Washington: U.S. Government Printing Office, 1973, p. 15).

It may also be because these effects take some time to work themselves out, and there is impatience with slow results. Finally, there is a reluctance to rely on secondary benefits dependent on factors such as market structure or government policies which are not very susceptible to donor or investor influence. As a result, large-scale infrastructure investment probably has to be justified for now in terms of its primary impact on the poor majority, though there clearly is a need for further study of the secondary effects of such investment.[26]

The primary impact of irrigation and river management infrastructure is felt in a number of ways, of which the following list is not by any means exhaustive:

1. The availability of irrigation water for one or more crops should induce farmers to switch, at least in part, to irrigated cultivation. All those with access to irrigated land are likely to benefit to some degree. Important variables are (a) the manner in which irrigation water is controlled and (b) the type and amount of charges assessed for use of the water.

2. Construction of irrigation facilities may aid the poor by creating jobs during the slack season, especially if relatively labor-intensive construction methods are used.

3. Environmental consequences of the construction and operation of an irrigation system may include the spread of shistosomasis and malaria, the salinization of soil and ground water, a reduction in downstream sediment deposits, etc.

4. Greater security of production resulting from better local water control should provide a more reliable source of food supply and cash income.

5. Regulation of seasonal river flows can increase possibilities for double cropping and river transport, but it may at the same time reduce flooded and flood recession agriculture. It may also substantially alter fish populations and movements and livestock pasture.

6. The creation of upstream reservoirs causes land to become unusable but may result in the growth of fish populations in that area.

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26 Some suggestions for this are made later in this report. It is worth noting here that few A.I.D. projects of any type have a large primary impact since "Almost invariably AID assistance would reach the poor majority not 'directly' from U.S. advisors working with villagers, but through:

(a) public or private intermediary institutions, and
(b) advice leading to changes in LDC policies which, in several ways, might improve benefits to the poor...."

(Agency for International Development, Implementation of New Directions...., p. 7).

7. Interannual river regulation generally increases security of production and allows a larger area to be irrigated, though it may not be helpful in mitigating the consequences of prolonged drought.

8. Exploitation of hydro-electric potential offers a new source of energy which can be used for a variety of purposes where an effective demand exists.

This very general list could be considerably extended and elaborated in the case of any particular project.

It is often quite difficult to identify specifically those who benefit from the primary impact of large-scale infrastructure investment without a detailed knowledge of land tenure systems, local political institutions, the structure of markets, the existing distribution of income and wealth, and so forth. As noted earlier, the chief beneficiaries are not apt to be poor farmers with limited access to credit, extension services, and other inputs. In order to offset the disadvantages faced by these farmers, infrastructure investments may be complemented with projects targeted to meet the specific needs of the poor. This generally involves the creation of institutions for distributing land, allocating water, delivering inputs, and providing credit. It may also result in the delivery of rural health and education services as part of an integrated rural development scheme. These complementary investments are a vital part of the total "package" necessary to ensure that benefits reach the poor.

The Lumpiness Problem of Large-Scale Infrastructure Packages

The dilemma that confronts decision makers in such cases can be summed up as follows: In order to develop a program containing a large, "lumpy" element that will have the desired distributive effects, it will ordinarily be necessary to include a rather substantial number of complementary projects that focus on the preferred beneficiaries. Often, however, the entire "package" that emerges is beyond the Agency's resources or would use up such a large portion of the Mission's total resources that little would remain for other types of activities. In addition, it would also preempt a large share of the host country's administrative and management skills. But if the "lumpy" infrastructure is left out, the environment that constitutes the necessary condition for successful implementation of the program will be missing, and if the complementary projects are omitted, the program will not have its desired distribution of benefits.

The technical and institutional issues involved in designing infrastructure-related "packages" are reasonably straight-forward and familiar. Such packages differ significantly by type of project and technology employed. Consider the example of an irrigation system. In addition to the main barrage, irrigation planners, even a decade ago, would have made provisions for canals and major distributaries. Now they would probably also be asked to design the lateral and field channel system where that does not already exist. If the area has not previously been irrigated, land forming would probably also be required. In addition, current project design principles, developed from past experience, dictate that project planners extend their concern to the micro level in order to ensure that the land and waters are allocated properly. Lastly, planning must now be concerned that organizations and institutions are available to deliver inputs such as seeds and fertilizer, to purchase the commodities produced by the farmers, and to provide such other services as may be desired.

Technical and institutional requirements, however, are only partial determinants of the program package. Another major factor is the size of the budget available for the total effort. Obviously, if there are few resources available, only a limited number of complementary programs can be initiated. Whether the program cuts needed to bring the entire package within designated financial and administrative limits can be accomplished without destroying the entire project is an empirical question. The answer will differ not only by type of project but also by the extent to which at least the rudiments of the necessary institutional structure are already in place.

Typically, where a project is large in relation to available resources, planners must make adjustments. There are several alternatives that may be employed:

1. Adjusting objectives. Although it might appear that lowering the cut-off rates of return or weakening the definition of acceptable distributive consequences is "cheating," in the practical world in which decisions are made the implications of choosing certain goals are not always fully appreciated until they are applied, and hence some flexibility regarding objectives is legitimate. Indeed, considerations such as this provide a justification for sensitivity analysis of various project parameters, a practice widely advocated by planning authorities. One would expect, for example, that lowering the acceptable rate of return would reduce the size and complexity of the entire program package. Even more significant would be acceptance of the development of a disadvantaged region as a sufficient condition for meeting the distribution objective since improving absolute levels of income in the region would also improve the distribution of income at the national level.

2. Truncating the project. Perhaps the most common method of reducing the size of complex programs is to truncate the projects that were the basis of the program design. In some cases the separation is physical. Separating drainage works from the provision of irrigation facilities is a frequent example. In other cases, particularly where the management of an entire, complex program is beyond the capacity of the organization charged with implementing the infrastructure project, it is assumed that complementary programs will be carried out in the course of already budgeted government activities. Common examples are programs dealing with extension, water management, crop research, rural credit, etc. Yet typically these activities are crucial to obtaining the benefits necessary to justify infrastructure investments.

There are, of course, legitimate ways of truncating the larger program when resource constraints make the implementation of the total package impossible. Efforts may be made to identify smaller projects, for example, that would have been a part of the complete system and to develop these individually. The return on these investments will be less than what could be obtained if they were part of the global design, but the truncation that permits piecemeal development of small and medium-scale activities has the virtue of producing projects that fall within the existing material and human resource constraints. In addition, where such small-scale projects have reasonable rates of return and desireable distributional characteristics, their risk advantage may make them attractive as an alternative to the larger system. It simply costs much less to be wrong on a small project than a large one. On the other hand, diminishing returns in the development of small-scale activities are likely to be reached sooner in the absence of the lumpy, large-scale component of the package.

3. Enlarging the pool of resources. Resource availability may be increased in a variety of ways, including everything from intra-Agency reallocations to the encouragement of other countries or foreign assistance institutions to pool their resources. By working on this constraint, the complementarities built into the original project can be kept intact at the same time that each of the government agencies or participating organizations remains within its individual budget limits. This is the major approach suggested for handling the problem of large-scale infrastructure investment in the Sahel.

The Multilateral Approach

Large-scale infrastructure investment in the Sahelian countries is taking palce within a multilateral framework. The institutions established to coordinate development efforts within this framework include, but are not limited to, the Comité Inter-Etats pour la Lutte Contre la Sécheresse dans le Sahel (CILSS), the Club du Sahel, the Organisation pour la Mise en Valeur du Fleuve Sénégal (OMVS), the Niger River Basin Commission, the Lake Chad Basin Commission, the Interafrican Committee for Hydraulic Studies, the West Africa Rice Development Association, and the Institut du Sahel.[27] The task of coordinating the aid and investment programs of the twenty-eight donors and eight Sahelian countries will not be easy. Yet a multilateral

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[27] Descriptions of these organizations are contained in Comptroller General of the United States, Report to the Congress: The Sahel Development Program..., and Agency for International Development, Report to the United States Congress: Proposal for a Long-term Comprehensive Development Program for the Sahel, July 1976.

approach seems essential if the lumpiness problem is to be overcome without altering fundamental objectives or excessively truncating investment packages.

This implies, however, that assessment of large-scale infrastructure investments must be made within the context of the multiple objectives held by donors and recipient countries. Although the Congressional mandate calls for concentration on assisting the poor, the U.S. aid program clearly has other objectives as well. Economic efficiency, for example, cannot be disregarded, because to do so would severely lessen the impact of aid expenditures and could cause severe financial problems for the recipient country governments. Programs aimed at improving literacy and health, for example, while effective in directly benefitting the poor, nevertheless place large demands on the public budget for recurrent expenditures. Similarly, security of food supply in the Sahelian countries is a fundamental concern of U.S. aid policy. While this may, in some cases, be related to aiding the rural poor, one can also imagine instances in which food security at the national level can best be assured through types of investment which do not directly benefit poor people. Large-scale, mechanized irrigation schemes, for example, may be the best way of obtaining a secure supply of surplus food -- available, perhaps, for shipment to drought-stricken areas -- but the distributional effects are not the most desireable. Consequently, one must bear in mind the whole range of objectives held and be prepared to assign weights to these whenever they are in conflict with one another.

This poses an additional problem. The weights given various objectives may differ between donor and recipient. The Sahelian countries, for example, all attach a very high priority to achieving self-sufficiency in essential foods. While this goal is not neglected in the U.S. aid program, it does not appear to be as important as the distributional objective implied by the new directions approach. The major markets for imported food are in the urban areas of West Africa. The most effective way of supplying these markets from domestic rather than foreign sources probably, again, is the construction and operation of large, centrally managed irrigation schemes. Yet smaller schemes involving labor-intensive techniques are much more effective in aiding the rural poor.[28] The output of these schemes, however, is frequently used to replace other riskier sources of food for the farmer, leaving little if any surplus available for reducing food imports.[29]

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28 This anticipates some conclusions discussed in more detail later in this report.

29 This potential conflict between U.S. and recipient country objectives is not always recognized. See, for example, Comptroller General of the United States, Report to the Congress: The Sahel Development Program....

The Agency has made it clear that its willingness to consider financing major infrastructure facilities depends on the recipient countries having a strong commitment to meeting basic human needs objectives. This generally will require investment in a total package, including the access networks required to reach the poor.[30] To the extent that the host countries are willing to make this commitment, perhaps altering the priorities they attach to various objectives, the United States should respond by declaring itself ready to finance a fair share of the whole package.

Finally, there may be conflicts between the objectives of different donors. Project evaluation should take place at two levels: 1) a global evaluation and 2) a decision concerning AID's participation. It may well be that AID might approve of a project generally but decline to participate because it feels that the project is more suited to another donor's goals and capabilities.[31] It has been suggested, for example, that the financing of large-scale infrastructure should be left to the large international development banks and that A.I.D. should concentrate on projects which directly benefit the poor. But this overlooks the fact that other donors, too, are increasingly concerned about distributional problems and are attempting to reorient their aid programs in the same direction as the United States.

Large-Scale Infrastructure as Part of a Total System

Large-scale infrastructure and related packages of complementary investments must be seen as rather large, lumpy components of a total system. To neglect this is to run the risk of overlooking many of the most important ways in which infrastructure contributes to general economic development and the improved well-being of the poor. Indeed, there is evidence to indicate that long-run systemic changes are often very different from short-run impact effects.[32]

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30 Agency for International Development, A Strategy for a More Effective Bilateral Development Assistance Program..., p. 37.

31 The need to evaluate projects from a common perspective first and then to divide up the task of implementation was an important reason for creating the Club du Sahel.

32 Sherman Robinson, "Toward an Adequate Long-Run Model of Income Distribution and Economic Development," American Economic Review, 66(2), May 1976, p. 123.

A good example is some of the changes induced by the expansion of food production resulting from investment in irrigation. Initially, this may benefit larger farmers most because of their better access to credit and other inputs. The increased production, however, will usually result in a decline in food prices, which generally benefits poor consumers most because food expenditures are a greater part of their total budgets. On the other hand, the reduced price of food will hurt large farmers for whom sales of food are relatively important. It may also injure some smaller farmers, but these are less likely to be producing much food for the market. Thus, on balance, the initial impact of irrigation investment probably favors large farmers whereas the ultimate systemic effects are likely to be more beneficial for the poor.[33]

Expansion of irrigated production may also increase the demand for labor, pushing wages up and aiding the poor. Whether this occurs or not depends on the type of technology employed and the response of rainfed agriculture to lower prices of farm products.[34] Another important element is government policy, which can be used to favor either labor-saving or labor-using technology. The spread of high yielding seed varieties in Asia, for example, may have initially benefitted large farmers primarily because government policies encouraged association of the HYVs with mechanization, which only large farmers could afford.[35]

Regional linkages may also be important. A major reason for developing large-scale irrigation in the Sahel is to take some of the pressure off of areas of marginal rainfall. Although those who remain in these areas do not benefit directly from irrigation, they do benefit indirectly because after others emigrate to irrigated land, they are able to use more extensive systems of cultivation and herding. This increases their incomes by substituting land for water and would be impossible in the absence of opportunities for emigration because of population growth.

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[33] A similar conclusion was reached concerning the effects of price policy in India by John W. Mellor, "Agricultural Price Policy and Income Distribution in Low Income Nations," World Bank Staff Working Paper No. 214, September 1975.

[34] William R. Cline, "Interrelationships between Agricultural Strategy and Rural Income Distribution," Food Research Institute Studies in Agricultural Economics, Trade, and Development, 12(2), 1973, pp. 141, 142.

[35] B. F. Johnston and J. B. Cownie, "The Seed-Fertilizer's Revolution and Labor Force Absorption," American Economic Review, 59(4), September 1969.

There may also be other kinds of linkages, such as those involving fiscal resources. Take, for example, the case of a multi-purpose dam used to generate hydro-electric power as well as to facilitate the expansion of downstream irrigation. Although the power generated by the project might be used for mining or urban consumption, and thus not contribute directly to aiding the rural poor, it may nonetheless be an essential part of the total system. The history of river basin development in the western United States, for example, amply demonstrates the importance of hydro-electric power in paying for the dams which make downstream irrigation possible.[36]

Production linkages may be important, too. As agricultural output grows, there will be expanded employment opportunities in processing and marketing. Similarly, the sectors providing inputs to irrigated agriculture can be expected to increase in size and to offer more possibilities for productive employment. What is essential is that government policies and complementary projects be designed to encourage the expansion of these sectors in ways compatible with the new directions approach. In most cases, this will call for the promotion of labor-intensive, small-scale activities rather than capital-intensive, large-scale enterprises.[37]

More generally, investment in infrastructure and complementary programs helps to set in motion the whole process of regional development, which results in increased incomes and expanded employment opportunities for most of the resident population and for newcomers attracted to the region. The particular form which this development takes and the way in which it affects the poor depend on the type of infrastructure, the kinds of resources being exploited, the available production technology, existing political and social institutions, the distribution of income and wealth, and the structure of markets, as well as on the role which government plays in the development process. Experience in the past has varied widely.[38] Nevertheless, several lessens seem clear.

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36 "Towards a Rational U.S. Policy on River Basin Development in the Sahel," Summary of an AID Colloquium held at the Department of State, Washington, D.C. March 31-April 1, 1978, p. 80.

37 Carl Liedholm, Research on Employment in the Rural Nonfarm Sector in Africa, African Rural Employment Paper No. 5, Department of Agricultural Economics, Michigan State University, April 1973, p.12.

38 An excellent account for a number of African countries of how infrastructure investment has stimulated the export sector and how this, in turn, has contributed to overall economic development is contained in Scott R. Pearson and John Cownie, et al., Commodity Exports and African Economic Development, Lexington, Massachusetts: Lexington Books, 1974.

First, there is no evidence to indicate that poverty among the poor can be significantly reduced in the Sahelian countries without substantial investment in large-scale infrastructure which is currently so lacking. There is, on the contrary, strong statistical evidence suggesting that the shortage of public investment in these countries has been a major factor inhibiting their growth.[39] Second, in countries in which significant large-scale infrastructure has been established, there are very few instances of a decline in the absolute levels of living of the poor associated with general economic development. In the few cases in which the standard of living of the poor has decreased, this has been because there has been no "increase in wages or incomes in the major occupational groups in which the poor are found."[40] This implies that an understanding of labor and product markets, as well as of institutional arrangements for allocating these resources, is essential for ensuring that benefits reach the poor.

At present, our knowledge of the systemic implications of infrastructure investment is slight. There have been a few studies which have tried to measure the regional effects of the construction of roads on economic development after the lapse of a few years.[21] None of these studies deals with the Sahel, however, and most of them suffer either from the lack of an adequate baseline survey or from the fact that sufficient time has not yet elapsed to measure the effects of road construction. There is also the problem of trying to distinguish between the influence of infrastructure investment and

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[39] J. Dirck Stryker, "Colonial Investment and Agricultural Development: The French Empire," Fletcher School of Law and Diplomacy, Tufts University, October 1975.

[40] Gary S. Fields, "Poverty, Inequality, and the Measurement of Development Performance," Center Discussion Paper No. 273, Economic Growth Center, Yale University, December 1977, p. 85. An additional necessary condition for worsening of absolute poverty appears to be lack of expansion of modern sector jobs, but the Sahelian countries are probably at too early a stage of development for this to have much of an effect.

[41] Several of these are described in U.S. Department of Transportation, The Role of AID in the Development of Sahel Transportation Infrastructure; A Strategy Proposal by the Office of International Transportation Programs, Washington: September 6, 1978, pp. VII-61 to VII-68. One study which concentrates explicitly on the distributional aspects of transport is Louis Berger International, Inc., Phase I: Study of Transport Investment and Impact on Distribution of Income in Remote Areas, April 1978. The World Bank has also undertaken a number of studies to establish the relationship between transport and local production and to monitor the incidence of benefits resulting from decreased transport cost and travel time: Yemen Arab Republic Feeder Road Study, May 1978; Ethiopia Feeder Road Study, April 1978; The Impact of the Andapa-Sambava Road: A Socio-Economic Study of the Andapa Basin, Madagasear, December 1977.

other changes which occur simultaneously. Nevertheless, these studies are a promising start and should be extended to include investment in irrigation.[42] It is also important that they be included as integral parts of each infrastructure project in order to ensure that comparable baseline and post-impact data are collected.

In the meantime, however, decisions have to be made concerning whether or not to invest in irrigation and river management infrastructure and, if the decisions are affirmative, what form this infrastructure should take. The answer to the first question will depend not only on the careful evaluation of a complementary packages of infrastructure and related projects but also on the examination of alternatives which might be more efficient in achieving donor and host country goals. This should be an ongoing process, using an integrated systems approach. The system will probably have to be relatively simple at first because of large information gaps, but as these are filled it can become an increasingly useful tool for planning and organizing existing information. At the same time, the conceptualization of such a system will help to identify critical missing information.

As far as the form which infrastructure takes is concerned, useful experience has already been acquired both outside and within the Sahelian region. This is discussed in the next sections of the report. Further experimentation with alternative forms of irrigation is also desireable, however, and, as suggested above, appropriate procedures for evaluation of these projects should be established at their inception. Finally, infrastructure required for river management must be developed on the basis of past experience, a sound base of current information, and a careful analysis of future options. A preliminary assessment for some of the major river basins in the Sahel is given toward the end of this report.

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[42] The World Bank, in fact, now includes an evaluation component in most of its agricultural projects, but it is too early to obtain much useful information from these.

EVALUATION OF LARGE-SCALE IRRIGATION PROJECTS

A worldwide review of A.I.D.'s irrigation projects suggests that these can be grouped into three broad categories.[43] First, there are projects, both large and small in scale, that improve and/or rehabilitate existing schemes. These range all the way from such massive undertakings as construction of Tarbela Dam in Pakistan to rehabilitation and improvement of water courses and field channels in already developed irrigation systems.

Second, the A.I.D. portfolio contains a number of projects to provide new irrigation facilities in densely settled, reasonably favorable agro-climatic environments. The Ganges-Kobadek project in Bangladesh provides an example of a large scale investment of this type; the Takerganj tubewell scheme in the northern part of that country also qualifies for this category. In both cases, irrigation facilities are used to make more intensive cropping possible.

The third category contains projects, primarily in arid and semi-arid areas, where only rudimentary, often nomadic agriculture was previously practiced. Examples are the Rahad Scheme in the Sudan and the East Ghor Canal in the Jordan Valley. The land in these schemes is, to a large degree, a <u>tabla rasa</u>, and virtually all aspects of each project involve donor or host government participation.

<u>Category I</u> projects have the following attributes:

1. There is a wide range of projects under this heading. Many are small-scale works that are associated with self-help programs such as rural public works. Large-scale projects, often involving significant water transfers or drainage schemes, however, are also fairly numerous.

2. The focus of many such schemes has been on micro aspects of water control, e.g., on-farm water management and irrigation research, as well as on improvements in the functioning of the physical system.

3. Because the basic irrigation system is already in place, the project's impact tends to occur at its margin, and additional costs per hectare and per family are relatively low.

4. Basic technology usually remains unchanged; improved cultural practices are ordinarily not required to reap project benefits.

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[43] See Appendix A for a more detailed discussion of these projects.

5. In most situations, drastic institutional and organizational changes are not undertaken, though some efforts may be made to strengthen existing systems. An exception is where a public authority is designated as an implementing agency and is superimposed on an already existing line agency in the administrative structure.

Category I projects fit A.I.D.'s new directions approach quite well. Because the area is already farmed by sedentary agriculturalists with some knowledge of irrigated agriculture, the implementation and strengthening of people-oriented programs aimed directly at enhancing the productivity of individual cultivators is economically feasible as part of an expanded program package. For example, the rehabilitation program aimed at improving water management can often be combined with a seed-fertilizer package that contains a significant profit incentive. Where a reasonable amount of the land and capital in the project is in the hands of small farmers, they can be expected to benefit accordingly.

Such improvement and rehabilitation schemes, however, are not without problems. It is very hard, for example, to assess the net benefits of the proposed activities. To what extent are the present low yields in the Indus Basin due to inadequate drainage? Is additional water the only bottleneck that keeps farmers from increasing cropped acreage or are there other constraints in the present system that are holding back greater intensity of land use? What would be the payoff to on-farm water management programs? Answers to these types of questions, of course, determine the project's desirability, but they are more difficult to obtain in an already functioning system than where the facilities provided involve large qualitative changes.[44] Nevertheless, one can at least be reasonably certain that the investment will be effectively utilized since the project is being implemented in the context of an already functioning irrigated agricultural system.

<u>Category II</u> projects have some characteristics which are similar to those of Category I. The reasonably intensive farming systems they are designed to supplement usually exist in areas of high, but seasonally variable, precipitation. These are environments where a substantial amount of complementary activity is already taking place. Because at least one season is characterized by relatively abundant rainfall, prior experience with fertilizer and other yield-improving inputs can often be assumed. This experience is significant not only for what it implies about farmer knowledge and attitudes, but also, equally important, for what it means with respect to the availability of systems for delivering intermediate inputs, rural credit, etc.

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[44] A similar example from the transportation field would be the evaluation of the benefits of opening up an isolated valley for agricultural development as opposed to a project increasing the <u>density</u> of an already existent farm to market road network.

Some broad characteristics of irrigation projects in already established agricultural communities are:

1. They ordinarily have relatively low per hectare costs, rarely exceeding $2,000/ha and usually less than $1,000/ha. Because of relatively high population densities in these areas, the cost per family is also low.

2. Construction of these projects can be accomplished using labor-intensive technology because many of the projects are small and because of their proximity to a large supply of unskilled labor.

3. Post-project technology tends to be labor intensive because, as in the case of improvement and rehabilitation projects, farmers simply extend their basic technology to exploit the opportunities created by supplementary irrigation.

4. The projects have reasonably high rates of return, e.g., 11-46 percent.

5. The distributive impact of providing irrigation facilities that permit land to be used during what would otherwise be a dry season are likely to be favorable. The highest rates of rural unemployment are found in rural areas having an intensive, but highly seasonal, agricultural labor requirement. Adding additional labor-intensive crops to the farming system in what would otherwise be a dead season has perhaps the greatest potential for improving the lot of the landless and near landless short of, say, direct employment in infrastructure construction programs.

The time required to reap fully the benefits from irrigation in these areas varies. Water management practices, even rudimentary ones, are usually learned over the span of many years, and the fine points are passed on from generation to generation. In many low-lying and flooded areas where the major crop is monsoon rice, for example, crude forms of irrigation using primitive water lifting devices are often practiced during the dry winter season. Farmers with this type of experience can be expected to adapt readily to the potential for expanding the area under irrigation provided by tubewells and low lift pumps. Where no previous experience with water management exists, on the other hand, full utilization of the potential generated by irrigation may take some time.

The characteristics of Category III projects indicate substantially different implementation problems:

1. High costs per hectare and per farm family, e.g., $2,000-8,000/ha.

2. Sophisticated mechanical methods of construction.

3. Capital-intensive technology, usually based on mechanization of at least primary tillage and often harvesting as well.

4. High degree of social control exercised by central authorities over land use, choice of crops, marketing, prices, etc.

5. Relatively low economic rates of return, e.g., 7-17 percent.

Such "new settlement" projects are ordinarily found in arid or semi-arid environments in which extensive agriculture is traditionally practiced. In the extreme case, the land is capable of supporting only nomadic herdsmen who harvest the meager vegetation that is produced by limited seasonal rains. In areas with somewhat higher amounts of rainfall, sedentary agriculture, generally based on cereals, is also found.

The dramatic increase in benefits shown by the difference in productivity with and without the project provides the attraction of this type of investment. In many of these schemes in developing countries, the climatic conditions are such that year-round cropping is possible and rates of return are higher than those obtained from similar projects in, say, temperate zones such as the western part of the United States.

The difficulties of implementing such projects, however, are obvious in comparison with the circumstances described in Categories I and II. First, the land is populated by farmers without experience in irrigation or water management. Their lives, dominated by natural events, are focused on simple gathering, herding, or planting and harvesting operations. The labor and management needed for irrigated agriculture are foreign in terms of both the skills required and the cultural and social attitudes of the farmers involved. Second, the entire structure of organizations required to provide inputs, to purchase and to transport outputs, to carry out research, etc., must be developed and put in place. Third, the complementary package may often require the construction of substantial physical infrastructure in addition to irrigation facilities. Housing, roads, processing facilities, and power are unlikely to be available to the extent required.

The technical and environmental conditions which projects in this category are faced with leave relatively little room for flexibility, at least in the early stages of implementation.

1. <u>High degree of mechanization</u>. Mechanization, at least in the initial period of development, appears to be virtually a necessity. At the outset, new lands that have not been farmed intensively cannot support the population of people and animals required to provide the necessary power for reclamation. Depending upon soils and other location-specific characteristics, even the variable costs of production could not be covered for two to five years and substantial subsidies would be required during this period in order to permit families to survive. Mechanization to a large extent avoids this problem.

2. <u>High costs per acre reclaimed</u>. In areas where relatively intensive agriculture is already practiced, part of the costs associated with an infrastructure project are often borne by organizations and agencies already active in the project area. In newly settled areas, on the other hand, the entire complementary package must be charged against the project. There are no hiding places in schemes that start from scratch.

3. Adverse distributive effects. The distributive consequences of Category III projects are often objectionable. In Categories I and II, the distribution problem arises because of class differences within projects. That is, planners are concerned with the benefits to large farmers versus small farmers, landlords versus tenants, or the landless versus the landed. In newly settled areas, on the other hand, the issue is one of the benefits accruing to the group chosen to populate the new scheme versus those in the region who have been excluded. Such unequal treatment may seem particularly acute when measured in terms of project expenditures per family. Given that the original number of settlers is small and that project costs must include the entire complementary package, there is no way for the outcome to be otherwise. The distribution of benefits from this type of investment must inevitably be highly sequential.

4. High degree of social control over participants. The development of a centralized authority to implement and to manage the project is a characteristic frequently associated with new settlement schemes, largely because of the technical requirements of the project. Use of machines by the authority to carry out such common operations as tillage, planting, and harvesting necessarily implies that the settlers also perform a number of operations according to a schedule. Furthermore, given the high costs of the project, there frequently is substantial pressure on the managing authority to produce results quickly. This pressure may lead to additional rules and regulations to insure that settlers carry out the operations for which management has been given responsibility. Individual initiative inevitably suffers in the process.

SOME PRELIMINARY CONCLUSIONS

There are a number of preliminary conclusions which emerge from the first sections of the report.

1. The new directions and basic human needs approaches to foreign assistant do not preclude support for broad-based economic development. Expansion of productive capacity is essential, in fact, if programs aimed directly toward the poor are to be sustained over the long run.

2. Investment in infrastructure is seen by the Congress as being important for economic development. No problems arise with respect to small-scale infrastructure; the Congress has only been reluctant to finance large-scale projects (the impact of which is felt over at least several villages or towns).

3. The Congress appears to be willing to approve financing of large-scale infrastructure in the Sahel as long as it can be demonstrated 1) that there are no better alternatives and 2) that the majority of benefits accrue to small producers with secure land tenure (i.e., the poor majority).[45]

4. Large-scale irrigation and river management infrastructure can ultimately be justified by the contribution it makes to increasing yields and providing greater security for food and other crops in the face of growing population pressure on limited land resources in a highly uncertain environment. The question is not if, but when, construction of such infrastructure will be warranted relative to other alternatives. Planning should already be underway, however, because of the long gestation periods involved.

5. The new directions and basic human needs approaches call for an increase in the absolute levels of living of the poor majority, not a reduction in relative income differences. Thus there is recognition of the fact that the poor require special attention if their needs are to be met.

6. Large-scale infrastructure investment cannot be justified to the Congress on the basis of secondary, "trickle-down" effects. Instead it must be shown that the primary impact effects will benefit the poor. This normally requires the development of complementary projects targeted directly toward the poor.

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[45] Additional requirements, not dealt with in this report, are 3) that river basin development projects do not cause health problems and 4) that the full potential of small-scale, decentralized energy technologies be utilized.

7. The resulting investment "package" must frequently be very large and lumpy relative to the total aid program. This implies a sequential distribution of benefits to the poor, with relatively large expenditures per family for those who benefit first and a subsequent widening of benefits at lower cost as irrigation systems are extended and land resettlement progresses.

8. The large size and lumpiness of the complementary package makes a multilateral approach to financing the total investment desireable. This may raise problems of conflicting donor and host country objectives.

9. The complexity of interactions surrounding large-scale infrastructure makes it highly desireable to use a systems approach in designing the investment package and examining the various alternatives.

10. A worldwide review of A.I.D.-financed irrigation projects suggests a large-scale, centrally controlled, highly mechanized prototype as being most applicable to the Sahel. In other areas of the world, this type of scheme has been costly, has had low economic rates of return, and has benefitted relatively few poor farmers, at least in the initial stages of development.

On the basis of these preliminary conclusions, the central problem is how to justify large-scale irrigation and river management infrastructure in the Sahel in terms of two essential criteria:

1. There are no better alternatives.

2. Most primary benefits will accrue to poor farmers.

The first of these criteria calls for an evaluation of river basin development within the context of an overall development strategy designed to achieve the major objectives of donors and host countries. This implies that large-scale infrastructure investment must be compared with other approaches such as development of rainfed agriculture and small-scale irrigation. The second criterion requires the identification and analysis of the benefits of various types of infrastructure and the determination of upon whom those benefits are likely to fall.

This analysis and evaluation involves addressing at least two central issues. The first has to do with the timing of large, lumpy capital investments required for a comprehensive irrigation and river basin development program to benefit the poor. Closely related here is the essentially sequential nature of this type of investment, implying that there must be an ordering through time of persons to whom benefits accrue.

The second major issue involves identifying the type of irrigation system which provides greatest benefits to the poor. Our review of A.I.D. experience outside the Sahel indicates that there is little latitude for choice, that the types of irrigation systems employed in most areas of the world have been more or less dictated by exogenous conditions such as climate, population density, and existing infrastructure. Detailed analysis of irrigation projects within the Sahel, however, indicates that there may be more room for flexibility in the design of irrigation systems.

The remainder of this report presents an evaluation of river basin development within the context of these criteria and issues. First, we briefly review the general situation and prospects concerning agricultural development in the Sahel. This is followed by an analysis of existing irrigation projects in the Sahelian countries to see how these effect the poor. Special attention is paid to the Office du Niger and the Gezira Scheme in Sudan as the only two really large-scale irrigation projects in this part of the world.[46] The next section outlines some general considerations relating to river management in the Sahel, followed by an evaluation, however tentative, of each of the major river basin programs. Finally, some general conclusions are drawn and recommendations made.

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[46] While the Gezira Scheme is not in one of the Sahelian countries, its proximity, similar agro-climatic conditions, and long history make it a very interesting case study.

THE SAHELIAN AGRICULTURAL SITUATION AND PROSPECTS

The most comprehensive overall analyses of the current agricultural situation and prospects for future development in the Sahel have been undertaken by the Food and Agricultural Organization of the United Nations and the Club du Sahel.[47] These two organizations have estimated current and future food production in relation to anticipated needs and have tried to lay out the various options which exist for achieving the objectives of donors and host countries. The planning horizon differs in the two reports -- the year 1990 in the FAO study and 2000 in the Club du Sahel report -- but the broad objectives to be achieved are generally seen as:

1. self-sufficiency in essential foods, first at the regional level and ultimately at the national level;

2. expansion of agricultural exports, especially in processed form;

3. general economic and social development;

4. preservation of the national environment.[48]

Primary importance among these objectives is attached to achieving food self-sufficiency. Projections of food demand were originally made by FAO for the year 1990 and were extended by the Club, using the same methodology, to the year 2000.[49] Assuming self-sufficiency in that year, the following minimum production targets were established by the Club:

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[47] Food and Agricultural Organization of the United Nations (FAO), Perspective Study on Agricultural Development in the Sahelian Countries, 1975-1990, 3 volumes, Rome: 1976 and Club du Sahel, Strategie et Programme de Lutte Contre la Secheresse et de Développement dans le Sahel, Paris: Organization for Economic Cooperation and Development, May 1977. In addition, there are a number of individual Working Group papers prepared as background for the Club du Sahel report.

[48] Club du Sahel, Strategie et Programme...., pp. 5-10.

[49] This methodology consists essentially of projecting future consumption as a function of population growth, estimated expenditure elasticities of demand, and assumed rates of growth of total private consumption expenditure.

Table 1[a]
Recent Agricultural Production and Future Targets
(thousands of metric tons)

Product	Average 1969-70	2000
Maize, millet, and sorthum	4,000	8,450
Wheat	8	560
Paddy	380	1,800
Sugar cane	270	4,700
Cattle	265	590
Sheep and goats	115	300
Fish	370	700

[a] Source is Club du Sahel, Stratégie et Programme de Lutte Contre la Sécheresse et de Développement dans le Sahel, Paris: OECD, May 1977, p. 13.

It is clear from Table 1 that achieving food self-sufficiency will be a formidable task even in years of average rainfall. To protect against shortfalls in periods of drought, it is envisioned either that a large part of the increase in production must come from irrigated agriculture or that expansion of rainfed cultivation must be accompanied by a large cereals storage program. Both alternatives are likely to be very costly. In any case, it seems unlikely that irrigated cultivation can furnish a very large proportion of the required expansion in production until after 1990, so rainfed agriculture must receive priority attention during the next decade. Nevertheless, the Club's strategy for the next ten years is to develop small- and medium-scale irrigation and to prepare for full-scale development of the major river basins in the following decade.[50]

The Club strategy emphasizes broad-based agricultural development resulting in expanded income and employment opportunities for the rural majority. Thus it explicitly rejects achieving food self-sufficiency primarily by investing in large-scale, mechanized farming operations which contribute little to the increased well-being of the poor.[51]

[50] Club du Sahel, Strategie et Programme..., pp. 16, 17.

[51] Club du Sahel, Strategie et Programme..., p. 18.

Rainfed Cultivation as an Alternative

Both studies suggest that there is substantial scope for improvement in rainfed agriculture. Less than 15 percent of Sahelian farmers presently use modern inputs and only 10 percent use animal traction technology.[52] In addition, there are large areas with favorable agro-climatic conditions which are very sparsely populated. One reason for this is the presence of onchocerciasis and trypanosomiasis, but as these disease problems are eliminated, the potential for increasing agricultural development in these regions will increase. This is fortunate because increasing population density is causing problems in areas such as the central groundnut basin of Senegal and the Mossi plateau of Upper Volta. Given the relatively extensive agricultural techniques still practiced in these areas, population growth means decreased periods of fallow and declining soil fertility and yields.[53] The solution would appear to be migration from high to low density areas, but this takes time and the effects of such migration are not all positive.[54] Nevertheless, to the extent that population is growing and yields cannot be raised in areas of high population density, out-migration must occur if people are to feed themselves. This problem is likely to be particularly acute where there are no opportunities for cash crop production or where rainfall is low and thus the use of chemical fertilizers is not financially feasible.

The availability of sparsely populated land in regions with favorable agro-climatic conditions varies markedly between countries. It is greatest in Chad and to a slightly lesser extent in Mali; it is least in Mauritania and Niger. In addition, rainfed cultivation even in these regions is fairly uncertain, requiring that large reserve stocks of cereals be held if self-sufficiency is to be maintained in bad as well as good years. Finally, even if relatively open, higher rainfall areas provide some breathing room, population growth will ultimately

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[52] Club du Sahel, Strategie et Programme..., p. 23.

[53] Overall it is estimated that only about 20 percent of the total 63 million hectares of cultivable land is actually used for agriculture in the Sahelian countries. Nevertheless, the extensive techniques of cultivation generally practiced require relatively long periods of fallow to maintain soil fertility, so that the intensity of land use should probably not be allowed to go above 30 to 35 percent without introducing fertilizers or other means of intensification. (FAO, Perspective Study..., vol. I, p. 50).

[54] For example, those migrating are usually in their most productive years, leaving behind a larger percentage of less productive people.

increase pressure on the land there as well. Given the fairly small amount of rain that falls in these areas even in good years, diminishing returns to intensification are likely to be reached reasonably soon. For all these reasons and because of the enormous potential of the Sahelian countries for irrigated agriculture, development of the major river basins is an important longer term goal.

The Potential for Irrigation

The potential for irrigation in the Sahel is considerable. Irrigable soils cover approximately 14 million hectares, or just over 20 percent of total arable land, and thus are no constraint on irrigation.[55] Water in the large river basins of the Senegal, Niger, Gambia, Casamance, Chari-Logone, and Volta Rivers is adequate to irrigate nearly 4 million hectares, though this would require total regulation of river flows. The amount of regulation envisioned by the year 2000 would permit irrigation of over 900,000 hectares with two crops per year.[56] Without control structures, double-crop irrigation is possible on approximately 200,000 hectares (exclusive of Lake Chad's natural water reserve, which could be used to irrigate roughly 375,000 hectares). In addition, there are substantial possibilities for irrigation outside the major basins using both ground and surface water. The potential for using ground water is relatively low, however, and it is very costly in relation to the use of surface water.[57]

The differences between countries, as can be seen in Table 2, are substantial. The figures in this table should be taken only as indicative, because of missing data, but they nonetheless indicate the orders of magnitude involved. The greatest potential is in Mali, Senegal, and Chad, but that of the other countries is considerable.

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[55] FAO, Perspective Study..., vol. I, p. 47.

[56] Club du Sahel, Strategie et Programme..., pp. 40-41.

[57] Club des Amis du Sahel, Specialized Group in Irrigated Crops, "Summary Report," May 1977, pp. 7-8.

Table 2
Potential Irrigable Land Area[a]
(thousands of hectares)

Country	Total Control[b] 1 crop/yr	Total Control[b] 2 crops/yr	Bottomlands and Controlled Flooding	Ground-water	Total
Cape Verde	-	5	-	-	5
Gambia	5	30	-	-	35
Upper Volta	10	75	40	-	125
Mali	115	110	280	-	505
Mauritania	10	135	15	-	160
Niger	20	80	20	40	160
Senegal	115	285	-	60	460
Chad	10	220	100	50	380
Total	285	940	455	150	1,830

[a]Source is Club des Amis du Sahel, Specialized Group in Irrigated Crops, "Summary Report," May 1977, p. 10. A more recent report of the Club du Sahel/CILSS increases the total potential irrigable land area, assuming construction of the necessary regulating dams, to 2,300,000 ha, with a breakdown of this total by country but not by type of irrigation system ("The Development of Irrigated Agriculture in the Sahel -- Review and Perspectives," April 1980, p. 13).

[b]Assuming construction of first series of dams by the year 2000.

Past Experience with Irrigation

Current utilization of this potential is very slight. In 1976 only 82,000 hectares were under total water control and 150,000 hectares were being irrigated with partial control. The area under traditional irrigation was estimated at 379,000 hectares. The country breakdown is shown in Table 3, which indicates the overwhelming dominance of Mali and Senegal in modern irrigated agriculture. As far as total water control is concerned, over one half of the total area for all the Sahelian countries lies within the Office du Niger in Mali.

Table 3
Distribution of Irrigated Land Area in 1976[a]
(thousands of hectares)

Country	Modern Irrigation Systems			Total	Traditional Irrigation
	Total Control		Partial Control		
	1 crop/yr	2 crops/yr			
Cape Verde	0.6	-	1.3	1.9	0
Gambia	-	1.5	-	1.5	19
Upper Volta	1.1	3.2	2.7	7.9	30
Mali	45.0	5.0	67.0	117.0	155
Mauritania	-	1.2	-	1.2	55
Niger	2.0	2.6	1.2	5.8	3
Senegal	12.1	7.0	76.5	95.6	65
Chad	-	0.7	1.6	2.3	52
Total	60.8	21.2	150.3	232.3	379

[a]Source is Club des Amis du Sahel, Specialized Group on Irrigated Crops, "Summary Report," May 1977, p. 14. The totals from this source for modern irrigation systems do not quite match the totals published in the Club du Sahel's final report (Strategie et Programme...), reflecting some probable last minute adjustments. The differences are not very large, however, and since the final report does not give a breakdown by type of irrigation system, we have used the earlier estimates. A survey conducted in 1979 suggests, furthermore, that the figures for 1976 are still largely valid today (Club du Sahel/CILSS), "The Development of Irrigated Agriculture in the Sahel -- Review and Perspectives," April 1980, p. 5).

Because modern irrigation was first introduced into the Sahelian countries over 4o years ago, it is reasonable to ask why more of the potential for irrigation has not been exploited. The reasons, according to the Club du Sahel, are numerous. First, irrigation has not been able to compete effectively with rainfed cultivation which uses very extensive techniques requiring few inputs. Second, the high cost of irrigation has resulted in little, if any, recovery of initial capital investments, and sometimes even the cost of operating and maintaining the systems is not covered. This has resulted in deterioration of the physical structures. Third, yields have lagged considerably behind expectations.[58] Fourth, the high cost of transport and the long distances between consumption centers and production areas have reduced the commercial value of irrigated crops. Fifth, since much of the irrigation has been in regions of low population density, finding enough farmers has been hard and has made intensive cultivation difficult. Sixth, the transition from rainfed to irrigated cultivation without a large well-trained cadre of managers and extension agents has been a problem. Finally, cooperation between countries in the major river basins has not been easy, and this has delayed the planning and implementation of basin development.[59]

Some of these points are elaborated and others are raised by the members of the Club's working group.[60] They emphasize the lack of a genuine tradition of irrigation in the Sahel, implying that there are few existing systems susceptible to improvement. They also note that total water control systems are very costly, averaging 1 to 2 million CFA francs per hectare for investment (not including structures for regulating and mobilizing water flow) and 50,000 CFA francs per hectare for maintenance.[61] This requires intensive cultivation to achieve high yields, and thus "the massive use of complex crop production inputs and techniques.... Modern irrigation systems therefore require stringent and demanding organization. They differ totally from traditional crop-producing systems and require an especially effective framework which will ensure a rapid changeover on the part of the farmers while guaranteeing that the management tasks of the perimeter are accomplished. The additional costs for the operation of this framework are added to the costs which the crops will have to support."[62] In the past, however,

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[58] According to Club des Amis du Sahel, Specialized Group in Irrigated Crops, "Summary Report," p. 12, yields with total water control have averaged 2 to 3 tons/ha/crop in comparison with a standard of 3.5 tons and those for controlled flooding have averaged 1.2 to 1.5 tons/ha compared with a standard of 2.5 tons.

[59] Club du Sahel, Strategie et Programme..., pp. 36-37.

[60] Club des Amis du Sahel, Specialized Group in Irrigated Crops, "Summary Report," pp. 16-24.

[61] At existing exchange rates, this was about $4,500/ha to $9,000/ha for investment and $225/ha for maintenance. At an interest rate of 10 percent per year and an infinite service live, this implies an annual charge for capital recovery and maintenance of $675 to $1,125/ha.

[62] Club des Amis du Sahel, Specialized Group on Irrigated Crops, "Summary Report," p. 16.

the difficulty of inducing a sufficient number of farmers in areas of low population density to work in the irrigation schemes has too often resulted in the allocation of holdings too large to encourage intensive cultivation.[63]

Irrigation has also not worked very well where systems have been inadequately designed to guarantee the farmer a reasonable degree of water security. This has been especially true of some of the controlled flooding polders, a number of which have had to be redesigned to provide greater water control.

There have also been technical problems, such as inadequate drainage resulting in waterlogging and salinization. Occasionally, too, poor tenure arrangements have left farmers uncertain about their rights over the irrigated land which they farm. More important, however, has been the problem of insufficient financing to provide adequate subsidies during the early years of operation so as to assure proper maintenance and farmer training.

A Program for Future Expansion

Plans for future expansion of irrigation should be seen in the light of past experience. These plans call for producing all of the Sahelian countries' requirements for rice, wheat, and sugar under irrigated conditions. They also suppose that a significant proportion of the traditional cereals - maize, millet, sorghum - will be grown using irrigated techniques in countries where climatic risks are high (Mauritania and Niger), where there are large areas of over-population (Upper Volta), or where rainfed cultivation of these cereals is expected to decline as a result of the expansion of modern irrigation (Senegal).[64] The major constraint on attaining these irrigated production targets appears to be the shortage of trained manpower available to implement the program. As a result, it is highly unlikely that all rice requirements can be met through irrigated cultivation by the year 2000. Instead, it is supposed that part of the demand for rice will be satisfied by rainfed production, leaving the proposed irrigation program shown in Table 4. The total capital cost of this program is estimated at $2,136 million. With regulatory dams, the total would come close to $3 billion.[65] The result would be an increase of 650,000 hectares

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[63] The best example of this is the Office du Niger, where holdings today average 8.5 hectares.

[64] Club des Amis du Sahel, Specialized Group on Irrigated Crops, "Summary Report," pp. 24-25.

[65] Club du Sahel, Strategie et Programme..., pp. 44-45.

under total water control, with about 70 percent of this total area available for double cropping, and 140,000 hectares of controlled flooding and bottomland development, mainly for rice cultivation. To this should be added approximately 165,000 hectares of improvement and intensification of existing irrigated perimeters.[66]

Table 4
Current and Projected Irrigated Land Area[a]
(thousands of hectares)

Country	1976[b]	1982	1990	2000
Gambia	1.5	9.5	14.0	19.7
Upper Volta	7.7	21.3	58.8	104.0
Mali	107.0	+125.0[c]	+160.0[c]	+132.0[c]
Mauritania	1.4	15.0	30.0	70.0
Niger	4.8	17.5	33.0	52.5
Senegal	96.0	+33.3[c]	+83.5[c]	+160.0[c]

[a]Source is Club du Sahel, Stratégie et Programme de Lutte Contre la Sécheresse et de Développement dans le Sahel, Paris: OECD, May 1977, p. 44.

[b]Differ from totals shown in Table 3 for reasons indicated in the note to that table.

[c]Includes both new irrigation works and improvements of existing works.

[66] Club des Amis du Sahel, Specialized Group on Irrigated Crops, "Summary Report," p. 27.

The possibility of achieving these objectives depends on a number of factors. First, there is a great deal of economic and agronomic information still missing which is necessary if the required projects are to be efficiently designed and implemented. Second, there is the need for an enormous effort to train the managers and technicians required to undertake such a program. Third, there is considerable doubt that the cost of irrigation can be covered by producing only food crops. There is a need, therefore, to find commercially viable cash crops which can be rotated with foodcrops.[67] Fourth, means must be found to decrease the cost of transporting grains and other crops from producing areas to centers of consumption. Fifth, if all costs are to be covered, there must be a decrease in the cost of constructing, operating, and maintaining irrigation systems. It is hoped that this will occur as the volume of activity picks up and as river regulation reduces the size of dikes required as protection against floods. Sixth, the sociological obstacles to resettlement, double cropping, and irrigated agriculture in general must be overcome. Seventh, adequate financing must be found not only for construction costs but also to provide subsidies for farmer training and maintenance during the early years of operation of each perimeter. Finally, there are a host of environmental and other considerations beyond the scope of this report.

Simply listing these problems indicates the difficulty of achieving the targets. More important, perhaps, is the need to maintain some perspective regarding the place of irrigation in overall rural development. As stated earlier, most increases in food production over the next ten to fifteen years must come from rainfed cultivation no matter what happens with respect to irrigation. It is very important, therefore, that the effort going into meeting irrigation targets not be so great as to detract from the development of rainfed agriculture.

The Club report, in fact, stresses the need to evaluate large-scale irrigation and river management projects in relation to other alternatives within a common multi-objective framework. It generally regards the targets shown in Table 4 as being ambitious and stresses the need to benefit from past experience in designing future projects. It also indicates that priority in the short run should be given to rehabilitating existing projects and, above all, to undertaking the studies and training the manpower necessary for river basin development over the longer term.[68]

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[67] This issue is discussed later in the report.

[68] Club du Sahel, Strategie et Programme...., pp. 42-43.

IRRIGATION IN THE SAHEL

Two major sources of information were used to examine past experience with different types of irrigation projects in the Sahel. The first was a review of all irrigation projects, both existing and contemplated, for which information is available. The results of this analysis of over twenty projects are contained in Appendix B to this report. The second source was a study of The Political Economy of Rice in West Africa, financed by AID and jointly undertaken by the Food Research Institute of Stanford University and the West Africa Rice Development Association. A particular advantage of this study is that every effort was made to estimate the costs and benefits of rice production on as comparable a basis as possible and to verify all relevant data in the field -- both of which were difficult to do in the project survey.

Classification of Projects

It soon became apparent that the three broad categories used to classify A.I.D. financed irrigation projects in the rest of the world were inadequate for the Sahel. For one thing, population density in the Sahelian countries is not very great in the higher rainfall areas, partly because of the presence of disease. On the other hand, some areas of relatively low rainfall have pockets of high population density, usually along the borders of rivers or other sources of water. A second factor is that projects involving rehabilitation of existing structures often also include substantial improvements in those systems, usually to increase the degree of water control. Finally, the extent to which controlled flooding is a viable technique in low rainfall areas varies substantially between regions.

The world-wide analysis of projects suggested that the type and cost of these is largely determined by exogenous factors such as existing irrigation structures, amount of rainfall, and density of the population. Accordingly, six categories of irrigation systems in the Sahel were identified on the basis of similar predetermined variables:

- Ia - Rehabilitation
- Ib - Rehabilitation and Improvement
- II - High Rainfall
- IIIa - Low Rainfall/High Population Density
- IIIb - Low Rainfall/Low Population Density with Flooding
- IIIc - Low Rainfall/Low Population Density without Flooding

Although in principle these categories differ only because of exogenous conditions beyond the control of project designers, in fact it is sometimes difficult to isolate these. The adequacy and reliability of the flood, for example, is a question which is decided in the course of project design. The Senegal River Delta was once thought to be suitable for controlled flooding polders, for instance, but subsequent experience has convinced irrigation engineers that better water control is required.

It was expected that once the important exogenous factors were identified and relevant categories established, fairly typical project types would emerge. This was not the case. Rehabilitation projects (Category Ia), for example, include both the total water control system of the Office du Niger and the controlled flooding of Action Riz-Sorgho in Mali. Similarly, high rainfall projects run the gamut from total water control at Kou in Upper Volta to marginal improvements in swamp cultivation in the Casamance region of Senegal. Project costs also vary substantially within categories. The capital cost of irrigation and land development in areas of low rainfall and sparse population without adequate flooding (Category IIIc) varies from $3,500/ha for SEMRY II in Cameroon to $8,800/ha at Diffa in Niger. Total project cost for low rainfall/high population density projects (Category IIIa) is estimated at $229/person for Bakel, Senegal, whereas for Kousseri in Cameroon the estimate is $6,110/person.

While some of this variation may reflect different general price levels when the projects were evaluated or lack of comparability of the assumptions upon which the cost estimates are based, it is unlikely that this would account fully for the large differences observed. More important may be relatively small local variations in the exogenous conditions facing project designers. But this merely suggests that some projects may be much better than others, and so careful screening is required. Despite the apparent heterogeneity which appears within project categories, however, there are some tentative generalizations which can be made.

Category I Projects

The costs per beneficiary of pure rehabilitation projects (Category Ia) are generally relatively low because of existing sunk capital. Thus the Club du Sahel's strategy of focusing on these in the short term is probably wise.[69] Another advantage is that since some form of irrigation is already being practiced, the amount of social disruption and required training is minimal and farmers can participate fairly actively in the decisions affecting them. As a result, the benefits to small farmers in most of these schemes are likely to be large as long as land holdings are fairly equal and systems for supplying credit and delivering farm inputs are reasonably effective.

On the other hand, where the projects involve improvement as well as rehabilitation (Category Ib), the advantages may be considerably less. Many of these projects involve increasing the degree of water control, and this usually means pumping, construction of tertiary irrigation systems, and land levelling, all of which increase significantly the cost of land development. The advantage of sunk capital, too, may

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[69] Club du Sahel, Strategie et Programme..., p. 43.

not be very great. Rehabilitation and improvement of an old polder at Bol (Chad), for example, cost an estimated $4,800/ha whereas the cost of constructing a new polder was estimated at $6,300/ha. Rates of return, too, are relatively low -- from 6 to 17 percent. In addition, the projects, especially if they are centrally managed, allow the farmer relatively little scope for decision-making. In general, then, these projects are likely to benefit the small farmer less per dollar invested than those of Category Ia. The sample of projects in this category for which we have data is quite small, however, and it is possible that there are other actual or potential projects which have more desireable characteristics. In fact, one would expect that rehabilitation and improvement are possible for many existing schemes in Categories II and III, adding the advantage of sunk capital to the other characteristics of these categories. In addition, whereas average net returns per farmer from capital invested in Category Ib projects may be less than in those of Category Ia, the higher degree of production security resulting from greater water control may receive a very high weight in some areas.

Category II Projects

As noted earlier, projects in high rainfall areas vary markedly with respect to the system of water control employed because of the greater availability of water in these areas. There is rainfed cultivation with bunding to make more efficient use of water (Niena in Upper Volta), improved swamp (Sikasso in Mali), controlled flooding (Sategiu-Deressia in Chad), diversion dams with gravity feed (Kou in Upper Volta), and storage dams with pumping (Bagré in Upper Volta). Land development costs are fairly low, ranging from $340/ha at Niena to $2,750/ha at Sategui-Deressia. Recurrent costs for overhead and intermediate inputs are also quite low, varying from about $100/ha at Bagré to $340/ha at Kou. This is partly because all of the projects involve either manual or animal traction techniques, avoiding the high operating costs associated with mechanization. Yields vary substantially from about 1.8 tons/ha for improved swamp rice at Sikasso to about 5.5 ton/ha/crop for irrigated rice with heavy doses of fertilizer at Kou. The limited data on rates of return indicate that these are moderate, averaging 13 to 16 percent.

Methods of organizing production also vary significantly. The Kou project, at one extreme, is centrally managed and farmers make relatively few decisions. In most of the other projects, on the other hand, decisions regarding which crops to produce and cultivation techniques to be employed are made by individual farmers. The allocation of water, however, is determined either by the project authority or by groups of farmers.

Benefits to poor farmers in these projects are relatively important but, again, depend on an equitable distribution of holdings and an efficient system for credit and input delivery. Average size of holdings is fairly small, in most cases between .12 and .33 hectares per person, implying either that relatively intensive techniques are employed (as at Kou) or that farmers also engage in rainfed cultivation (as at most of the other projects). Linkages to other sectors are relatively great, especially where animal traction exists because of the requirements for equipment, spare parts, and repair services. In addition, the small scale of production implies that most processing uses labor-intensive, small-scale techniques. On the other hand, since marketable surplus is limited, these projects contribute relatively little to the goal of self-sufficiency or to the benefits consumers derive from decreased food prices. There is also little demand for hired labor. Still, if these projects could be used to encourage migration from lower rainfall areas, this would not only increase total food production but would also take some of the pressure off of farmers who remain in the regions of origin. The relatively low population densities which exist in most of these high rainfall areas imply that the potential for this may be considerable.

On balance, then, Category II projects appear to be effective in providing direct benefits to poor farmers. Given the varied nature of these projects, however, further investigation should be undertaken to evaluate the relative advantages and disadvantages of centralized versus decentralized systems of management and total versus partial water control. Whereas centralized management may facilitate the diffusion of new technology, it also discourages farmer participation in decision-making. Decentralized management, on the other hand, requires the development of an adequate system of incentives to guide decisions regarding production, credit, and the use of agricultural inputs. The choice between different degrees of water control is also more ambiguous than in areas of lower rainfall because natural variation in water availability is not as great and the need to increase security of production is less important. Finally, even though farmers in relatively advantaged regions are not those most in need of assistance, they are, by any standard, quite poor. In addition, the possibility of immigration increases the benefits to the very poor in less advantaged regions.

Category III Projects

Among the different sub-categories of projects in low rainfall areas there is a greater degree of homogeneity. Within the high population density areas (Category IIIa), for example, there appear to be two distinct groups.[70] First, there are the very labor-intensive projects at Matam and Bakel in Senegal, which have full water control with pumping and manual construction of tertiary irrigation systems. Manual methods are used to cultivate two irrigated crops per year on very small holdings averaging less than one-quarter hectare per family.

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[70] Although Table 1 in Appendix B indicates that the general population density in these project areas is 30 to 40 persons/km^2 this is deceiving since the density of population clustered along the borders of major waterways, where the projects are actually situated, may easily exceed 100 persons/km^2.

These are supplemented by some additional cultivation of rainfed and flood recession crops. Land development costs are about $2,000/ha, but because the holdings are so small total project costs per person are very low -- only $229 at Bakel. Most decisions are made by individual farmers or by groups of about 50 farmers which control the irrigation system for each perimeter. Yields are high, as are internal rates of return (26 percent at Bakel). Primary benefits are fairly evenly distributed among farmers from the same village, though villages without perimeters are obviously less well off than those which have access to irrigated land. The major benefit is probably the increased security of crop production provided by these schemes. The chief disadvantages are the lack of secondary benefits resulting from low levels of marketed surplus, little demand for outside labor, and few locally produced inputs.

The second group of projects within Category IIIa involves the use of animal traction techniques. These projects also have total water control with pumping, tertiary irrigation systems, and land levelling. Development costs are higher, ranging from $3,320/ha to $6,300/ha, as are total project costs per person. Rates of return are quite low, averaging about 10 percent, even though yields are high. Holdings are also somewhat larger than for the manual techniques so that there is greater possibility of developing a surplus. This together with the use of animal traction implies that linkages to the rest of the local economy are fairly important. Thus secondary benefits to the poor are likely to be greater than for the first group of projects even if primary benefits per dollar invested are considerably lower. The benefits of higher incomes and greater crop security should be equitably distributed among those who participate in these projects. It is not yet clear, however, how much farmers will participate in decision-making. Presumably, they will have some control over crop and technique choices and less say over the allocation of water, except possibly through cooperative groups.

It should be possible to combine these two project types so as to gain the advantages of each. It has been recommended, for example, that average holding size in projects of the first group be increased to about one half a hectare and that animal traction be introduced. This would increase benefits to the farmer and linkages to the rest of the economy without foresaking the advantages of labor intensive construction methods and low costs for land development. Project costs per person, however, would probably rise and rates of return fall somewhat because the irrigation system would not be used as intensively and yields would be lower. The major constraint on expansion of this type of system in higher population areas is, ultimately, the availability of suitable land in close proximity to water. Once the best locations have been developed, costs rise because of the need to construct major water delivery systems.

Where flooding is adequate and fairly reliable in low rainfall areas with low population density (Category IIIb), controlled flooding is the dominant technique. The only examples of this are in Mali, where animal traction is employed to produce a single annual crop, though occasional deep plowing with tractors and some mechanical threshing are also used. Average holdings are from 2.5 to 3.0 hectares per family. Some rainfed cultivation is also practiced by many of these farmers. Rice is the only crop grown within the polders, and individual farmers make all decisions except the timing and extent of flooding. They are also required to market part of the crop through the public agency which manages the project. Yields are fairly low, averaging about 1.5 to 1.8 tons/ha, with only very limited quantities of fertilizer being used. The major advantage of these projects is their low cost for land development -- from $400 to $1000 per hectare. Recurrent costs of overhead and intermediate inputs are from $80 to $160 per hectare, and rates of return vary from 12 to 31 percent. The major problem associated with this type of irrigation system is the lack of security of production due to occasionally poor or late floods.

Project benefits appear to be quite evenly distributed among poor farmers, though there is some consolidation of land holdings through family ties. Credit and input delivery appear to be adequate so that all participating farmers can take advantage of the schemes. Secondary benefits to the poor also seem to be quite favorable. There are linkages to small-scale industry because of the animal traction technique employed and because a fairly substantial part of the crop is milled locally in small-scale hullers. Effects of the relatively large marketed surplus on the goal of import substitution and on local cereals prices are also favorable. Overall, these projects contribute quite effectively to aiding the poor.

The situation is different in areas of low rainfall and sparse population where there is inadequate or unreliable flooding. Here the dominant system is one of total water control through pumping or gravity feed. Because of high initial capital costs, averaging $3,500 to $8,800 per hectare, there is a need to make full use of the system as quickly as possible. Since population density is low, this generally necessitates the use of machine services for plowing, seedbed preparation, and sometimes even harvesting. If capital charges are to be covered, double cropping is also required.[71] If this is extended over a wide area, seasonal river regulation also becomes increasingly important. Recurrent costs, too, appear to be quite high -- from $200 to $376 per hectare -- and, during the initial years of operation at least, probably have to be subsidized. Yields tend to be quite good, averaging over 4 tons of rice per hectare in some areas.[72]

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[71] The most notable exception to this is the Office du Niger, where the initial capital investment has long since been written off.

[72] Again, the Office du Niger is an exception. Yields there currently average about 2.3 tons/ha because the techniques employed are very extensive for irrigated agriculture. This is possible only because so many capital costs are sunk.

Rates of return very markedly. They may be negative in some perimeters of the Senegal River Lower Valley and Delta whereas SEMRY I in Cameroon appears to have an internal rate of return of close to 22 percent.

One major problem with this type of project is that the primary benefits per participant are fairly low for each dollar invested. Average holdings are slightly smaller than in Category IIIb -- from 1.8 to 2.7 hectares per family. Even with high yields, however, net income after deduction for capital charges and recurrent costs is low in relation to the amount of capital invested.[73] Since these centrally controlled schemes also have a high demand for trained managers -- a very scarce resource in the Sahelian countries -- the primary benefits from such projects must be distributed very sequentially, i.e., a relatively long period of time must elapse before all members of the target population receive their benefits. This contrasts with the projects of Categories IIIa and IIIb which can be spread among a larger number of people in a shorter period of time even though the initial benefits per person might not be as great as for projects in Category IIIc.

On the other hand, these Category IIIc projects have the advantage of assuring a high degree of crop security in regions where the risk of loss is great. In addition, because total yields per person are high, there is a large marketable surplus which can be used to substitute for imports and to lower cereals prices to consumers. Finally, this type of project has the advantage that it can be replicated on a large scale, albeit with high costs for constructing feeder canals, drainage systems, diversion and storage dams, etc.

Secondary benefits from linkages to small-scale activities in the rest of the economy are relatively low because of the mechanized techniques employed in construction and cultivation and because the marketed surplus is generally processed in modern, large-scale mills. There is also little scope for individual farmer decision-making with respect to choice of crops, type of technique, timing of agricultural operations, and disposal of the harvest. In addition, there may be high social as well as economic costs associated with land resettlement and the shift from traditional systems of production to double-crop, irrigated cultivation.[74] Finally, this type of scheme is likely to have

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[73] See Hasan A. Tuluy, "Comparative Resource Costs and Incentives in Senegalese Rice Production," Food Research Institute, Stanford University, July 1979 and J. Dirck Stryker, "Comparative Advantage and Public Policy in West African Rice," Food Research Institute, Stanford University, July 1979 for a more thorough treatment of this issue.

[74] For a more complete treatment of the sociological issues see Abraham S. Waldstein, "Government Sponsored Agricultural Intensification Schemes in the Sahel: Development for Whom?" USAID Papers on Sahelian Social Development, August 1978.

substantial costs related to the displacement of flooded and flood recession agriculture and animal grazing.

It may be possible to modify these schemes so as to increase benefits to the poor. One possibility might be greater use of animal traction.[75] The shift from mechanized, centrally controlled production to the use of animal traction on a decentralized basis, for example, has resulted in substantially increased yields and improved performance at the Office du Niger in Mali. It may also be possible to use more labor-intensive methods in construction and to allow farmers greater choice over crops and disposal of the marketed surplus.

Summary

This analysis of the six categories of irrigation projects is summarized in Table 5. Perhaps the most striking feature of this table is the substantial variation in characteristics which exists within most categories, indicating that there is probably some scope for flexibility in project design or at least that there are a variety of project types to choose from. There is a need, therefore, to screen carefully irrigation projects on the basis of these and other indicators, as well as to maintain a flexible and experimental approach to project design.

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[75] This is the technique envisioned for Diffa and Namarigoungou in Niger.

Table 5
Summary of Irrigation Project Characteristics[1]

Category	Water Control	Cultivation Technique	Scope for Small Farmer Decision-making	Land Develop-ment Cost ($/ha)	Recurrent Cost ($/ha)	Rice Yield (mt/ha)	Internal Rate of Return (%)	Average holding Size[2] (ha)	Linkages	Marketed Surplus
Ia	Diversion dam, con-trolled flooding	Animal traction	Little-Medium	1,000	50	1.5-3.5	10-14	7.5	High	Medium
Ib	Pumping, field levelling	Mechanized, animal traction	Very little-little	4,000-5,000	750	2.5-3.0	6-17	2-2.5	Low-High	Medium
II	Varies	Animal traction	Very little-great	340-2,750	100-340	1.8-5.5	13-16	1.2-3.3	Low-High	Low-Medium
IIIa(1)[3]	Pumping	Manual	Medium	2,000		4.0-4.8	26	.2-.5	Low	Low
IIIa(2)[3]	Pumping, field levelling	Animal traction	Little-Medium	3,300-6,300	240-500	3.5-5.8	8-12	1.0-5.2	High	Medium-High
IIIb	Controlled flooding	Animal traction	Medium	400-1,000	80-160	1.5-2.5	12-31	2.5-3.0	High	Medium
IIIc	Pumping, diversion dam, field levelling	Mechanized, animal traction	Very little-medium	3,500-8,800	200-376	2.3-5.0	0-22	1.8-2.7	Low-High	Medium-High

1 Source is Appendix B
2 Calculated on the basis of 10 persons per family
3 Category IIIa has been divided into two sub-categories for reasons given in the text.

GEZIRA AND THE OFFICE DU NIGER

Plans for expanding irrigation and river basin development in the Sahel should be viewed within the context of past experience in this part of the world. Of major concern, then, are the lessons to be learned from the Gezira Scheme in Sudan and the Office du Niger in Mali, the only two truly large-scale irrigation projects lying within this ecological zone.

Each of these schemes has been the subject of considerable study.[76] No attempt is made here to summarize this work but only to discuss a few of the most important lessons which appear to be relevant to the future of irrigated agriculture in the Sahel.

By way of introduction, the Gezira Scheme is a largely gravity-fed irrigation system covering approximately 1 million hectares, of which about one half are double cropped. Water flow from the Blue Nile is regulated by upstream storage dams, of which the first at Sennar, completed in 1925, also acts to divert water into the irrigation system. Individual farmers with secure tenancy cultivate cotton, wheat, groundnuts, sorghum, and fodder. Average holdings originally were close to 17 hectares, but these have been subdivided several times. The Sudan Gezira Board (SGB) supervises agricultural operations, maintains and operates the irrigation system, furnishes inputs and credit, and purchases the cotton and wheat crops. There is considerable degree of mechanization, with services provided both by the SBG and by private contractors. Proceeds from the cotton crop are divided in fixed proportions among tenants, the Sudanese government, and the SGB, after deduction for certain expenditures. Wheat is purchased from tenants at a fixed price.

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[76] Arthur Gaitskell, Gezira: A Story of Development in the Sudan, London: Faber and Faber, 1959; D.S. Thorton, "Contrasting Policies in Irrigation Development, Sudan and India," Department of Agricultural Economics, University of Reading, September 1966; D.S. Thorton, "Agricultural Development in the Sudan Gezira Scheme," Sudan Notes and Records, vol. 53, 1972; John C. de Wilde, Experiences with Agricultural Development in Tropical Africa, vol. 2: The Case Studies, Baltimore: John Hopkins Press, 1967; West Africa Rice Development Association (WARDA), Mali: Office du Niger, Monrovia: June 1974; WARDA, Mali: Etude Prospective de l'Intensification de la Riziculture à l'Office Du Niger, Monrovia: June 1977.

The Office du Niger is a much smaller scheme totaling 57,000 hectares of irrigable land, of which 43,000 ha are presently under single-crop cultivation. When created in 1932, the scheme was intended to serve a much wider area. The irrigation system is gravity-fed from a barrage at Markala on the Niger River, which diverts water into the main canals. There is no storage capacity at Markala. Rice is cultivated by farmers on holdings which average 8.5 hectares. They do not own the land but have secure tenure. Extensive, ox-drawn techniques are generally used. Sugar cane is also grown using hired labor on 2,700 hectares managed by the Office du Niger, a publically owned agency. Extension services, credit, inputs, and mechanical threshing services are provided to rice farmers by the Office, which also maintains and operates the irrigation system, purchases part of the rice crop at a fixed price, and mills the purchased paddy. In return for these services farmers pay a levy of 400 kg of rice per hectare.

One of the major differences between the Gezira Scheme and the Office du Niger is the highly favorable environmental situation in which the former operates and the numerous technical problems which have plagued the latter. First of all, the Blue Nile provides huge quantities of water in close proximity to very large areas of irrigable land. "The slope of the river enabled the dam at Sennar to operate both as a barrage and a storage reservoir at a point where it could command most of the Gezira plain by gravity flow. This location and the gentle incline of the land from this point northwards had a basic effect on costs, for the heavy capital expenditure on one single dam could be spread cheaply over a large paying area."[77] Downstream from the dam, on the other hand, the river is much lower than the surrounding plan, even at full flood, so that only a shallow surface drainage system is necessary to prevent waterlogging. Furthermore, the high clay content of the soil obviates any need to prevent seepage, by lining canals. Finally, the climate is ideally suited to growing long-staple cotton.

In contrast, the Office du Niger has suffered from numerous technical problems. For one thing, the barrage at Markala has no storage capacity, which inhibits double cropping and prevents early irrigation to kill weeds and to soften the soil during the last two months of the dry season. For another, the slope of the land and river are such that the project has been plagued throughout its history by waterlogging and drainage problems, and these are still far from being solved. This is exacerbated by sporadic but heavy rains during

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[77] Gaitskell, <u>Gezira....</u>, p. 275.

part of the growing season, which was particularly detrimental to cotton production and contributed to its abandonment in 1971. Another major disadvantage which the Office du Niger suffered in relation to Gezira was the absence of a significant resident population when the scheme was initiated. As a result, the project has continually suffered from a shortage of workers and farmers.[78]

Both schemes have extensively employed mechanization at one time or another. In Gezira, this started with tractor plowing and has more recently included ridging of cotton fields and even combine harvesting. While the result may have been less use of available labor and excessive demands on foreign exchange, at least the system seems to operate fairly effectively. In the Office du Niger, on the other hand, the use of mechanized techniques to overcome the labor shortage, especially after World War II, has been very expensive because of the high cost of importing fuel and spare parts and the difficulty of ensuring proper maintenance. In addition, the long distances of the various sectors within the Office from each other and the multiplicity of activities has complicated the employment of machinery. As a result, its use except for mechanical threshing was largely abandoned in 1970.

Initially, land holdings in the Gezira Scheme were close to 17 hectares per family. Allowing for fallow, this implied that approximately 11 hectares could be cultivated in any given year. This was so much land that a market for hired labor soon developed. Over time, land holdings decreased because of subdividing among succeeding generations, but the use of hired labor, if anything, increased. Since machinery services have also increased in importance, one can only conclude that the number of "gentleman farmers" and absentee landlords has risen as well. A similar trend is also observed in the Office du Niger, but appears to have advanced less far. Although the use of hired labor helps to distribute more widely the benefits from these schemes, the practice is not encouraged by project authorities, especially in

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[78] One should be careful, however, not to overestimate the importance of sparse population density. It is clear, for example, that because of its success the Gezira scheme has continued to attract immigrants from other regions, whereas the Office du Niger has had continuous difficulties in doing so.

the Office du Niger. It also appears to conflict with the Congressional requirement that large-scale infrastructure financed by U.S. aid must primarily benefit small producers with secure land tenure.

One way of inhibiting the employment of hired labor is to decrease the average size of land holdings and increase their number. This may also have the advantage of increasing yields if farmers cultivate their own land more intensively than does hired labor.[79] One result is the spreading of overhead and capital costs over a larger volume of total production. This is an important current objective of the Office du Niger.

Although cotton was cultivated for many years in the Office du Niger, it was abandoned because of technical difficulties and because the government of Mali decided to place major emphasis on achieving self-sufficiency in rice production. This strategy will remain viable until the import substitution market for rice is saturated, as is already the case in some years, at which point Mali will either have to find export markets for rice elsewhere in West Africa or will have to develop other crops, such as cotton, which can be sold overseas. Fortunately, it appears that Mali can export rice profitably to other countries in West Africa and may have an even more valuable crop in cotton if the technical problems can be overcome. The history of Gezira, in any case, clearly indicates that the financial viability of these schemes depends critically on having a reasonably valuable cash crop to sell on assured markets, and this has important implications for the development of irrigation elsewhere in the Sahel.

The experience of these two schemes does not auger well for active farmer participation in decision-making. The role of cooperatives or other farmer groups in the Office du Niger has been very passive. Tenants' associations in the Gezira Scheme have been much more vocal in recent years, but their major concern has been to enlarge their share of the net return from cotton rather than to become involved in the operation of the scheme. Until levels of education and literacy are increased, therefore, greater scope for small farmer influence on decisions in these large-scale schemes will probably result more from freedom concerning choice of crops and techniques than from the organizing of formal groups. This creates problems of inefficiency, however, especially in the allocation of water, which the farmer generally thinks of as being free.

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[79] There is abundant avidence from all over the world that this is true. See, for example, Kenneth Bachman and Raymond Christensen, "The Economics of Farm Size," in Herman Southworth and B. F. Johnston, (eds.), Agricultural Development and Economic Growth, Ithaca, New York; Cornell University Press, 1967.

There is one more very important conclusion to be drawn from the Gezira Scheme. The first modern efforts in the Sudan to control water for purposes of cultivation began shortly after the turn of the century. Many of these ended in failure, but lessons were learned and experience was accumulated. This period of experimentation was extended because the First World War delayed construction of the dam at Sennar. By the time this dam was finally completed, there had been 25 years of accumulated experience and a substantial number of farmers trained in irrigated agriculture. This was fortunate, because once the dam was constructed, the irrigation system had to be expanded as rapidly as possible in order to assure adequate production to meet overhead expenses and repayment of interest and principal on the loan. Management became locked in, and the period of trial and error was over.

SAHELIAN RIVER MANAGEMENT

The place of river management in overall rural development and food production should be analyzed using a systems approach which integrates the various components into a whole which may extend into the future for several decades. Complete quantification of this sytem is impossible here, but its outline can be described and applied to each of the major river basins, with primary emphasis on the Senegal River because of the greater availability of data.

Outline of the General System

The general system can best be described in terms of two major phases of rural development.[80] The first is characterized by concentration of limited capital and management on increasing production in higher rainfall areas, where they will have the greatest impact, and by setting the stage for subsequent development of lower rainfall areas. The second phase involves major river basin development and improvement of living conditions, including food security, in the lower rainfall areas.

Phase One

Acute shortages of capital and, above all, indigenous management skills exist during this period. It is vitally important, therefore, to make best use of the limited resources which are available. Unfortunately, this probably means that a major developmental effort cannot be made in the lower rainfall areas (e.g., below 800 mm), despite their greater insecurity of food supply, for several reasons:

1. The increase in cash and food crop production associated with application of a given amount of these scarce resources is greater in higher than in lower rainfall areas.

2. There is no presently known technology for significantly increasing yields and security of production in lower rainfall areas which is economically viable without some form of irrigation. Since capital is very scarce, it is unlikely that governments will want to indefinitely subsidize projects which are not economically viable.

3. Expansion in these areas of large-scale irrigation with total water control would have to be very rapid in order to increase food production significantly. It would be very costly relative to other opportunities, would involve a substantial amount of social disruption, and would place an enormous demand on scarce capital and management resources. It would also imply a highly sequential distribution of benefits to the poor.

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[80] These phases correspond quite closely to those described in Club du Sahel, Strategie et Programme...., 1) short and medium term and 2) long term.

Instead, it seems better to concentrate these scarce resources where they will do the most good, i.e., by increasing production in higher rainfall areas. To take some of the pressure off poorer regions, migration to zones of higher rainfall should be encouraged. At the same time, however, the groundwork must be laid for Phase Two through

1. development of improved technologies for drier regions;

2. experimentation with alternative systems of irrigation in order to provide some direct benefits as well as to train managers, extension agents, and farmers and to aid in designing the best system for subsequent extension on a large scale;

3. a major effort to train the managers and a cadre of farmers required for large-scale river basin development in Phase Two;

4. gathering of all the data and undertaking all the studies required before Phase Two can begin.

Phase Two.

The timing of Phase Two may depend on a number of factors:

1. easing of the severe shortage of managers and capital through training and experience and through the mobilization of foreign and domestic sources of investment;

2. completion of the data-gathering, studies, and experimentation required to proceed;

3. availability of technological packages and systems of irrigation which are technically and economically sound;

4. diminishing returns being reached to improvement in rainfed cultivation;

5. increased population pressure for which outmigration is no longer an effective relief.

It is possible that these factors might not all simultaneously indicate the desireability of moving to Phase II, in which case there could be some delay during a catchup period. But the pressure will be building to shift to the next stage of development.

Once Phase Two is initiated, planning flexibility will be markedly decreased. Even supposing that the large-scale irrigation projects of Category IIIc can be modified to employ more labor and less capital in construction and operation, initial capital costs are going to be high. To cover those costs, double cropping will have to be employed, probably involving a cash crop as well as a locally consumed food crop. This is eventually going to require the construction of upstream storage dams for seasonal regulation of river flows. Unless these dams can be paid for in other ways, e.g., through the sale of hydroelectric power, they are going to have to be justified on the basis of returns in irrigated agriculture. Because of discounting and the long gestation periods involved in the construction of dams and the development of profitable irrigation, the irrigation system will have to be expanded as rapidly as possible in order to have adequate economic rates of return and to avoid severe problems of financial liquidity.

Even then, it is questionable whether irrigation alone will be able to pay for the cost of storage dams. This was feasible for the Gezira Scheme, but, as was noted earlier, conditions there were especially favorable. Even so the financial pressure was intense. Elsewhere in the world, irrigation has seldom been able to pay for itself. Thus it is vitally important to explore for possible markets for the potential hydroelectric power which could be generated by these dams, since this frequently can be used to pay for a large part of the initial investment cost. It is also essential to see this electrical power as being used to finance irrigated development which aids smaller farmers even if the power itself does not directly benefit the poor.

It is the lumpiness of large storage dam construction, therefore, which marks the shift from Phase One to Phase Two. Without this lumpiness the transition could proceed much more smoothly in an incremental fashion. It is highly desireable, therefore, to delay construction of storage dams until as many as possible of the preparatory conditions for this investment have been met. Once Phase Two arrives, it will be too late to worry about the small farmer and aiding the poor unless the system in all its hydrological, agronomic, economic, and sociological dimensions has been properly designed for this purpose.

Having very briefly described the outlines of the systematic approach to be used in analyzing river basin development in the Sahel, we next try to evaluate the current situation in each of the basins with a view to recommending policy actions consistent with the intent of the Congressional Mandate. In so doing, the first step is to assess how far along in Phase I are the countries included in each basin; the second step is to evaluate alternatives, primarily with respect to the timing of major dam construction. This will be done in considerably more detail for the Senegal River than for the other basins.

Senegal River Basin

The final studies have been completed for the Diama and Manantali dams in the Senegal River Basin, and most of the financing has been acquired for their construction. The former will be a salt water barrage with very little storage capacity, the latter a multi-purpose upstream storage dam. The major benefits associated with the construction of these dams are the possibilities they will create for double cropping, thus permitting expansion of total water control irrigation systems over a wide area (up to 390,000 hectares in total).

The first question to be asked is what is the need for these dams at present and what are the alternatives? The second question is how well prepared are the OMVS[81] countries for the dams and, in particular, are they likely to benefit the small farmer?

The answers to these questions require estimating some quantitative dimensions of the general system outlined above. The best, though still incomplete, effort to do this is the linear programming model developed by FAO to analyze alternatives in rainfed agriculture.[82] This model provides some idea of how much of the potential for improvement in rainfed cultivation may be realized by the year 1990 if that sector is to furnish the grain required for self-sufficiency in essential foods after allowing for a given projected rate of growth of irrigated cultivation.[83] Production of various crops using different levels of technology are projected for several agro-climatic zones, allowing for some interzonal migration. The model also projects the redistribution of population which might occur by 1990 and the resulting population pressure on the land.

The three member countries of OMVS will face quite different situations in 1990 according to the results of this model. The potential for expansion into higher rainfall areas appears to be greatest in Mali, and a large part of the needed increases in food production could come from a growth of cultivated area from 2,000,000 ha in 1970 to 3,680,000 ha in 1990, mostly in the southern part of the country. Only modest intensification in the production of rainfed cereals is required -- perhaps an increase in yields of 30 to 40 percent. Thus there should be considerable scope for future improvements in rainfed agriculture after 1990 when increasing population density may start to become a problem.

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[81] Organisation pour la Mise en Valeur du Fleuve Sénégal, the regional organization responsible for developing the Senegal River Basin.

[82] FAO, Perspective Study..., Vol. 1.

[83] This projection calls for the following amounts of land under full and partial water control in the OMVS member countries by 1990:

(thousand hectares)

	1970		1990	
	Full Control	Partial Control	Full Control	Partial Control
Mali	44	66	75	120
Senegal	6	12	50	22
Mauritania	3	--	18	--

In Senegal, the situation will be more severe. There is already excessive crowding in the central groundnut basin, with a consequent decline in soil fertility as fallow periods are shortened. The problem can be solved, however, by simultaneously intensifying production in this basin and by encouraging migration from this region towards the higher rainfall areas to the south or the Senegal River Valley to the north. It is also possible to replace groundnut production with that of cereals, but this would decrease exports and is not currently profitable. The model anticipates that total cultivated area will grow from 2,440,000 ha in 1970 to 2,710,000 ha in 1990 through the expansion of both irrigation (54,000 ha) and rainfed cultivation (216,000 ha) in the south. Even more important, there must be approximately a doubling of rainfed cereals yields by 1990. This can only be accomplished if the south is opened up to resettlement. Should this not be done, Senegal can anticipate a sharp rise in the current level of grain imports.

This remains largely true even if irrigation were to be expanded at a more rapid rate. It is inconceivable, in fact, that irrigation can provide anything more than a small part of total consumption needs in Senegal during the next decade. It is critical, therefore, that the expansion of irrigation during this period not be allowed to lessen the effort to increase food production in the southern part of the country. By 1990, however, the need for irrigation will increase because of diminishing returns to further efforts to increase rainfed production.

Mauritania has by far the least amount of land available for cultivation under any conditions. Because of its low level of rainfall, irrigated agriculture must play a key role in providing for future food needs. The alternative is rising imports of food.

In summary, then, the situation of the three countries with respect to the timing of Phases One and Two is very different. At one extreme, Mali could profitably continue investing in rainfed cultivation on into the next century. In addition, Mali has substantial opportunities to intensify and expand existing irrigated cultivation at the Office du Niger and in the controlled flooding projects without embarking on a major program of river regulation.[84] As a result Mali has little need as far as agriculture is concerned for regulation of the Senegal River.[85]

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[84] As will be seen later, the Selengué dam, which is currently under construction, will add to existing irrigation potential even though its primary justification is hydro-electric power.

[85] On the other hand, Mali would very much like to be able to use the Senegal River to gain direct access to the sea. This was the major motive, in fact, for locating the proposed storage dam at Manantali in Mali rather than in Senegal, where several better sites are available. This raises the question of whether it would not, instead, be preferable to locate the first upstream storage dam in Guinea, which offers the best sites of all, since Mali would then be able to benefit even more from downstream regulation of water flows. Although not currently a member of OMVS, Guinea has recently joined several other regional river basin commissions and could probably be induced to join OMVS as well.

At the other extreme is Mauritania, which is heavily dependent on irrigated and flood recession agriculture. Given the limited potential for increasing yields of flood recession cultivation, it appears that irrigation is the only alternative. This does not necessarily, however, have to involve double-cropping or the large-scale schemes of Category IIIc described earlier. Along much of the border of the Senegal River, population density is fairly high and projects similar to those at Matam and Bakel have already been initiated. Since these are very intensive in the use of land, and probably also in the use of water compared with the large-scale schemes, they could contribute significantly to national food production without requiring large-scale irrigation expansion and river regulation for some time even if double-cropping were required. This of course depends on cooperation with Senegal since there is sufficient water in the Senegal River to irrigate only about 30,000 hectares for a second crop with total water control in 4 out of 5 years without upstream storage.[86]

If Senegal were to devote its primary effort to improving rainfed cultivation in the south during the next decade, by 1990 it would have used up a large part of the potential for increasing production in this area. This together with growing population density, especially in areas of low rainfall such as the central groundnut basin, would imply that Senegal was approaching the need to begin Phase Two -- a major effort to develop irrigation in the Senegal River Basin during the following decade. Included in this development would be completion of a major regulatory structure in the early 1990s to prevent a shortage of water during the dry season from limiting the expansion of double cropping.

From the point of view of growing population density and the potential for developing rainfed agriculture, therefore, it appears that Mauritania and Senegal will be ready to enter Phase Two in about ten years. This assumes, however, that Mauritania is given priority over increased use of water in the dry season during the next decade. Constraints on water use would not be too restrictive for Senegal, however, because Mauritania in 1976 had only 1,200 hectares capable of being double cropped.[87] In addition, the country has very few trained personnel currently available for carrying out a major irrigation program. A large effort is therefore required in Mauritania during the next ten years to develop a cadre of managers and farmers experienced in techniques of irrigation. In Senegal, the manpower situation is less critical, but much of this will be needed to develop rainfed agriculture in the south. Therefore, Senegal, too, needs to expand its human resource base before embarking on Phase Two.

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[86] Club des Amis du Sahel, Specialized Group on Irrigation Crops, "Summary Report," p. 9.

[87] See Table 3 on p. 37 of this report.

There is a need also for further experimentation with various types of irrigation schemes. The discussion earlier of different categories of irrigation projects left some doubt as to whether the ideal prototype has yet been developed. Assuming that river flows in the Senegal River Basin are too irregular for controlled flooding to be a viable technique, we are left with two broad categories of projects in this low rainfall area -- those related to high (IIIa) and low (IIIc) population densities. Both are currently being practiced within the basin, and each seems to have advantages and disadvantages. Since full development of the Senegal Basin can only occur if there is extensive migration and resettlement, however, population density should probably not be the key variable determining the type of production system to be employed. Instead, it should be possible to combine some of the best features of both kinds of projects with the particular objective of providing major benefits to small farmers.

The construction of major irrigation works, such as protection dikes and primary feeder canals and drains, for example, could be by mechanized means, whereas manual labor could be used to build the secondary and tertiary systems. Similarly, rough levelling might be accomplished with bulldozers, but micro-levelling within individual parcells would be undertaken by farmers. A variety of construction techniques are already being used on some of the smaller perimeters of Matam, where farmer groups have in some cases themselves paid for the mechanical construction of protection dikes.

Production methods might also be altered. Periodic deep plowing by tractor could be complemented by manual or animal traction methods of annual tillage or even the use of small power-tillers.[88] Similarly, mechanical threshing can take place side by side with hand flailing, as occurs in the controlled flooding projects of Mali. In addition, average size of holdings should be adjusted to the point where farmers and their families can cultivate all their land using relatively intensive techniques, producing enough to feed themselves and have a sizeable surplus left over for marketing. Various methods of irrigation control should also be experimented with so as to improve incentives for efficient use of water.

This will require the development of appropriate farmer organizations required to undertake community tasks and to avoid conflicts over use of water. The experience of the small-scale perimeters indicates that this can most successfully and equitably be done within the context of traditional social structures.[89] More must also be learned about economic and sociological constraints on double cropping and how the use of the river for pasture and flood recession agriculture can best be integrated

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[88] This cannot be done on the heavy soils of the Delta but is possible on the lighter soils of the Valley.

[89] For a recent sociological analysis of farmer organizations in the Matam perimeters, see Sylviane Fresson, Village Participation in Pump Irrigation Areas in the Matam Zone in Senegal, Experiments in Rural Development Special Document No. 4, Paris: OECD, April 1978. The findings of this study suggest that benefits have been broadly spread within the villages participating in this scheme.

with the expansion of irrigated cultivation.[90]

Although there has been a wide range of project types developed, each of these has disadvantages insofar as benefitting the poor and satisfying other objectives. Since one of the preconditions for successfully entering Phase Two is the establishment of a prototype which can be replicated on a broad scale, more time is required for active experimentation in this direction.[91] Even though the major studies for construction of the Diama and Manantali dams are completed, much remains to be done before double crop irrigation can be rapidly expanded.

The analysis thus far suggests that Phase Two in the Senegal River Basin should probably begin around the year 1990. Assuming that a viable prototype along the lines suggested above can be developed by then, there appears to be no reason why investment in the large-scale infrastructure required for development of this basin should not be justified in terms of:

1) there being no better alternatives, and

2) these investments primarily benefitting the poor.

In the meantime, additional large-scale infrastructure investment can be justified to the extent that it either contributes to the development of the prototype or provides direct benefits to the poor in other areas, in particular by increasing production and facilitating immigration in the higher rainfall areas in the south. In addition, development of small-scale irrigation, especially in Mauritania, appears also to be justified at present.

Given the desire to press ahead with river basin development, there is a danger of diverting scarce resources from better alternatives during the next decade and of expanding a type of system which is not in the best interests of the poor majority and will result in a very sequential distribution of benefits. Ten years from now this sequential nature of the spread of irrigation should be reduced because of the greater capacity which will exist for rapid expansion and because of the prospects for developing a prototype which will have lower per capita costs in relation to benefits.

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[90] Thayer Scudder, "African River Basin Development and Local Initiative in Savanna Environments," paper prepared for the Burg Wartenstein Symposium No. 79, on Human Ecology in Savannah Environments, August 3-13, 1978.

[91] In this respect, the perimeters at N'Galanka, Senegal and Boghé, Mauritania should be studied carefully. Here experiments have been initiated to aggregate small perimeters into larger blocks so as to increase the rate of their development and provide for the selective use of mechanization.

Cost-benefit analyses to date have shown the dams to be economically feasible only if irrigation can pay for most of their costs. Experience suggests, however, that this may not be possible. A recent study shows the production of rice in the lower Senegal River Valley using total water control and largely mechanized techniques to produce two crops per year not to be profitable except as a substitute for on-farm consumption of imported rice. The net loss associated with producing rice in this way for the Dakar market was approximately 33,000 CFAF (or $147 at the existing exchange rate) per metric ton of milled rice.[91] Similar losses could be expected for other cereals crops. Since part of these crops must be sold on the more important domestic markets in order to cover operating expenses and capital charges, it is difficult to see how this type of irrigation can pay for major dams. Crops other than cereals could, of course, be produced, but their markets are limited and research on production of these crops in this region is inadequate.

These results conflict substantially with estimates of costs and benefits used in the feasibility study for the Manantali dam.[92] It is impossible to compare these results precisely because the methods used differ substantially.[93] In addition, the calculations for the Manantali study are made for both large-scale mechanized perimeters (two-thirds of the total hectarage) and small-scale perimeters which are cultivated using animal-traction and manual techniques (one-third of the total hectarage).

Nevertheless one very important difference between the studies is evident. The Manantali study substantially overestimates the opportunity cost of rice and other cereals delivered to Dakar. Supposedly taking into account the cost of transport and processing, the study estimates the farm gate reference price of paddy, for example, to be 60.3 CFAF/kg. But in 1975/76, the base year used in the study, the average CIF price of imported rice delivered to Dakar was only 62.5 CFAF/kg. Substracting the average cost of milling and transport

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[91] Tuluy, "Comparative Resource Costs....," Table 6.

[92] Organization pour la Mise en Valeur de Fleuve Sénégal (OMVS), <u>Etude d'Execution du Barrage et de l'Usine Hydroélectrique de Manantali, Rapport Final; Actualisation des données de base, Annexe 4: agriculture - mission A.I.4.</u>, Groupement Manantali, December 1977.

[93] For one thing, the Manantali study does not calculate the net benefit of irrigation separately but includes both costs and benefits of irrigation in estimating the internal rate of return to the project as a whole, including the dam. The Manantali study also estimates costs and benefits for a theoretical irrigated hectare upon which a number of different crops are grown in fixed proportions, whereas the study by Tuluy looks only at rice cultivation.

from the Senegal River producing regions, and converting to equivalent paddy, the reference price should be much lower than that used. The same also appears to be true to a lesser extent of the other cereals. This illustrates the difficulty of producing grain in Senegal which can complete effectively in the Dakar market with the cheap broken rice which is imported. It also demonstrates the importance of developing a viable cash crop which could be sold at a high enough price to pay for the large capital investments involved. Possibilities include cotton and vegetables, but the economic feasibility of doing this has yet to be established.

In sum, then, construction now of major dams in this region appears to be highly questionable from the perspective of economic feasibility as well as aiding the poor. On the other hand, production of rice for on-farm consumption is economically profitable for some techniques, though probably not financially feasible where recurrent expenditures and capital charges are large.

This suggests several things. First, development of irrigation in the Senegal River Basin over the next ten years for the purpose of directly aiding farmers should probably concentrate on small-scale perimeters which are more economically and financially viable,[94] especially if a second crop can be marketed locally. This will provide greater security of production and will introduce farmers to irrigated cultivation within a traditional social setting with maximum farmer participation. Second, this effort should be complemented by experiments to develop a prototype for irrigation on a larger scale. These experiments may have to be subsidized initially, but once a successful prototype is established, the subsidies can be withdrawn. The projects, in fact, should then be taxed so that the surpluses generated can be used to pay for capital charges on regulatory structures. Experience with these projects can then be used to estimate the extent to which these structures can be paid for with irrigated cultivation. Third, it is vital to explore new possibilities for developing irrigated cash crops upon which the financial viability of the whole river basin

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[94] According to Tuluy, "Comparative Resource Costs...," Table 6, net social profit on a ton of rice grown for home consumption at Matam was in 1975/76, 24,900 CFAF, whereas it was 6,200 CFAF for rice grown on the large-scale perimeters.

program may depend. The lesson from Gezira is absolutely clear in this respect, and this was the only scheme we looked at which paid for its regulatory dams with irrigated agriculture -- and then under only very favorable environmental conditions. Finally, ten years delay in constructing the dams will allow time for exploration and development of mining enterprises, which, together with expanded demand for electricity in urban areas, might allow the generation of hydro-electric power to pay for a larger part of dam construction.

Although it is not recommended that A.I.D. participate directly in the building of the large dams at this time, the Agency should consider very seriously financing the types of projects which will allow construction of these dams to proceed in another decade or so. This would include small-and medium-scale irrigation projects to train farmers in techniques of irrigation and to try out new production systems. It would also involve agricultural research in the region with high-value crops as well as with cereals. Other needs for financing would include training of specialists, planners, and managers; identification and preparation of future irrigation projects; evaluation of current and past experience with irrigation in the region; and studies of the impact of large-scale irrigation development on livestock, energy resources, transportation and marketing, and land use patterns.

Gambia River Basin

The Gambia River Basin comprises not only most of the Gambia but also a large part of Eastern Senegal.[95] Population density varies markedly from 52 persons per square kilometer in the Gambia to 5 persons in Sénégal Oriental. The potential for irrigation is not well known but could be as high as 270,000 ha.

Within the Gambia, intensity of land use is fairly high, but the potential of the country in terms of soils and rainfall is also quite favorable and there is a reasonably adequate infrastructure. Quite the opposite is the case of Sénégal Oriental, where land use is very extensive, rainfall and soils are not as good, and infrastructure is lacking. In both regions, however, there is room for expansion of rainfed production over the next one or two decades -- through intensification in the Gambia and by bringing new land into cultivation in Senegal.[96]

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[95] Of the total basin territory, in fact, 77 percent is in Senegal, 14 percent in the Gambia, and 9 percent in Guinea.

[96] Despite the availability of cultivatable land in this area, the government of Senegal has opted to press rapidly for the adoption of relatively capital-intensive, high-yielding techniques in rainfed agriculture. See United Nations Development Programme, Aménagement du Bassin du Fleuve Gambie, Mission Multi-disciplinaire Multi-donateurs, Rapport de Mission, Version Final, Summaire Executif/Chapitre V, April 1980, p. V-35.

Although there may be considerable potential for irrigation in the basin, a major constraint on realizing that potential in the near future is the lack of hydrological data observations over a sufficiently long period of time to assess the risks associated with alternative development plans. These data should be acquired and analyzed before either of the three major dams which have been proposed -- the salt water barrage at Farafeni or the storage dams at Kekreti and at Sambangalou -- is allowed to proceed much further toward construction. In the meantime, small-scale irrigation and bottomland development appear to be economically viable and to demand less in the way of scarce technical and management skills. They are nevertheless very useful for training farmers in techniques of irrigation.

In any case, it is highly unlikely that irrigation can provide more than a small part of total food needs for the next decade, so its development should not be allowed to detract from the improvement and extension of rainfed cultivation, which is required during this Phase One period. This is consistent with the FAO analysis, which projects an increase in irrigated (including free flooding) production of cereals from 24,000 tons (grown on 15,000 ha) in 1970 to 74,000 tons (33,000 ha) in 1990, whereas rainfed production is supposed to expand from 58,000 tons (69,000 ha) in 1970 to 108,000 tons (90,000 ha) in 1990.[97] Separate estimates are not made in this study for the Senegal portion of the river basin, but it is clear that substantial expansion of rainfed production is assumed to take place there as well.

The major problem which this strategy poses is that even small-scale irrigation in the Gambia is limited by salt-water incursion up the river. Since the salt water barrage which has been proposed would also serve as a bridge, providing a major transportation link between the two sides of the Gambia River, top priority should be assigned to determining the technical and economic feasibility of this project as soon as possible.

Equal priority should be given to developing a prototype double-crop irrigation system for extension on a large scale in Phase II. It is clear that such a system does not currently exist. The pump irrigation project at MacCarthy Island, for example, has a cropping intensity of only 1.2 instead of the planned 2.0, probably because of unforeseen competition for labor from rainfed crops at certain times of the year. In many respects, the problems faced in designing a viable prototype are similar to those of the Senegal River Basin.

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[97] FAO, Perspective Study..., Vol. 1, pp. 91, 109.

Niger River Basin

The Niger River Basin has by far the greatest potential for irrigation of any river system in West Africa -- perhaps as much as 1,500,000 hectares. Of this potential only about 250,000 hectares are currently being used for flood recession, flooded, and irrigated cultivation. The only significant large-scale irrigation scheme in the basin is the Office du Niger, with 57,000 ha of irrigable land.

The most distinctive feature of the basin is the large interior delta located in Mali. This acts as a huge reservoir which links, but at the same time tends to separate, the upstream and downstream flow systems. The large surface area of water in the delta also results in evaporation losses of 50 to 65 percent of the entering flow.

The two most important Sahelian countries which can benefit from the irrigation potential of the Niger Basin are Mali and Niger. These differ radically in their ability to expand food production from rainfed crops. As discussed earlier, Mali has substantial room for expansion at least through 1990. Niger, on the other hand, is in a very different situation. This is because virtually all of its land receives less than an average of 800 mm of rainfall per year. This results in the employment of very extensive agricultural and livestock practices and considerably reduces the carrying capacity of the land. The FAO projections, in fact, call for an actual decline in the area devoted to cereals, from 1,970,000 ha in 1970 to 1,616,000 ha in 1990, and for substantial outmigration from very marginal agricultural areas.[98] A modest increase in yields of about 40 percent is also anticipated during this period, but diminishing returns to further improvements are likely to become increasingly important. As a result, the need for irrigation is particularly acute in this country.

Roughly 8,000 ha in Niger are currently being irrigated -- 3,700 ha along the Niger River, 3,000 ha in the Konni scheme, and the rest distributed throughout the country, mostly in areas of low population density. The total potential for irrigation in Niger is estimated at about 217,000 ha, of which almost 50 percent is along the Niger River where population pressure is already relatively great. As a consequence the Niger River Valley is the priority area for irrigated cultivation.

The major constraint on expanding irrigation in the valley is the lack of regulation of the river. Experimentation with simpler and less expensive forms of water control over the past few years has convinced Nigerian authorities that only total control is viable

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[98] FAO, Perspectives..., Vol. I, pp. 91,109.

from the point of view of economic feasibility and security of production. But this implies constructing dikes, digging irrigation canals and drainage ditches, levelling land within the perimeters, and installing pumps for water delivery, all of which are quite costly. If these costs are to be covered, it is essential that two crops per year be produced. As it stands now, this can only be done on about 16,000 ha. At the current development pace of 1,300 ha per year, this implies that lack of regulation of the river will become an important constraint by the year 1988. A feasibility study for an upstream storage dam to be located at Kandaji has been completed, though we have little information on what the total cost of construction will be. It will be a multi-purpose dam, however, which will provide hydro-electric power and improve river transportation as well as regulate the supply of water for irrigation starting in the second half of the 1980s.

There is some evidence that a viable prototype irrigation system for this region has been developed. Experience at Toula has been very encouraging with respect to yields, area double cropped, loan reimbursement rates, and farmer organization. The World Bank project at Namarigoungou, modeled to a considerable extent on Toula, calls for relatively intensive cultivation (less than 1 ha per farming unit) and the use of oxen to overcome labor bottlenecks resulting from excessive competition with rainfed crops at critical periods. This type of scheme corresponds quite well to the prototype suggested earlier for the Senegal River Basin.

There is one other respect in which Niger has a distinct advantage over Senegal in producing rice and other cereals for the local market. Whereas the economic price of paddy produced in Senegal for the Dakar market is very low because of the low price of imports and high cost of delivering local rice to Dakar, the opposite is true in Niger. There the cost of imported rice is appreciably higher because of the need to transport it long distances from the ports of entry, but the cost of delivering local rice to Niamey is much lower because of the close proximity of the major producing areas to the capital city. This in itself does much to improve the economic viability of substituting local production for imports.

The profitability of local production needs to be studied further to ensure that the results at Toula can be extended elsewhere, but even if this is the case, it is clear from the existing data that the high cost of constructing irrigation systems in Niger leaves little surplus with which to pay off the costs of upstream storage dams. These must probably be paid for primarily by sale of the hydro-electric power produced, and the economic feasibility of doing this has not yet been demonstrated. In any case, however, it appears that Niger is very close to entering Phase Two.

Despite the apparent lack of immediate need, Mali is already entering this phase with the current construction of the Selingué dam on a tributary of the Niger. Although the dam is being built primarily to provide Bamako with electrical power, it will also increase irrigation possibilities downstream. Double cropping will be possible, for example, on up to 100,000 ha, whereas without regulation it would be limited to 50-60,000 ha. Given the very small amount of double cropping which currently exists in Mali, however, this benefit presently seems relatively unimportant.[99] Still, the Selingué dam is likely to provide any regulation upstream of the interior delta which will be necessary until the end of this century.

One remaining issue should be mentioned. Thus far planning for management of the Niger River has proceeded primarily on a national basis. Yet decisions on the construction of the Selingué and Kandadji dams and of associated irrigation facilities will have effects which will spill over beyond national frontiers. River management in Niger will have important effects, for example, on the use of the Kainji dam in Nigeria. It is essential, therefore, that integrated planning be carried out within the context of the Niger River Basin Commission.

Lake Chad Basin

The Lake Chad Basin covers 2.5 million square kilometers, or approximately 8.2 percent of the total land area of the African continent. The irrigation potential around the borders of the lake and in the Logone-Chari River system to the southeast is only about 680,000 hectares, however, because of limitations on the availability of water. Of this total, 200,000 ha are in Chad and 30,000 ha in Niger, the rest being located in Cameroon and Nigeria. There is relatively little potential for upstream storage.

The need for extending irrigated cultivation in Niger has already been discussed. This need is perhaps less acute, however, in the extreme southeast part of the country, which lies within the Lake Chad Basin, because of the low population density there. Chad, on the other hand, has the greatest land potential in relation to its population of any of the Sahelian countries, and the area devoted to rainfed cultivation can be expanded substantially for at least two more decades. Intensification will be necessary primarily to avoid depleting soils where cereals and cotton are grown in rotation and in a few areas of higher population density.[100]

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[99] There are two major reasons why double cropping in Mali is very limited. One is that the controlled flooding systems which have been developed there are quite efficient even if they are also occasionally unreliable. The second reason is that the cost of constructing the total water control system at the Office du Niger has long ago been written off. If that system were to be established today, double cropping would be essential -- as it also might be at some time in the future if the system were to be extended.

[100] FAO, Perspective..., Vol. 1, pp. 112-14.

Rice cultivation in Chad using uncontrolled flooding techniques is currently practiced on about 30,000 ha, principally on the Logone plains. There are also about 7,000 ha cultivated with controlled flooding and 500 ha with total water control. In addition, there are approximately 10,000 ha planted to rainfed rice, mostly in bottomlands, and 5,000 ha of traditional wheat cultivation in old polders in the Lake Chad and Kanem areas. Finally, there is a small amount of land devoted to flood recession and irrigated cultivation of rice, wheat, and sorghum in the Niger portion of the basin.

There are several factors inhibiting the development of irrigation. First, the cost of developing polders on Lake Chad has proven to be exceptionally high. This is partly because of the relatively small size of the polders in a region where population density is low and partly because of the high cost of transporting equipment and materials to the polders.

Second, development of total water control systems is inhibited by the low-water flow rate of the Logone. Upstream storage potential is limited and, in any case, cannot be allowed to interfere with river overflows which are indispensable to maintain economically vital fish populations.[101] At the same time, however, the prevalence and uncertainty of uncontrolled flooding cultivation are impediments to raising farmer productivity.

One of the key unanswered questions concerning this basin is why the salinity level of Lake Chad is as low as it is given that there is no known outlet to the lake. Several theories have been proposed, but all are as of yet unproven. Low salinity may be due to a very fragile ecological balance which could be upset if substantial alterations were made in the existing hydrological system. Given the profound implications of this for agriculture and fishing in this region, it seems wise to proceed very cautiously until more is known about the functioning of this system.

With the relatively great potential which exists for rainfed cultivation and controlled submersion in the region and because of the high cost and uncertainty associated with irrigation involving total water control and upstream storage, it appears that Phase Two of the development of this basin should be postponed for some time. High priority should be given, instead, to gathering basic data and developing a comprehensive plan which takes into account the present fragile water balance before major development projects are initiated.[102]

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[101] Sahel Friends Club, Irrigated Agriculture Group, "Republic of Chad: Programming of Hydro-Agricultural Development," March 1977. It is estimated that over 100,000 tons of fish are harvested from Lake Chad alone annually.

[102] USAID, Report to the United States Congress, Proposal for a Long-Term Comprehensive Development Program for the Sahel, Part II, Technical Background Papers, p. 208.

Volta River Basin

The Black, White and Red Volta Rivers could be used to irrigate approximately 100,000 hectares after damming. Under present conditions, with a dam on the Sourou tributary of the Black Volta, approximately 30,000 ha can be double cropped in 4 out of 5 years. If the dam proposed for Bagré on the White Volta were to be constructed, this figure would rise to 60,000 ha. All this land is in Upper Volta in areas which receive on average over 800 mm of rain per year.

Population pressure on the land varies markedly between regions. The Mossi plateau, in particular, has a high intensity of cultivation, with substantial soil deterioration and outmigration. The Volta valleys, on the other hand, are relatively underpopulated, primarily because of the riverblindness which has been endemic. A campagne to eliminate this disease was initiated in 1973 and should open up an estimated 600,000 ha of land suitable for agriculture. Most of this will be devoted to rainfed cultivation. This land cannot absorb all the surplus labor of the Mossi plateau, however, so it is essential that agriculture on the plateau be intensified.[103] Since Upper Volta's management capability is relatively limited, irrigated agriculture, which can contribute relatively little to the supply of food, should not be allowed to drain off scarce talent and skills.

In addition to the limited potential which exists for irrigation in Upper Volta in comparison with the other Sahelian countries, there is evidence that costs of irrigated cultivation are likely to be quite high. At Bagré, for instance, the land area dominated by the reservoir will be very limited and pumping will have to be extensively employed. As a result, the development of this type of irrigation in Upper Volta is likely to result in a very sequential distribution of benefits. In addition, many irrigation projects may not prove to be economically viable.

This is particularly important because irrigation is not necessary in the Volta Rivers Basins as it is in many of the other major basins of the Sahel. The region is fairly well watered, and supplemental bottomland development probably is economically more profitable and has a better distribution of benefits than irrigation with total water control. Phase II in this basin should therefore be postponed for at least several more years, though there might be some individual irrigation projects worth developing.

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[103] FAO, Perspectives..., Vol. I, p. 113.

A Postscript

An important conclusion which emerges from the previous analysis needs to be highlighted. There is no evidence at present that large upstream storage dams can be paid for by downstream irrigation systems involving total water control. Yet these dams are essential if irrigation is going to be developed very far because they increase the water available during the dry season for a second crop and double cropping is required to make the systems economically viable. Furthermore, the construction, operation, and maintenance of total water control systems is expensive and places a large demand on scarce management skills. Thus the pace at which these systems can be extended is likely to be modest for some time to come and to involve a highly sequential distribution of benefits to the poor. In addition, the river regulation required for total water control irrigation may result in substantial losses for livestock grazing, fishing, flooded rice cultivation, and flood recession agriculture -- activities which have benefits that are widely distributed.

There are a limited number of alternatives. First, irrigation systems without a high degree of water control may be constructed at much lower cost, avoiding the necessity for double cropping. While this has worked fairly well in Mali and Chad, it has been rejected as too insecure in Senegal, Mauritania, and Niger. In addition, as population pressure grows, the need to obtain higher yields from irrigated cultivation will increase, and this can only be done with a high degree of water control.

Second, the use of dams for river regulation and flood control might be done gradually. This could be accomplished by first regularizing flooding so that some of the uncertainty associated with grazing, fishing, flooded cultivation and flood recession agriculture could be reduced.[104] Then, as total water control irrigation systems are slowly extended, the amount of water which is released during the dry season could be increased to permit double cropping on these perimeters. The pace at which this is done would have to be studied carefully in order to avoid too rapid a decline in traditional practices before enough people can be absorbed into irrigated agriculture. To date, relatively little attention has been given to this issue.

The possibilities for better integrating traditional production techniques with modern systems of irrigated agriculture are complicated by the economics of dam construction. Given the high cost of upstream storage dams, benefits needed to offset these costs cannot be delayed too long because of the effects of discounting. The benefits associated with regularizing the flood for traditional grazing, fishing, and

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[104] Thayer Scudder, "African River Basin Development and Local Initiative in Savanna Environments" paper prepared for the Burg Wartenstein Symposium No. 79 on Human Ecology in Savanna Environments, September 1978. Scudder also recommends making use of the reservoir drawdown for similar activities.

cultivation have not been estimated, but they are not likely to be sufficiently great to pay for the dams. Nor, for that matter, are any surpluses generated from irrigated agriculture. Instead, these dams are likely to be profitable only if and when they can be used to produce hydroelectric power for which there is an available market. But the need to produce this power in sufficient quantities to pay for the dams relatively soon after construction could be in conflict with the timing of water flows required to generate an adequate flood. The tightness of this constraint will depend on a number of variables, including the terms of the loans used to finance the dams. There clearly is a need to study this question further and to gain some idea of the magnitude of benefits that traditional herdsmen, fishermen, and farmers might gain from flood regularization.

CONCLUSIONS AND RECOMMENDATIONS

The preceding analysis has shown that there is no fundamental conflict between investment in large-scale infrastructure for irrigation and river management in the Sahel and the Congressional mandate to aid the poor majority. It is clear that Congress is willing, in principle, to provide financing for such investment as long as it can be demonstrated 1) that there are no better alternatives and 2) that the majority of benefits will acrue to small producers with secure land tenure (i.e., the poor majority). Since Congress is unwilling to rely on secondary, "trickle-down" benefits, infrastructure investment must be accompanied by complementary activities targeted directly to reach the poor. The choice of projects for these complementary activities is an essential element in justifying infrastructure investment. The resulting overall package, however, will frequently be very large and lumpy and involve a sequential distribution of benefits. Timing, then, is critical. It is very important, therefore, to examine these investment programs within the context of an overall systems approach to rural development. This has the additional advantage that it permits a preliminary evaluation of some of the secondary, as well as primary, benefits to the poor.

The major thrust of rural development for the next ten years should be in the higher rainfall areas of the Sahelian countries, where there is room for people from lower rainfall areas to resettle and where there is considerable potential for expanding food production. Only in this way can substantial progress be made in increasing food self-sufficiency. At the same time, however, there is a need for development of small and medium-scale irrigation and preparation for full-scale development of the major river basins in the 1990s. This should involve agricultural research, training of manpower, gathering of data, completion of necessary studies and planning, and experimentation with alternative forms of irrigation. Above all there is a need to develop a viable prototype which can be rapidly expanded once construction of regulatory structures is begun.

The experience with irrigation to date in the Sahel has not been particularly encouraging. Nevertheless, an enormous potential exists for irrigated agriclture, and in the long run, development of this potential appears to be the only way in which a secure and adequate source of food supply can be achieved for an expanding population.[105]

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[105] Accumulating evidence underlines the vital importance of irrigation as a necessary condition for the success of the "green revolution" in the food deficit countries of Asia. For a review of some of that evidence, see Vernon W. Ruttan, "The Green Revolution: Seven Generalizations," International Development Review, 19(4), 1977, pp. 16-23.

Fortunately, the experience acquired so far suggests that it should be possible to develop a viable prototype which will not only be technically and economically sound, but will also provide substantial benefits to the poor without being socially disruptive.

Our review of past experience suggests some of the elements of this prototype, keeping in mind the need for flexibility to accommodate variations in local conditions. First, it will in most areas involve total water control, through either pumping or use of a diversion dam. Second, it should be possible to reduce current investment costs and to increase benefits to the poor by combining mechanized construction of major works with labor-intensive methods of completing the system. Third, manual, or intermediate forms of mechanized, techniques of cultivation should be used to the maximum extent possible. Fourth, farmer groups should be organized, within the traditional social structure if possible, to assist in construction and maintenance of the irrigation system, to facilitate efficient and equitable allocation of water, to engage in such other cooperative activities as might be desireable, and to participate as much as possible in the overall decision-making process. Fifth, one or more commercially viable cash crops with assured markets must be introduced together with food crops into the double crop production system. Sixth, average holding size should be adjusted to the point that farmers with their families are able to cultivate all their land relatively intensively and to produce enough to satisfy their food needs as well as to earn a significant net cash income. Finally, the prototype must eventually operate without subsidy and should, if possible, contribute significantly to the repayment of invested capital.

The following recommendations for future action are offered on the basis of the analysis contained in this report:

1. That A.I.D. participate actively in the development of a prototype irrigation and production system along the lines described above. This will involve studying past experience as well as investing in a variety of types of infrastructure. The justification in terms of ultimate benefits to the poor could be very high.

2. That A.I.D. promote agricultural development, including irrigation, in the higher rainfall areas of the Sahelian countries and, in particular, experiment with various ways of facilitating immigration into these areas from those with lower rainfall. Attention should be focused on finding an approach somewhere between very expensive land resettlement programs and spontaneous migration, which can sometimes be rather disruptive. The approach should probably be closer to the latter than to the former method, however, if significant numbers of people are to be involved. A survey of the existing literature on migration and land resettlement in West Africa, as well as a number of micro-level field surveys in key areas, should be undertaken.

3. That A.I.D. encourage a thorough examination of marketing possibilities for irrigated crops. This should include not only outlets for cash crops such as cotton, which might feed into domestic textile industries, but also the implications of expanding the production of food with respect to both import substitution and its effects on local prices of non-traded cereals.

4. That A.I.D. promote research and development for potential irrigated cash crops as a means of financially sustaining the river basin development programs.

5. That A.I.D. participate in the training of the specialists, planners, and managers who will be required for major river basin development.

6. That A.I.D. incorporate into the infrastructure projects which it finances a systematic means of evaluating both the primary and secondary costs and benefits of those projects.

7. That A.I.D. promote the use of a systems approach to river basin planning along the lines discussed earlier in this report. Quantification of this system should help to identify information gaps and to evaluate alternatives concerning the timing and direction of development. It would be useful in this respect to consider the methodology suggested by the U.S. Water Resources Council, which is consistent with the Club du Sahel's suggested multi-objective approach to planning and project analysis.[106]

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[106] U.S. Water Resources Council, "Water and Related Land Resources: Establishment of Principles and Standards for Planning," Federal Register, Vol. 38 (174), September 10, 1973, Part III.

Appendix A

A TYPOLOGY OF AID-FINANCED IRRIGATION PROJECTS

by

Frederick C. Roche

This annex reiterates and expands upon the main points made in the text regarding the characteristics of AID-financed irrigation schemes throughout the world. The data for this discussion come primarily from AID Project Papers (PP's), and, hence, figures relating to costs and benefits are estimates rather than actual measurements. Since documents for projects completed prior to 1974 are generally not readily available, the sample is confined largely to schemes carried out in the years following the Congressional new directions mandate.

Projects were grouped into three categories depending upon the type of agricultural environment in which they were implemented. A number of cases involved activities that could be included in more than one category. For example, there was considerable overlap between Categories I (rehabilitation and improvement) and II (new infrastructure in hitherto unirrigated areas with relatively favorable environments). Such cases often turned up when an existing irrigation system was expanded.

Almost all projects included complementary activities (e.g., the provision of new inputs, extension, credit, and in some cases, roads, electrification, and community development efforts) in addition to work on the basic physical infrastructure. Cost and benefit figures in these cases generally applied to the project as a whole, it not being possible to analyze the separate effects of the various project components.

Category I Projects

The following projects were grouped together in Category I:

Project		AID Funding Period
Afghanistan:	Central Helmand Valley Drainage II	1977-80
Chile:	On-Farm Irrigation	1977
Egypt:	Irrigation Pumping	1977
	Water Use and Management	1976-81
Indonesia:	Luwu Agricultural Development	1975-81
	Sederhana Irrigation and Land Development	1976-78
	Citanduy River Basin Development	1975-81
Jordan:	Zarqa Triangle Sprinkler Irrigation	1974-77
Mali:	Action Riz-Sorgho	1976-81
Pakistan:	Indus Basin Project	1960-80
	Salinity Control and Reclamation Project (SCARP) I-IV	1961-71
	On Farm Water Management	1976-81
Peru:	Sierra Water and Land Use	1971-75
Philippines:	Small Scale Irrigation	1976-78

General Description. As noted in Section III of the text, projects in this group are aimed primarily at the rehabilitation and improvement of existing irrigation systems. In one sub-group of projects within this category, the physical infrastructure necessary to carry water from its source to the farm is upgraded and, in some cases, extended (e.g., projects in Chile and Mali, the Indus Basin Project in Pakistan, sub-projects within the Indonesian, Philippine, and Peruvian schemes). Specific project activities have included the repair and lining of canals and laterals, the construction of water storage facilities (which have ranged in scale from village-level ponds in the Chilean project to the massive Tarbela Dam in Pakistan), the repair and extension of flood control structures (e.g., dikes in Mali and in the Citanduy scheme in Indonesia), and the provision or replacement of pump sets (e.g., the Egyptian and Philippine projects).

A second sub-group within Category I consists of projects aimed at the correction of salinity and waterlogging problems arising from inadequate drainage or poor management of irrigation water after it has reached the farm. Examples here include the Helmand Valley project in Afghanistan, the SCARP projects in Pakistan, and the water management schemes in Pakistan and Egypt. In Afghanistan, drainage ditches were constructed and land was flooded in order to leach salt deposits. The projects in Pakistan and Egypt included activities such as land levelling, the provision of tubewells in order to lower water tables, and farmer education in water management.

Because these projects merely supplement existing infrastructure and established agricultural activity, they can usually be carried out with a minimum of disruption of socio-economic patterns. Generally, they leave the existing system of land ownership intact. Of the rehabilitation projects examined, substantial amounts of land resettlement were anticipated only in the Helmand Valley project in Afghanistan and in the Luwu project in Indonesia. National land reforms were underway in Peru and Chile during the dates of the AID projects there, but no additional changes in land distribution were undertaken within the project areas.

The agricultural technologies were also left essentially unchanged. With the exception of Afghanistan's Helmand Valley, where a significant share of agricultural operations are mechanized, the post-project systems remain largely labor-intensive. Many of these projects occur in areas where the use of modern inputs such as improved seed and fertilizer is already well-established (e.g., Afghanistan, Egypt, Pakistan, and the Philippines). In areas where this is not the case, complementary activities designed to introduce these inputs are generally either included as part of the project or are occurring separately but simultaneously. In any event, the use of new inputs is typically a voluntary choice on the farmer's part as are decisions regarding land use, cropping pattern, etc. Agricultural production is generally oriented toward subsistence needs and domestic rather than foreign markets.

Projects in this category vary widely in scale. At one extreme, for example, the small Riz-Sorgho scheme in Mali involved the repair of submersible dikes flooding 5,000 hectares of the Niger River Basin and the construction of new insubmersible dikes for the complete control of flood waters covering an additional 5,000 hectares. At the other extreme, the Indus Basin Project, which includes the Mangla and Tarbela Dams, will rejuvenate roughly 12 million hectares of irrigated land in Pakistan. More typical are the projects in Chile, Peru, Indonesia, and the Philippines. These were not confined to single, self-contained areas, but instead affected numerous small sub-project areas generally covering from one hundred to a few thousand hectares each.

Project Benefits -- Micro Level. Because of their supplemental nature, the projects grouped in Category I are usually quite consistent with A.I.D.'s new directions policy. Project areas are often densely settled and labor-intensive construction, which makes use of local landless and underemployed labor, is generally possible. Typically, the irrigation structures are simple in design, and local contracting firms can be utilized for construction. Labor and domestic materials were to be the principal inputs, for example, for rehabilitation in Chile, Indonesia, Mali, and the Philippines. In some cases, however, the scale of the project and the nature of the physical and human environment dictate that more capital and skill-intensive technologies be employed. The construction of the Tarbela Dam, for example, required elaborate imported earth-moving machinery and a large technical staff, in addition to 12,000 unskilled laborers. In the PP for the Citanduy River Basin project in Indonesia, specific reference is made to the employment needs of the "poor majority," but the project designers concluded that heavy machinery would be essential in certain aspects of construction in order to assure the system's integrity (e.g., for proper compaction of dikes).

The positive employment and income effects of rehabilitation projects carry over into the post-construction environment as well. By increasing water supplies to the farm or improving the efficiency of water use on the farm, substantial increases in yields per crop and the number of crops per year are made possible, particularly when modern inputs are being introduced for the first time. The implications of these changes for the absolute levels of income in the project areas are obvious. Farm incomes were projected to increase by 30 percent and 65 percent, respectively, in the Sederhana and Luwu project areas in Indonesia, by 25 to 55 percent as a result of the Irrigation Pumping project in Egypt, by 67 to 300 percent with the irrigation scheme in Mali, and by 400 to 8,200 percent as a result of the water management project in Chile.

Apart from absolute income changes, almost all of the PP's make specific references to the significant relative income gains anticipated for the poorer groups in the project areas after the rehabilitation work is completed. These gains arise in three, often interrelated, ways. First, productivity, and hence income, can be expected to increase more on smaller farms where a more intensive level of cultivation is practiced. In the Chilean project, for example, the most substantial income gains were expected to accrue to farmers cultivating five hectares or less. Tenants (average holding 0.72 ha) were expected to gain relative to landowners (average holding 1.3 ha) as a result of the Irrigation Pumping project in Egypt.

Second, the increases in multiple cropping and overall productivity made possible by these projects generate substantial expansion of demand for agricultural laobr. As a result of the dike rehabilitation component of the Riz-Sorgho project in Mali, labor use was projected to increase by 30 man-days per hectare per year. The Sederhana scheme in Indonesia will, by 1985, create 179,000 wet season and 59,000 dry season jobs in an area covering 550,000 hectares. In addition, 4,400 full-time workers will ultimately be required to operate and maintain the new and rehabilitated irrigation works. While most other PP's do not contain employment estimates as specific as these, all refer to the growth in labor demand and the consequent benefits to the landless and smallest farmers as being major positive aspects of the projects. Even where mechanization will increase somewhat on the larger farms as irrigation systems are improved and extended, significant net employment gains are nonetheless projected.[1]

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[1] This is true, for example, of the projects in Afghanistan and Chile. In the Chilean case, the AID component of project funding was to be used only by smaller farmers, but the Chilean government's share was available for use by all farmers, regardless of the size of their holdings. The distribution of land remains highly skewed in rural Chile despite the reforms of the Allende government.

Third, it has been possible in some cases to design projects so that participation is limited to the poorer farmers within the project areas. A number of rehabilitative schemes have been "self-help" in nature. In the Philippine project, for example, groups of small farmers were formed into Irrigation Service Associations for the purpose of acquiring AID-financed loans and contributing their collective labor to the rehabilitation and maintenance of irrigation systems. Location has also been used to concentrate resources on the relatively disadvantaged. Schemes in Chile, Indonesia, and Peru have been targeted toward specific sub-project areas where the needs of the people are especially great.

In addition, restrictions on the disbursement of funds have been used in at least three cases to minimize the benefits accruing to large farmers. The AID component of a loan fund created in the Chilean project was to be used only by farmers who either fell below certain limits of land size and quality or who had received land title through the national Agrarian Reform program. In both the Sederhana project in Indonesia and the On-Farm Water Management project in Pakistan, areas were selected or rejected as sites for watercourse improvements on the basis of the concentration of land ownership. Furthermore, within those areas selected in the Pakistan project, farmers were required to repay one-half the cost of land improvement for up to five hectares, and the full cost thereafter. Since the median farm size in Pakistan varies between 2.8 and 4 ha, this provision clearly benefits the smaller farmers.

While restricting project participation to small farmers is one means of addressing the issue of relative income inequality, these efforts probably succeed only indirectly in reaching the poorest of the poor, i.e., the landless. Doubtless, the long-run employment and income gains for this group from irrigation rehabilitation are substantial. However, they are of a "trickle down" nature, whereas the immediate benefits of these projects go to those who have access to land, be they owners or tenants.

Project Costs and Benefits -- Macro Level. Because they vary widely in scale, the rehabilitative schemes in Category I also differ substantially with respect to total costs. Because of the low levels of construction technology that can usually be employed and the minimum of complementary activities that are generally required, however, costs on a per hectare or per family basis are quite low relative to projects in Categories II and III.[2] The Indus Basin project, doubtless the

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[2] The Zarqa Triangle project in Jordan is one exception so atypical of this category that it has not been included in this discussion. This scheme involved the replacement of a gravity-fed irrigation system with a sprinkler system in an area of 1,505 hectares and 376 families. Advanced levels of construction technology and post-construction agriculture resulted in extremely high project costs ($3,986 per hectare and $15,970 per family). The scheme was justified on the basis of the project area's tremendous potential for the year-round production of high-valued export crops. One suspects that the political situation in the Middle East also had a bearing on this project's approval.

largest in AID's experience, for example, is affecting an area of some 12 million hectares at a total cost of over $2.25 billion. Yet on a per hectare basis, this works out to about $188. At the other extreme, the Riz-Sorgho scheme in Mali affects an area of 13,000 hectares at a total cost of five million dollars, for a per hectare cost of $375. Of the projects examined in Category I, the average per hectare cost is about $325, with the Indus Basin project being lowest and the Sederhana scheme highest at $539.[3] The average cost per family was $820, with the Citanduy project in Indonesia being lowest at $204, and the Chilean project, at $2,800 per family, by far the highest.[4]

As a result of these low per unit costs and the high projected returns discussed above, the internal rates of return (IRR's) for rehabilitative projects are generally quite impressive. The lowest IRR for the projects examined was 10.4 percent in the case of the project in Mali. All other IRR's were at least 18 percent, and the returns from several projects were estimated to be as high as 45 to 50 percent (the project in Chile, the Sederhana scheme in Indonesia, and the water management project in Pakistan).

Category II Projects

The following projects were included in Category II:

Project		AID Funding Period
Bolivia:	Village Development	1978
Indonesia:	Luwu Agricultural Development	1975-81
	Sederhana Irrigation and Land Development	1976-78
Korea:	Small/Medium Scale Irrigation	1974-78
Mali:	Action Blé	1978-81
Peru:	Sierra Water and Land Use	1971-75
Philippines:	Bicol Integrated Area Development II	1977-78
	Small Farmer Systems	1978-80
	Small Scale Irrigation	1976-78
Senegal:	Bakel Crop Production	1976-80
Thailand:	Lam Nam Oon Integrated Rural Development	1977-81

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[3] The Sederhana project includes considerable new irrigation construction as well as rehabilitation of existing structures.

[4] As previously mentioned, much of the land area in the Chilean projects is in the hands of a small number of families. This would account for part of the high project cost per family.

General Description. Projects in this category involve the construction of new irrigation and water control structures in areas of relatively dense population where rainfed or flood recession agriculture is already well-established. Water supplies often are highly seasonal, but are of sufficient quantity and reliability to allow at least one intensive crop per year. Irrigation typically involves obtaining water from rivers or streams and its distribution to farms via gravity or small mechanical pumps. Depending on the particular location, project activities may include the construction of dams, the digging of primary canals and laterals, and land levelling. As with projects in Category I, the irrigation structures are generally simple in design, with local firms and materials frequently being used in construction. In addition, complementary activities for the distribution of new inputs, credit, and extension services typically already exist in the project areas.

Projects confined mainly to these activities comprise one sub-group within Category II. Examples include the projects in Korea, Mali, and Senegal, and sub-projects within the schemes in Indonesia and Peru as well as in the Small Farmer Systems and the Small Scale Irrigation projects in the Philippines. In comparison with the rehabilitation schemes in Category I, these projects often are accompanied by relatively extensive changes in the existing socio-economic structures of the project areas. The provision of irrigation water requires new management practices which may necessitate a high level of extension density and influence, even though the choices of crops and inputs typically remain voluntary. Many of these projects involve the formation of farmer associations for the collective construction, operation and maintenance of the new systems (e.g., in Indonesia, Korea, Mali, and the Philippines). Given that irrigation is a novel innovation, the successful institutionalization of these associations requires strong cooperation among farmers and coordination between farmer groups and distant government agencies. Serious problems in either of these areas may result in project failure. Additional problems are posed because of the need for government agencies to provide adequate trained manpower in what are often geographically dispersed sub-project areas.

At the same time, however, these projects generally do not entail major land reforms or resettlements. Agricultural production remains oriented toward subsistence needs and domestic markets. Crops grown are usually familiar to the farmers, as is the use of improved seed and fertilizer.

A second subset of projects in Category II consists of Integrated Rural Development (IRD) schemes in which project activities extend beyond basic agricultural needs to roads, rural electrification, health care and family planning, potable water, and education. Land reform or consolidation of fragmented holdings is often a project activity. Examples in this group include the Bicol project in the Philippines, the Lam Nam Oon scheme in Thailand, and the Village Development project in Bolivia.[5]

IRD schemes have much broader socio-economic implications than projects consisting of agriculture-related activities alone. Participants are generally oriented toward market activity and receptive to change. Unfortunately, these schemes are of fairly recent vintage and no social evaluations are available at this time.

As with the projects in Category I, projects in Category II vary widely in scale. The Bicol IRD scheme in the Philippines will cover an area of 2,300 hectares and will directly affect only 1,230 families. In contrast, the project in Korea will benefit a total of 95,000 rural households on over 55,000 hectares in 88 sub-project areas.

Project Benefits -- Micro Level. The micro-level benefits of projects in Category II are essentially the same as those of the rehabilitation schemes discussed previously. Many of the schemes in Category II are targeted toward especially impoverished regions within the recipient countries (e.g., those in Bolivia, Korea, and Peru and the Bicol project in the Philippines). These schemes take place in fairly densely settled areas and intensive use of local labor is almost always a feature of project construction.[6] In the "self-help" schemes, those who benefit directly from the project also contribute their labor in construction. The employment of landless labor and the seasonally unemployed during the construction period is frequently cited as a major positive aspect of these projects.

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[5] Tentative A.I.D. plans call for the extension of IRD activities into the Indonesian project areas as well.

[6] An exception is the Lam Nam Oon scheme in Thailand. See below.

Absolute income gains projected for the post-construction period lie within a range similar to the projects in Category I.[7] Among the schemes in which project activities are related primarily to agriculture, farmer incomes are projected to rise by 40 percent in Korea, by 90 percent after completion of the Action Blé scheme in Mali, by 300 to 400 percent after the Bakel project in Senegal, and from 200 to 1,600 percent as a result of sub-projects in Peru. As for the IRD schemes, farm incomes are projected to increase by 65 percent in the Bicol area of the Philippines and by 190 to 220 percent in the Lam Nam Oon project area of Thailand.

The estimates of income changes given in the PP's are generally conservative. Nonetheless, one must be somewhat more skeptical about projections for Category II schemes compared with those for the rehabiitation projects in which a familiar technology is merely being improved or extended. The problem areas cited above for new irrigation projects -- e.g., on-farm water management, inter-group coordination -- are all difficulties capable of keeping potential income gains from being fully realized.

Project Costs and Benefits -- Macro-Level. As with the rehabilitation projects in Category I, the wide variation in scale for the irrigation schemes in Category II entails an equally large variance in total project costs. Of the projects examined, for example, the Bakel scheme in Senegal is the smallest in area, affecting 1,900 hectares at a total cost of $6.7 million. The Korean scheme, involving 55,000 hectares, cost a total of $17.2 million. the Lam Nam Oon IRD project in Thailand, which involved the construction of a large dam with an intermediate to high level of construction technology, was the most expensive of these projects at $62 million.

The provision of new infrastructure and the attendant need for more extensive complementary activities also tend to raise per unit costs above those cited for the schemes in Category I. The total cost of projects in Category II averages about $1,950 per hectare and $2,500 per family. The Small Farmer Systems project in the Philippines is the lowest for both measures, with per unit costs of $650 and $460, respectively, for each hectare and family. This project consists largely of the formation of water users associations for the construction of simple irrigation systems fed by gravity or small pumps. At the other extreme, the Bicol IRD scheme, which will involve roads, electrification, and community development activities, in addition to irrigation, will cost $2,374 per hectare and $[illegible]40 per family. The Lam Nam Oon IRD scheme will cost $2,086 per hectare and $5,167 per family.

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[7] Many of the micro-level benefits of IRD projects are, of course, difficult to value, e.g., increased life span due to health care activities.

The projected financial benefits of projects in Category II are sufficiently great to insure relatively high internal rates of return. The lowest IRR is 11 percent for the Lam Nam Oon scheme and a few of the sub-projects in Korea. For all other projects, IRR's lie within the 18 to 50 percent range, comparable with those of the projects in Category I.

Category III Projects

The following projects were included in Category III:

Project		AID Project Period
Afghanistan:	Helmand/Arghandab Valley Irrigation	1954-80
Jordan:	East Ghor Canal	1955-65
	East Ghor Canal	1973-78
Morocco:	Doukkala/Zemambra Sprinkler Irrigation	1976-81
	Lower Moulouya Irrigation	1960-76
	Triffa High Surface Irrigation	1976-79
Sudan:	Rahad Project	1973-77

General Description. Projects grouped in this category involve the construction of new, high-technology irrigation structures in areas of relatively sparse population. Typically, both project construction and post-project agricultural technologies are highly mechanized and capital-intensive. These schemes are generally undertaken in arid regions marked by seasonal rainfall which is insufficient on average or too irregular to support intensive agricultural activity.

Projects in Category III are relatively large in scale. Serious utilization difficulties have often been encountered, particularly in cases where essential complementary activities are truncated in order to lower project costs. Long gestation periods are common. American participation in the 363,000 hectare Helmand/Arghandab Valley project in Afghanistan, for example, began in 1954 and will continue through 1980 due to drainage and on-farm water management problems. A.I.D. involvement in Morocco's Lower Moulouya scheme (40,000 hectares) started in 1960 and continued until 1976 because of design problems and cost overruns.

Category III project activities have included the construction of structures for long-distance water transfers over rough geographical terrain. In Sudan's Rahad scheme, for example, water is to be pumped a total of 369 miles from the Blue Nile to the project area. In the Triffa project in Morocco, six pumping stations will be necessary to lift water from the Moulouya River to the higher altitude Triffa Plain.

The water delivery systems described in the project documents are often elaborate, involving sprinkler systems or quartenary canals. In gravity or pump-fed systems, principal structures are frequently made of concrete or pipe rather than compacted earth. Land clearing and levelling are provided for where necessary. The construction of roads and village infrastructure and the provision of electrification are also common activities in these projects. Because schemes in this category typically require sophisticated design and construction procedures, there is relatively little scope for the use of local contracting firms and materials in comparison with the projects in Categories I and II.

In contrast to projects in the other categories, where small sub-projects can often be targeted at particular populations with relatively little social disruption, projects in Category III generally are concentrated in single, self-contained areas and may require the creation of entirely new settlements. Nomadic herdsmen are being settled in new communities, for example, as a result of the Helmand/Arghandab Valley project in Afghanistan and the Rahad scheme in Sudan. Because these settlers may have little experience with sedentary agriculture and certainly none with irrigation, decisions concerning cropping patterns and farm management practices must be highly centralized. For these projects to be profitable, it is often also necessary that agricultural production be oriented toward export markets rather than subsistence or domestic needs, and this may imply a lack of farmer familiarity with the crops he is growing.

In the Sudanese case, for example, farmers are required to follow a set rotation in return for secure tenancy rights. Land preparation, spraying, and harvesting are highly mechanized activities performed by project authorities. The principal crop is export cotton, which is purchased from farmers at fixed prices. In essence, project farmers form a rural proletariat. In Morocco's Lower Moulouya scheme, central authorities in Rabat make decisions concerning water allocation, input use, and cropping patterns, though farmers are generally familiar with the crops grown.

Land reform or resettlement is a frequent characteristic of Category III projects in the more established agricultural regions. Foreign-owned lands were expropriated and given to the landless in Morocco's Triffa scheme. Uneconomic fragmented holdings were consolidated in the Lower Moulouya and Doukkala/Zemambra projects. The East Ghor Canal project in Jordan involved a land reform and the resettlement of 18,000 Palestinian refugees.

Project Benefits -- Micro-Level. In comparison with the project papers for Categories I and II, fewer references are made in Category III PP's to employment benefits for the landless laborer during the construction period. Part of the reason may simply be a matter of project timing since several of the PP's for this category were written prior to the new directions era when mention of the "poor majority" became obligatory. More importantly, these schemes are generally undertaken in difficult physical environments where large amounts of surplus labor cannot be readily tapped. Furthermore, since production techniques are relatively skill and capital intensive, this type of project will inevitably use less unskilled labor per unit of irrigated land than infrastructure projects in more intensive agricultural areas.

By bringing marginal, extensively-farmed land under intensive cultivation, the post-construction income effects of these projects are potentially enormous. An evaluation by A.I.D. several years after completion of the East Ghor Canal in Jordan showed that net income per unit of land had increased by 500 to 600 percent.[8] As a result of the East Ghor Extension scheme, the output from a hectare of land is projected to increase from $5 to $1,100 in annual value. Farmer incomes are projected to grow by 400 percent from the Doukkala/Zemambra Sprinkler project in Morocco and by 200 to 300 percent as a result of Sudan's Rahad scheme. Specific estimates are not given for the remaining projects in Category III, but it seems safe to conclude that the potential farmer benefits of these projects are at least as great, if not considerably greater, than for projects in the other two categories.

This is a potential, however, which has not always been realized. In Afghanistan, poor water management by previously nomadic tenants, in combination with inadequate drainage, quickly led to serious salinity and water logging problems. As noted above, this necessitated additional A.I.D. involvement (the Central Helmand Drainage project described under Category I), but not before a significant number of tenants had left the project area as a result of declining yields. During the first years following the East Ghor Canal's construction, lack of pre-settlement land preparation and poor implementation of the land reform program resulted in dissatisfaction among many farmers who experienced incomes and living standards that were lower than anticipated.[9]

Distributional and environmental issues are also associated with these projects. In Sudan's Gezira scheme, after which the Rahad project was modeled, serious social problems were created by income differences between project participants and non-participants, particularly since the latter were denied access to project lands that had traditionally been tribal grazing areas. In addition, water-related diseases such as schistosomiasis and malaria became endemic.

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[8] Awwad, Abdul W. J., Agricultural Production and Income in the East Ghor Irrigation Project: Pre and Post-Canal, U.S.A.I.D./Jordan, August 1967, pp. 29-30.

[9] Sutcliffe, Claud R., "The East Ghor Canal Project: A Case Study of Refugee Resettlement, 1961-66," Middle East Journal, 27(3) pp. 471-482.

[10] Beer, C.W., "The Social and Administrative Effects of Large-Scale Planned Agricultural Development," Journal of African Development, 5(3), pp. 112-118.

Project Costs and Benefits -- Macro-Level. The projects in this category are ambitious. They attempt to transform relatively marginal lands into intensive agricultural systems on a large scale. Accordingly, they are also quite expensive. Because individual farmers are often allocated relatively large plots of land (4 to 24 hectares), project costs per family are extremely high. Surprisingly, however, these projects exhibit a great deal of variance with respect to per hectare costs, and one suspects this is due to truncation of complementary activity expenditures.

The cost of the schemes in Category III averages about $3,300 per hectare. The East Ghor Canal Extension scheme is highest with a per hectare cost of $7,900 for 4,900 newly irrigated hectares. At the other extreme, the Helmand/Arghandab Valley project cost about $1,000 per hectare, but this figure does not include dam investments financed by Japan and Germany during the 1930s, nor does it include the costs of correcting salinity and waterlogging problems that are now being financed by A.I.D. At $768 per hectare, the Rahad project in Sudan is the least expensive in this category, but this figure applies to an aggregate land area of 125,000 hectares and not to the actual irrigated area, which should be considerably smaller. All other schemes grouped in Category III were in the $1,800 to $8,000 range. It seems safe to say, therefore, that projects of this nature can be expected to cost from something under $2,000 to as much as $8,000 per irrigated hectare when all project costs are included.

The projects examined cost on average over $10,000 per family. The Doukkala/Zemambra scheme in Morocco was highest at $16,800 per family; the Helmand/Arghandab Valley scheme was the lowest at $3,330 per family.

Because of these generally high absolute and per unit costs, the internal rates of return to projects in Category III are low relative to those in the other categories. For the PP's in which IRR's were calculated, the Doukkala/Zemambra and Triffa schemes in Morocco had IRR's of 10.4 percent and 14 percent, respectively. The Rahad scheme showed an IRR of 13 percent.

Appendix B

IRRIGATION PROJECTS IN THE SAHEL

by

John McIntire and J. Dirck Stryker

Agricultural policy objectives of the Sahelian countries[1] have included improving security of food production, increasing rural incomes, and moving towards food self-sufficiency. In working toward these objectives, the countries have invested in traditional rainfed cultivation, established grain reserves and national crop marketing agencies,[2] and developed new systems of crop production.

Much of the effort to create new production systems has been directed towards irrigated agriculture. This emphasis is derived from the knowledge that irrigated cultivation is more productive (has a higher mean) and less risky (has a lower variance) than rainfed agriculture. Although irrigation is also much more costly than rainfed production, the development of rainfed systems is constrained by low price and income elasticities of demand for such cereals as millet and sorghum, by the difficulty of processing these crops, and by the lack of technologies for increasing land and labor productivity in areas of sparse and uncertain rainfall.

This appendix reviews most of the important irrigation projects in the Sahel and attempts to answer several broad questions:

1) What are the characteristics of those projects (technical, institutional, scale)?

2) What have been their benefits and how have these been distributed among
   a. direct and indirect benefits,
   b. recipients (e.g., producers and consumers),
   c. time?

3) What have been the costs of the projects and how have these been distributed among
   a. water control and land development,
   b. input supply,
   c. crop processing,
   d. resettlement programs,
   e. associated programs, such as health and nutrition?

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[1] Chad, the Gambia, Mali, Mauritania, Niger, Senegal, and Upper Volta. Cape Verde has been excluded because of the unavailability of information on irrigation projects there. Several projects in the Cameroon have been included for comparison.

[2] All seven of these countries now have national crop marketing boards, with varying degrees of authority.

4) What fiscal transfers have been associated with irrigation projects?
   a. What are the characteristics of the price relationships?
   b. What has been the structure of recurrent public expenditures?

5) What have been the effects of projects on policy objectives and how have those effects been achieved?

6) Which characteristics of irrigation systems are most important for project results and policy objectives?

Project Characteristics

Analysis of irrigation projects in the Sahel suggests the difficulty of classifying these according to the categories suggested in Appendix A. Category I rehabilitation projects sometimes include substantial alterations of the irrigation system. Many of the polders in the Senegal River Delta, for example, are being converted from controlled flooding to pump irrigation. Higher rainfall zones, in which most Category II projects are located, are characterized by relatively dense populations in most areas of the world, but in the Sahelian countries, these zones are often sparsely settled because of disease and other factors. Finally, several sub-categories of projects should be distinguished within Category III, found in areas where agro-climatic conditions are unfavorable.

Six sub-categories of projects, within the three broad categories developed earlier for the rest of the world, are here identified for the Sahelian countries using combinations of the following variables: existing irrigation infrastructure, average rainfall, population density, and availability of an adequate and reasonably regular flood. Characteristics of these sub-categories are shown in Table 1.[3]

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[3] Many of the projects described here have not yet been implemented. Discussion of them is generally based upon appraisal reports or feasibility studies and cost figures, especially, must be taken only as orders of magnitude.

TABLE 1 - CHARACTERISTICS OF PROJECTS

Project (Country)	Irrigation system, technology & crops	Regional population density (#/km^2)	Scale: Project Population(#)	Scale: Project area (hectares)	Institutions	Scope of farmer decision making
Category Ia - Rehabilitation						
Office du Niger (Mali)[1]	Animal traction; some machine services rented to farmers; diversion dam w/o storage; rice; single crop	roughly 20	50,000	37,500	Large local project authority (LPA) with much autonomy	Little
Action Riz-Sorgho (Mali)[2]	Animal traction; controlled flooding; rice, sorghum; single crop	5-50	n.a.	13,300	Large LPA with autonomy	Medium
Category Ib - Rehabilitation and Improvement						
Bol (Chad)[3]	Animal traction; some machine services rented to farmers; controlled flooding with pumping backup; wheat, cotton; double crop	5-30 (only nearby city of importance is N'Djamena at 305kms)	11,000-14,000	2,784	LPA	Little
Delta (Senegal)[4]	Mechanized; pumping with field levelling; rice; single crop	10-30	n.a.	9,000	Regional project authority (RPA)	Very little

TABLE 1 (cont.) - CHARACTERISTICS OF PROJECT

Project (Country)	Irrigation system, technology & crops	Regional population density ($\#/km^2$)	Scale: Project population (#)	Scale: Project area (hectares)	Institutions	Scope of farmer decision making
Category II - High Rainfall						
Kou[5] (Upper Volta)	Animal traction; diversion dam; rice; douple crop	10	10,000	1,200	RPA	Very little
Niena[6] (Upper Volta)	Animal traction; rainfed with bunding; rice, corn, sorghum, cotton, peanuts; single crop	10	4,500	6,700	RPA	Medium
Bagré[7] (Upper Volta)	Animal traction; dam and pumping; rice, sugar, wheat, corn, soybeans; double crop	30-50	200,000	30,000	RPA	Medium
Sikasso[8] (Mali)	Animal traction; improved swamp; rice, vegetables; some double crop	10-15	15,000	4,000	RPA	Medium
Sedhiou[9] (Senegal)	Manual; improved swamp; rice, vegetables; some double crop	25-30	35-40,000	1,650	LPA	Medium
Satégui-Déressia[10] (Chad)	Animal traction; controlled flooding; rice; single crop	20-30	10-12,000	4,000	LPA	Medium

TABLE 1 (Cont.) - CHARACTERISTICS OF PROJECTS

Project (Country)	Irrigation system, technology & crops	Regional population density (#/km^2)	Scale: Project Population (#)	Scale: Project area (hectares)	Institutions	Scope of farmer decision making
Category IIIa - Low Rainfall/Higher Population Density						
Bakel[11] (Senegal)	Manual; pumping; rice, vegetables; double crop	30-40	31,000	1,700	RPA	Medium
Matam[12] (Senegal)	Manual; pumping; rice, vegetables; double crop	30-40	25,000	400	RPA	Medium
Kousseri[13] (Cameroon)	Animal traction; pumping; rice, sorghum, fruits and vegetables, fodder; double crop	35	10,500	5,500	LPA	Medium(?)
Malo[14] (Chad)	Animal traction; pumping; rice, sorghum, fruits and vegetables; double crop	40	16,000	5,400	LPA	Medium(?)
Namarigoungou[15] (Niger)	Animal traction; pumping; leveling; rice, sorghum, fruits and vegetables; double crop	30-40	16,000	1,550	LPA	Little
Category IIIb - Low Rainfall/Lower Population Density with Flooding						
Mopti I & II[16] (Mali)	Animal traction with some machine services rented to farmers; controlled flooding; rice ; single crop	10-25	120,000	34,800	LPA	Medium
Segou I & II[17] (Mali)	Animal traction with some machine services rented to farmers; controlled flooding; rice; single crop	30-40	160,000	44,000	LPA	Medium

TABLE 1 (cont.) - CHARACTERISTICS OF PROJECTS

Project (Country)	Irrigation system, technology & crops	Regional population density (#/km^2)	Scale		Institutions	Scope of farmer decision making
			Project Population (#)	Project area (hectares)		
Category IIIc - Low Rainfall/Lower Population Density without Flooding						
Senegal River Lower Valley and Delta (Senegal)[18]	Mechanized; pumping with field levelling; rice, vegetables; single or double crop	10-30	40,000	9,000	RPA	Very little
Diffa (Niger)[19]	Animal traction; pumping; rice, millet, wheat, sorghum, and fodder; double crop	10	13,000	2,300	LPA	Little
SEMRY I & II[20]	Mechanized; pumping or storage dam; rice; double crop	30-40	67,500	12,300	LPA	Very little

n.a. not available

Notes to Table 1:

1. World Bank, "Office du Niger: Identification Report," March 1978. Sugar cane at this scheme is produced on a state farm using machines and crews of hired labor, thus permitting little decision making by individual farmers. Wheat and cotton, on the other hand, will be produced by small farmers, presumably under the same rules which now govern the production of rice.

2. United States Agency for International Development, "Action Riz-Sorgho," Project Paper, July 1976.

3. SCET International Aménagement des Polders du BOL: Etude de Factibilité, 5 volumes, 1972: SCET International and Charles T. Main, consultants to the Lake Chad Basin Commission, Multidonors Mission, General Report; CH2M Hill, Inc., Tandal Polder Feasibility Study, April 1978.

4. Hasan A. Tuluy, "Comparative Resource Costs and Incentives in Senegalese Rice Production," Food Research Institute, Stanford University, August 1978.

5. West African Rice Development Association (WARDA), "The Irrigated Rice Area of the Kou Valley, Upper Volta," Case Study No. 1, June 1975.

6. United States Agency for International Development, "Upper Volta: Niena-Dionkélé Rice Production," Project Paper, November 1976, and FAO/World Bank, "Rapport de la Mission au Project de Développement Agricole de Niena," June 1978.

7. SOGREAH, "Barrage et Périmetres d'Irrigation de Bagré: Etude de Factibilité -- Note d'Orientation," January 1978.

8. World Bank, Appraisal of the Mali-Sud Agricultural Project: Mali, 1976.

9. Tuluy, "Comparative Resource Costs..."

10. World Bank, Appraisal of the Sategui-Deressia Irrigation Project: Chad, March 1974.

11. United States Agency for International Development, "Bakel Crop Production," Project Paper, July 1976.

12. Tuluy, "Comparative Resource Costs..."

13. SCET International and Charles T. Main, consultants to Lake Chad Basin Commission, Multidonors Mission, Kousseri Integrated Rural Development Project.

14. SCET International and Charles T. Main, consultants to Lake Chad Basin Commission, Multidonors Mission, Malo Integrated Rural Development Project.

15. World Bank, Appraisal of an Irrigation Project: Niger, March 1977.

16. John McIntire, "Resource Costs and Economic Incentives in Malian Rice Production," Food Research Institute, Stanford University, August 1978.

17. McIntire," Resource Costs and...."

18. Tuluy, "Comparative Resource Costs..."

19. SCET International and Charles T. Main, consultants to Lake Chad Basin Commission, Multidonors Mission, Diffa Integrated Rural Development Project.

20. World Bank, Appraisal of a Second SEMRY Rice Project: Cameroon, December 1977.

Category Ia projects involve rehabilitation of existing systems. There are few projects in this category and only one of any size -- the Office du Niger in Mali. The technical characteristics and scale of these projects vary considerably. Projects in Category Ib involve not only rehabilitation but also improvement. Generally, this means increasing the degree of water control and intensity of crop production. All of the techniques of Category I involve the use of mechanization or animal traction. This is partly because these projects are all in areas of low population density where labor is scarce.

Although there is some scope for expansion of this category,[4] increases in irrigated cultivation must come primarily from the development of new land and not from reclamation or improvement of existing schemes. This implies that, with the possible exception of the Office du Niger, the gains from increasing utilization of current capacity are small, as are other benefits of these schemes such as the use of familiar technology and the minimum amount of environmental disruption.

Category II projects are located in areas with reasonably favorable agro-climatic environments. Despite this, they are hindered by low population density resulting from the incidence of disease. As these higher rainfall areas are cleared of the disease vectors, immigration is likely to become increasingly important.

Water control within this category varies from small dikes used to control runoff in rainfed agriculture (Niena) to full control provided by diversion dams (Kou). Cultivation is relatively labor-intensive, involving either animal traction or manual techniques. Most projects are small, at least at the local perimeter level (e.g., Niena, Sikasso, Sedhiou). Where small perimeters are spread over a wide area, the farmer is more involved in making decisions, though some group organization is usually necessary to manage water supplies. Since this type of project is dispersed over a relatively wide area, the distribution of benefits is reasonably equitable but supervision and extension work are more difficult. A greater role must be played, in this case, by an incentive system which allows decisions to be made on a decentralized basis. Other projects in higher rainfall areas are larger in scale and more centralized in their decision making (e.g., Kou, Bagré, Satégui-Déressia).

Category III projects, in areas of unfavorable agro-climatic conditions, are the most numerous. They have been divided into three sub-categories. The first group (IIIa) exists in areas where population density is fairly high, especially along major rivers. As a result, there is pressure on the best land, which is generally used for flood recession

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[4] For example, rehabilitation in the Haute Vallée area of Mali and in some settled areas of Upper Volta, Niger, and Chad.

cultivation. With the introduction of irrigation and the possibility of increasing yields substantially, farmers are willing to employ more labor intensive techniques, whether manual or involving animal traction. This system of irrigation, as it has been developed in the Senegal River Valley, is quite decentralized and allows most decisions to be made by small groups of farmers.[5]

The second sub-category (IIIb) consists of projects in areas where there is adequate and fairly regular flooding of the plains bordering the major rivers. The best example of this is the floodplain of the Niger River in Mali, where the height and timing of the flood can be predicted with some accuracy and the use of a perimeter dike to control flooding is quite effective. Elsewhere, the same type of polder development has been tried with less promising results. In the Senegal River Delta, for example, the irregularity of flooding has caused a shift from simple polders to full water control through pumping.

The last sub-category (IIIc) consists of projects in areas of low rainfall and sparse population where natural flooding is insufficient or too irregular to permit the relatively inexpensive technique of controlled flooding to be employed. Techniques of cultivation involve either animal traction or tractor services for land preparation. Some double cropping is possible, but water constraints during the dry season generally prevent a second crop from being grown on all irrigable land.

The establishment of irrigated agriculture in drier areas of low population density typically results in limited scope for individual decision making. Farmers have few choices with respect to techniques, crops, or the size of their irrigated holdings. Because irrigation techniques are novel to these farmers, some of whom have been resettled, project agencies must decide all questions concerning allocation of water and maintenance of irrigation works. Even small projects (e.g., Diffa in Niger or Bol in Chad) are centrally managed and often quite inflexible.

Project Benefits

Primary benefits from improved water control include increases in crop production and reduction of crop losses due to flooding and drought. There may also be benefits associated with opportunities for employment

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[5] Similar decentralization has been proposed for the Kousseri and Malo projects in Cameroon and Chad, but this may be more difficult because of the larger scale of these schemes.

during the construction of the irrigation systems. Secondary benefits accrue from the economic and environmental changes caused by the primary effects, e.g., increased demand for hired labor in crop production and processing, expanded human and animal work capacity resulting from improvements in health and fodder production.

Net primary benefits of some of these irrigation projects are expressed as internal rates of return (IRRs)[6] in Table 2. Because many of these projects are still only proposals, these IRRs should be treated sceptically. In addition to uncertainty concerning prices, technologies, and institutions, estimated IRRs may lack comparability because of different assumptions, e.g., those related to the difference between financial and economic rates of return. Experience with established projects is limited, but some systems (e.g., Mopti I in Mali and SEMRY I in Cameroon) have achieved rates of return between 14 and 22 percent. Others such as the early development of the Office du Niger, some of the small projects in Upper Volta, and the mechanized projects in the Senegal River Valley have done poorly and may even have negative rates of return.[7]

It is difficult to generalize otherwise about the rate of return estimates presented in Table 2. Projects which would seem likely, on the basis of experience elsewhere in the world, to have high rates of return -- those, for example, involving rehabilitation of existing schemes -- show unimpressive IRRs. On the other hand, rates of return are relatively high for at least one project in each of the low rainfall sub-categories. Whether these unexpected results are due to measurement errors, to differences in methodology, or to project-specific variation in costs and benefits is impossible to determine without scrutinizing each of the projects much more closely.[8]

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[6] Some project documents do not distinguish clearly between financial and economic rates of return. The discussion here refers to economic rates of return where possible.

[7] See, for example, the analysis of irrigation systems in Senegal contained in Hasan Ahmet Tuluy, "Comparative Resource Costs and Incentives in Senegalese Rice Production," Food Research Institute, Stanford University, July 1979.

[8] This was the approach taken in the Stanford University Food Research Institute/West Africa Rice Development Association (WARDA) study, on the Political Economy of Rice in West Africa, where every effort was made to ensure that results for different kinds of rice growing activities were as comparable as possible. Some of the results of this study are discussed in the main body of the report.

TABLE 2 - RATES OF RETURN, YIELDS AND FERTILIZER CONSUMPTION[1]

Project (Country	Internal Rate of return (%)[2]	Irrigation system	Crops[3]	Gross Yields (mt/ha)[4]	Cropping intensity (%)	Fertilizer consumption (kgs/ha)
Category Ia - Rehabilitation						
Office du Niger II[5] (Mali)	14	Diversion dam without storage	rice	3.5	70	100, urea; 100, TSP
Action Riz-Sorgho (Mali)	10	Controlled flooding	rice	n.a.	100	none
Category Ib - Rehabilitation and Improvement						
Bol (Chad)	6-17	Pumping and controlled flooding	wheat cotton	2.5, 3.0 2.5, 3.0	200 100	100, urea; 100, TSP n.a.
Delta (Senegal)	n.a.	Pumping	rice	2.5	100	n.a.
Category II - High Rainfall						
Kou (Upper Volta)	n.a.	Diversion dam	rice, 1st crop rice, 2nd crop	4.4-6.9 4.0-6.9	100 100	200, urea; 150, DAP; 100, KCL
Niena (Upper Volta)	16	Rainfed with bunding	rice	2.3	100	100, urea; 50, AP; 50, KCL
Bagré (Upper Volta)	n.a.	Dam and pumping	rice wheat corn	n.a. n.a. n.a.	n.a. n.a. n.a.	n.a. n.a. n.a.
Sikasso (Mali)	n.a.	Improved swamp Diversion dams[6]	rice rice	1.8 2.5-3.0	100 200	none n.a.
Sedhiou (Senegal)	6-23	Improved swamp	rice	1.5-2.4, 3.6	100	150, urea; 250, 8-18-27
Satégui-Déressia (Chad)	13-14	Controlled flooding	rice	2.5	100	50, urea

TABLE 2 (Cont.) - RATES OF RETURN, YIELDS AND FERTILIZER CONSUMPTION

Project (Country)	Internal rates of return (%)	Irrigation system	Crops	Gross yields (mt/ha)	Cropping intensity (%)	Fertilizer consumption (kgs/ha)
Category IIIa - Low Rainfall/Higher Population Density						
Bakel (Senegal)	26	Pumping	rice	4.0	100	150, 18-54-0
			maize	3.0	100	none
			millet	3.0	100	none
			sorghum	2.5	100	none
Matam (Senegal)	n.a.	Pumping	rice	4.75	100	200, urea; 200, 16-48-0
			vegetables	n.a.	100	n.a.
Kousseri (Cameroon)	8-10	Pumping	rice	5.0	150	100,TSP; 100,AS;180,urea
			red sorghum	3.0	100	200, urea
			white sorghum	3.0	100	200, urea
			fruits & vegs	20.0	100	300, urea
Malo (Chad)	10	Pumping	rice	5.0	150	100,TSP; 100,AS; 180,urea
			sorghum	3.0	100	200, urea
			fruits & vegs	20.0	100	300, urea
Namarigoungou (Niger)	12	Pumping	rice	4.8	200	200, urea
			sorghum	2.5	100	100, urea; 100, TSP
Toula[7] (Niger)	n.a.	Pumping	rice, 1st crop	5.2	200	n.a.
			rice, 2nd crop	4.6		n.a.
Other[7] (Niger)	n.a.	Pumping	rice, 1st crop	3.5-5.1	200	n.a.
			rice, 2nd crop	3.6-5.8		n.a.
Category IIIb - Low Rainfall/Lower Population Density with Flooding						
Mopti I (Mali)	14	Controlled flooding	rice	1.5, 1.75	100	none
Mopti II (Mali)	18	Controlled flooding	rice	1.75-2.5	100	none-50, urea
Segou I (Mali)	n.a.	Controlled flooding	rice	1.5-1.8	100	none

TABLE 2 (Cont.) - RATES OF RETURN, YIELDS AND FERTILIZER CONSUMPTION

Project (Country)	Internal rates of return (%)	Irrigation system	Crops	Gross yields (mt/ha)	Cropping intensity (%)	Fertilizer Consumption (kgs/ha)
Segou II (Mali)	n.a.	Controlled flooding Diversion dam[8]	rice rice	1.75 2.5-3.0	40 50	none 50 kgs, urea
Category IIIc - Low Rainfall/Lower Population Density without Flooding						
Senegal River Lower Valley & Delta (Senegal)	n.a.	Pumping	rice tomatoes maize	3.8 n.a. n.a.	100 100 n.a.	n.a. n.a.
Diffa (Niger)	7-9	Pumping	rice wheat sorghum	5.0 3.5 4.0	50 50 35	100, urea; 100, TSP 160, urea; 120, TSP 100, urea
SEMRY I (Cameroon)	22	Pumping	rice, 1st rice, 2nd	4.4 4.1	134	200, urea 200, urea
SEMRY II (Cameroon)	14	Gravity irrigation and controlled flooding	rice, 1st rice, 2nd	4.0 4.7	160	150, urea, 100 AS 150, urea, 100 AS
Office du Niger I[5] (Mali)	n.a.	Diversion dam without storage	rice cotton sugar cane	1.5-4.0(avg.2.3) 1.0 50-60	75 0 n.a.	30, urea n.a. n.a.

n.a. not available

Notes to Table 2:

1. Sources of data for projects are those cited in Table 1, except where otherwise noted. Some projects have been included here which are not shown in Table 1 because they show Sahelian experience with crop yields even if other information is not available. Underlined numbers (e.g., 8.5-9.8) are expected IRRs or crop yields; actual IRRs or crop yields are written without underlining.

2. It is not possible to calculate internal rates of return for many of these projects because they are carried out discontinuously. For example, the projects in the Senegal River Lower Valley and Delta developed incrementally over many years, during which time input and product prices changed so much as to make standardization impossible.

3. Only irrigated crops are shown in this column. Many of these projects permit farmers also to cultivate holdings of rainfed crops (usually millet or sorghum).

4. Gross yields without subtracting field losses.

5. The Office du Niger began producing irrigated rice and cotton in the 1930s under French colonial authority. This was generally unsuccessful until the end of the 1960s when cotton cultivation was abandoned. Since 1970, yields, output, and marketing of paddy have increased greatly as the result of new policies introduced by the Malian government.

6. The diversion dam is part of the Klela scheme, which was expected to begin production on slightly more than 1,000 ha in 1978-1979.

7. Source is Union Nigérienne de Crédit et de Coopération, Division des Aménagements, Rapport d'Activité: 1975-76 Niamey, 1977.

8. Several polders in the Segou II project (known as the "Extension de l'Operation Riz Segou") will be fed from a canal behind the barrage at Markala, which irrigates the Office du Niger, and are thus referred to here as being irrigated by diversion dam.

Gross primary benefits depend almost entirely on the value of crop production, which usually consists of one or two annual crops of paddy, the contribution of vegetables, fodder crops, wheat, cotton, maize, and sorghum generally being much smaller. Table 2 shows that the benefits from paddy production are often estimated on the assumption of very high yields -- from 3.5 to 5.0 metric tons per hectare. Although these estimates are often matched or even exceeded by actual yields, the question arises as to whether this performance can be sustained as irrigation is expanded beyond its current rather narrow limits.

Development of other profitable primary crops (e.g., wheat and cotton) has been limited by various special factors. Agronomic research on wheat production in the Sahel has made progress only recently, and output is almost nil despite rising imports of wheat and flour. Development of irrigated cotton and sorghum has been slow because their rainfed cultivation is less costly. Production of irrigated cotton might increase, however, as land suitable for rainfed cultivation becomes scarcer. Fruits and vegetables are quite profitable in limited areas, but their markets are narrow and are characterized by considerable seasonal price variation.

Primary benefits, because they consist mainly of increased crop production, accrue principally to project farmers. Because access to land is, in principle, restricted by project authorities so that holdings are roughly equal in size, the distribution of benefits among farmers ought to be fairly egalitarian. This distribution is also influenced, however, by family size and composition and by differential access to modern inputs and credit. Maintaining a relatively equal distribution of benefits requires, therefore, the establishment of credit and input delivery systems which favor the small farmer.

Management of all the projects described here is by specialized, vertically integrated public agencies. These agencies typically have direct contact with farmers -- they allocate land, sell inputs, provide extension services and credit, operate and maintain the irrigation system, and buy crops. They also maintain relations with national agencies or ministries responsible for irrigation development or crop marketing. Because many of these projects are in areas where little agricultural development has taken place, the agencies are sometimes also involved in the resettlement of farmers or the reallocation of land from its traditional uses and users.

The relationship between project agencies and individual farmers has an important effect on the distribution of benefits. The more direct is that relationship, the more closely does the agency determine how those benefits are allocated. Where the agency deals, instead, through a farmer group or cooperative, it is less able to ensure that distribution is equitable. On the other hand, farmers in this situation have a greater say themselves over resource allocation. If the local society is relatively egalitarian, the distribution of benefits may be more equal than if all decisions are made by the agency. On the other hand, there is also greater scope for local abuse of power. Thus the column in Table 1 indicating "Scope of farmer decision making" suggests the possibility of local determination of the allocation of benefits. This possibility is probably greater for small-scale projects found in areas of high rainfall or relatively dense population.

The major secondary benefits consist of increased demand for on-farm hired labor, forward and backward linkages to input suppliers and to downstream processing and marketing activities, and changes in the prices of farm outputs. Demand for hired labor depends on the type of cultivation technique, on the size of holdings relative to the number of active workers in each family, and on the seasonal pattern of cultivation. Mechanization can increase the demand for labor if it eases bottlenecks which prevent labor from being used for manual operations. Demand for farm labor exists in the Senegal River Delta, for example, only because mechanical plowing makes the earth workable for rice production. On the other hand, the very labor-intensive techniques used in the Middle Valley of the Senegal River are not sufficient to create much demand for hired labor because of the small size of individual holdings. Only a careful analysis of the project will reveal the likely demand for hired labor.

The benefits derived from an increase in the demand for hired labor depend on the local labor supply. Clearly there are greater benefits to be derived if the region is one of high population density and substantial underemployment than if it is sparsely populated and labor must immigrate from outside the region. Although many tasks (e.g., plowing, sowing, and weeding) can be done without hired labor, rice harvesting and threshing, in particular, often create a demand for it. Because these tasks are usually done after millet and sorghum have been harvested, farmers in irrigated projects are able to offer work to otherwise unemployed laborers from rainfed areas. The same temporal pattern also holds where there is a dry-season crop -- irrigation stimulates demand for labor when it is most available.

Other secondary benefits also vary with the type of agricultural project. Although investments and recurrent expenditures for capital-intensive construction and maintenance of irrigation works, purchase and operation of vehicles, and installation and operation of modern mills are large, they consist mostly of imported inputs and offer little demand to local suppliers of labor, goods, and other services. Irrigation works which can be constructed using labor-intensive techniques, such as those at Matam and Bakel in Senegal, on the other hand, tend to have stronger linkages to the local economy. Similarly, projects which create greater local crop surpluses do more to stimulate development of small-scale processing and marketing. Finally, animal traction techniques, in particular, induce the development of a local agricultural equipment industry.

Another linkage results from the expansion of final demand for consumer goods and services. Farm families at low levels of income spend their incremental earnings on foods, condiments, cloth, and some consumer durables such as bicycles. Most of those goods have a low import content, and the multiplier effects are likely to be fairly large. The more broadly spread are the primary benefits, the greater will be the developmental impact of these final demand linkages.

Finally, there are gains and losses from expansion of farm output that changes prices faced by producers and consumers. Farmers, as producers, generally lose because of these price changes; as consumers, however, they gain. Since smaller farmers and other poor consumers, are more likely than larger farmers to be buyers rather than sellers in the market, these groups will benefit most from reduced prices. Projects which result in large increases in marketings are likely to benefit poor consumers most by decreasing the cost of food. These projects are most likely to involve total water control with high yields and large holdings.

The importance of this price effect is also related to the crop produced. The prices of cereals, such as millet and sorghum, that do not have any close imported substitutes, may change substantially with an increase in supply. On the other hand, the price of domestically produced rice is closely related to that of imported rice. Increases in production will result in a decline in imports but no substantial change in price until all imports have been replaced by domestic production. Therefore, the relative importance of this price effect will be greater for millet, sorghum, some vegetables, and possibly maize than it will be for rice.

Thus, far benefits have been described as increasing the mean value of real income. Reducing the variance of that income and decreasing the probability of severe loss must also be counted as important benefits in their own right. These goals are more likely to be achieved with systems involving greater degrees of water control.

The distribution of benefits over time has a characteristic pattern in most of these projects. Benefits are low at the outset, partly because only part of the irrigable surface is being cultivated, and partly because yields have not yet reached their expected values. Gross benefits increase and reach their maximum values between the 6th and 10th years of most projects. Most projects do not have positive cash flows, therefore, before the 6th or 7th year of operation since paid-out costs of irrigation construction are high in the first five years of the project. Farmers are generally protected from financial losses by input subsidies and credit during the first years of project operation.

Project Costs

Table 3 shows project cost estimates, decomposed into capital and recurrent items per hectare or hectare/crop. Although reliable figures for some projects are unavailable, a few general observations can be made.

1. Total project costs are typically fairly small. The largest project is certainly the original Office du Niger (not shown in Table 3), which involved the construction in the 1930s and 1940s of a dam and works to irrigate roughly 55,000 hectares. The most expensive modern project is that proposed at Kousseri (Cameroon), although when some of the Senegal River Basin projects are completed, they will probably be more expensive.

2. Total cost per member of the population included in the project vary enormously -- from a low of $216 in the Bakel project of Senegal to a high of $6,110 in the Kousseri project in Cameroon. These cost differences do not appear to be closely associated with project categories.[9]

3. Capital costs are the largest part of total project costs, and irrigation is the largest part of capital costs. More detailed estimates, not shown in Table 3, show that the construction of irrigation works and the purchase of equipment such as pumps are a greater proportion of capital costs than are such items as investment in mills, trucks, and buildings.

4. Irrigation costs are an increasing function of the degree of water control, especially in low rainfall areas. Modified rainfed systems (Niena in Upper Volta) and controlled flooding systems (Segou and Mopti in Mali) are comparatively inexpensive, less than $1,000 per ha, and cover large areas. Small-scale pumping schemes, such as those at Bakel and Matam, cost about $2,000 per hectare, whereas large-scale projects involving pumping, diversion dams, and levelling of land cost $5,000 in the Senegal River and up to $9,000 in Niger and Chad, where they cover smaller areas. Even rehabilitation projects, which are less costly

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[9] Some of these differences may be due to the occasional inclusion of the cost of rainfed project components. The most important instances of this, such as the Sikasso and Sedhiou projects, have been omitted from Table 3. Another source of cost variation is the effect of inflation on costs of projects

TABLE 3 - COSTS OF PROJECTS[1]

Project (Country)	Total Costs (million$)	($/ person)	Cultivable Area[2] (hectares)	Irrigation &[3] Land Dev ($/ha)	Overhead[4] ($/ha/crop)	Inputs[5] ($/ha/crop)	Total Industry[6] ($ million)	Total Other[7] ($ million)
Category Ia - Rehabilitation								
Office du Niger (Mali)	43	860	37,500	1,000	$50 all costs			
Action Riz-Sorgho (Mali)	5	n.a.	13,300	$375 all costs				
Category Ib - Rehabilitation and Improvement								
Bol (Chad)	24	1,920	3,000	4,800 (rehabilitation of old polder) 6,300 (new polder)	300	450	n.a.	10
Delta (Senegal)	n.a.	n.a.	9,000	4,000 (for tertiary polder with pumping and field levelling)	n.a.	n.a.	n.a.	n.a.
Category II - High Rainfall								
Kou (Upper Volta)	n.a.	n.a.	1,160	1,400-2,200	90	250	n.a.	n.a.
Niena (Upper Volta)	5.3	1,180	6,700	340	-------225-------		n.a.	n.a.
Bagré (Upper Volta)	n.a.	n.a.	30,000	n.a.	-------$80-120/ha all recurrent costs------			
Satégui-[illegible]	25	2,270	4,000	2,750	-------$250/ha all recurrent costs---------			

TABLE 3 (Cont.) - COSTS OF PROJECTS

Project (Country)	Total Costs (million$)	($/person)	Cultivable Area (hectares)	Irrigation & Land Dev ($/ha)	Overhead ($/ha/crop)	Inputs ($/ha/crop)	Total Industry ($ million)	Total Other ($ million)
Category IIIa - Low Rainfall/Higher Population Density								
Bakel (Senegal)	7.1	229	1,700	1,300	n.a.			
Matam (Senegal)	n.a.	n.a.	400	2,000	n.a.			
Kousseri (Cameroon)	64.2	6,110	5,500	5,000	380	n.a.	2.55	0.25
Malo (Chad)	32.1	2,010	5,400	3,320	$240/ha all recurrent costs			
Namarigoungou (Niger)	10.5	656	1,550	6,300	$500/ha all recurrent costs			
Category IIIb - Low Rainfall/Lower Population Density with Flooding								
Mopti I (Mali)	12-13		26,000	400-800	30	50	n.a.	n.a.
Mopti II (Mali)	31		8,800	500-1,000	60	100	n.a.	n.a.
Segou I (Mali)	n.a.		35,000	400-800	30	50	n.a.	n.a.
Segou II (Mali)	n.a.		8,000	500-1,000	60	100	n.a.	n.a.

TABLE 3 (Cont.) - COSTS OF PROJECTS

Project (Country)	Total Costs (million$)	($/person)	Cultivable Area (hectares)	Irrigation & Land Dev ($/ha)	Overhead ($/ha/crop)	Inputs ($/ha/crop)	Total Industry ($ million)	Total Other ($million)
Category IIIc - Low Rainfall/Lower Population Density without Flooding								
Senegal R. Lower Valley and Delta (Senegal)	n.a.	n.a.	10,000	5,000	————————n.a.————————			
Diffa (Niger)	21.6	1,660	2,300	8,800	--------$376/ha all recurrent costs--------			
SEMRY I (Cameroon)	9.1	412	5,350	————————$1,700/ha all costs————————				
SEMRY II (Cameroon)	56	1,230	7,000 irrig. 8,000 rainfed	3,500	--------$200/ha all recurrent costs--------			

n.a. not available

Notes to Table 3:

1. Sources of data are as shown in previous tables unless otherwise noted. CFA francs are converted to US $ at 250 CFAF/$; Malian francs are converted to US $ at 500 MF/$. All estimates of recurrent costs (notes 4, 5, 6, 7) are annual, based on typical project years, generally after the fifth year of production when staff is assumed to be trained and when input deliveries and capacity use of equipment are at long-term levels.

2. Cultivable areas are estimated from total project areas minus areas used for irrigation works, roads, buildings, and other land not planted in crops. Cultivable area is sometimes referred to as net area.

3. Includes all investment in irrigation during first five years of project.

4. Includes extension costs, management, maintenance and operation of irrigation works, crop marketing and storage.

5. Includes costs of inputs used by farmers (e.g., fertilizers, pesticides, plows).

6. Rice mills, etc.

7. Research stations, seed farms, health and literacy projects, foreign technical assistance, socio-economic studies, training of local technicians.

in other areas of the world,[10] are expensive in the Sahel when they involve increasing the degree of water control, such as at Bol (Chad) or in the Delta (Senegal).

5. Total recurrent costs also vary substantially among projects. They tend to be lower in high compared with low rainfall areas. They are also relatively low in controlled flooding schemes, probably because cultivation is less intensive in these than in projects involving full water control. There is also a tendency for recurrent costs to be higher in Chad and Niger than in the other countries.

6. Input costs typically are the most important part of recurrent costs and are borne largely by project farmers. Although there often are subsidies, especially for fertilizers, most input costs are paid by farmers in cash or as credit repayment.

7. Overhead costs are less important than input costs. Overhead, because it consists of inputs that are not sold directly to farmers but are indirect services (e.g., warehousing and extension), is often paid partly out of land use fees (redevances) levied per hectare of project land.

8. Ancillary programs (literacy, public health, and research) contribute little to total costs. In spite of this, these programs must be subsidized because they do not produce direct or immediate economic returns. Such subsidies are typically paid with external aid or with taxes on land use fees, input prices, or crop prices.

9. The foreign exchange component of project costs in all categories, but especially in irrigation design and construction, is large, generally more than 70 percent. This is especially true where local contractors cannot perform the work, or are unable to do so competitively. The foreign exchange component of other items, such as irrigation maintenance and overhead, is smaller, generally between 20 and 40 percent. This implies that significant foreign exchange savings are possible if labor-intensive construction methods can be used, as at Bakel, Matam, and Satégui-Déressia. It also suggests the importance of increasing the supply of trained local irrigation engineers and project managers.

The projects discussed in this appendix are designed so that their benefits exceed the sum of recurrent and fixed capital costs. Thus the projects should not, in principle, require public subsidies. Experience, suggests, however, the difficulty of achieving this goal under present conditions in the Sahel.[11] The structure of farmers' incomes and payments

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[10] See Appendix A.

[11] J. Dirck Stryker, "Comparative Advantage and Public Policy in West Africa Rice," Food Research Institute, Stanford University, July 1979.

for inputs implies, moreover, that project agencies must also maintain sufficient working capital to extend credit to farmers. The problem of having adequate capital is likely to be especially important in the early years of each project before crop yields have attained their expected values, and, hence, before farmers are able to meet all of their obligations.

Conclusions

Investment in irrigated agriculture has been one of the instruments used by Sahelian governments to achieve their policy objectives. Those objectives have included increasing self-sufficiency in essential foods, maintaining food security, and expanding rural incomes.

In practice, the goal of increasing self-sufficiency has applied primarily to rice, wheat flour, and sugar, the main food imports of the region. But with the exception of Mali, and to a lesser extent Senegal, modern irrigated production has contributed little to increased self-sufficiency.[12] Irrigated production has enabled Mali to regain rice self-sufficiency and even to export, but this is the only outstanding success in the region. Growth of wheat production has been almost nil, and sugar cane output has increased only recently in Senegal and Upper Volta.

Irrigated production has also made only a small contribution to food security and that contribution has been almost entirely at the local level, i.e., among populations farming irrigated areas. Although there has been significant growth of irrigation in Mali and Senegal, most of this is in controlled flooded polders, which provide little security against poor floods. Those polders are much less expensive than those with full water control, but they are also exposed to greater risks.

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[12] Club du Sahel/CILSS, "The Development of Irrigated Agriculture in the Sahel -- Review and Perspectives," April 1980.

Irrigation has also contributed little so far toward increasing rural incomes. This is because of the limited number and small scale of irrigation projects. Development of new projects is limited by shortages of trained manpower and investment capital; increasing project size is restricted by the perceived need to have secure irrigation systems, which are expensive.

Nevertheless, the contribution of each irrigation project to these national goals is influenced in an important way by the characteristics of the project. Several broad conclusions emerge from the preceding analysis:

1. Water control is the most important variable in project results. Irrigation is the largest component of project cost and crop production is the most important benefit. Although net benefits do not seem to vary systematically with degree of water control, returns in more secure systems, having higher expected crop yields, are more sensitive to shortfalls in yields because of greater outlays per hectare for irrigation works, fertilizers, and other inputs. Furthermore, if farmers in secure systems depend exclusively on irrigated production, shortfalls in that production due to pest attacks or to declining soil fertility after several years of intensive production are likely to cause severe problems.[13] This plus general considerations of economic efficiency suggests that higher cost, secure, intensive systems, which contribute most to local and national security, should probably be placed in the ecologically and economically most favorable areas where soils and terrains are most suited to long-term intensive agriculture and where complementary infrastructures can be established efficiently.

2. Projects must have appropriate combinations of population density, total size, and average holding size. In areas of low rainfall, projects generally follow two courses. The first is to use mechanized techniques on fairly large holdings to overcome labor shortages. This may be objectionable on grounds of income distribution and economic efficiency.[14] The advantage of this course, however, is that it holds the possibility of producing marketable surpluses for substitution against imports and of helping countries to increased food security and self-sufficiency. The second course is to use intensive manual techniques on small plots. This makes work demands manageable within the constraint of family labor supplies and keeps land development costs low. This course has been shown to be reasonably efficient and clearly is preferable to mechanization on income distribution grounds alone.

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[13] See WARDA, "The Irrigated Rice Area of the Kou Valley, Upper Volta," Case Study No. 1, June 1975 for a discussion of the problems of establishing intensive double cropped rice culture in an area where it has not previously existed.

[14] Tuluy, "Comparative Resource Costs..."; Abraham S. Waldstein, "Government Sponsored Agricultural Intensification Schemes in the Sahel: Development for Whom?" USAID Paper on Sahelian Social Development, August 1978.

The principal disadvantage of such schemes (e.g., Namarigoungou in Niger, Matam and Bakel in Senegal) is that they do not produce marketable surpluses and thus do little for national self-sufficiency or food security.

3. Introduction of animal traction seems to be an effective compromise between extensive mechanization and intensive manual cultivation if projects are designed properly. But on projects with small holdings, individual farmers do not have enough land to amortize investments in animal traction equipment. Increasing holding size to solve this problem naturally reduces the number of project farmers and thus has undesirable distribution effects as long as perimeter size is kept constant. One alternative is to establish rental systems, either for animal traction equipment or for small power tillers, to which farmers would subscribe. Another is to enlarge, where possible, the total size of the perimeters. Such intermediate systems help to break labor bottlenecks at planting time and to increase the total demand for labor without incurring the disadvantages of full-scale mechanization.

4. Development of ancillary institutions for credit, marketing, and extension is particularly important. Adequate credit and extension programs are vital for assuring small farmer participation. In addition, if projects are designed principally to raise farm incomes by increasing marketings, institutions for this purpose will have to be developed. Maintaining planned marketings is crucial, for without them the indebtedness of farmers and of project agencies, which depend for their revenues on marketing margins and on in-kind land use fees, is likely to grow. If projects are designed principally to reduce the variance on farm incomes with some increase in the mean, marketing systems are less important.