RESEARCH ON IRRIGATION IN AFRICA

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RESEARCH ON IRRIGATION IN AFRICA

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FORUM ON IRRIGATION SYSTEMS RESEARCH AND APPLICATIONS: IRRIGATION IN AFRICA

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In response to recent interest in irrigated agriculture in Africa, the Water Management Synthesis II Project undertook a series of irrigation-related activities on that continent. An early WMS-II team reviewed the potential for irrigation development in the Sahel. This was followed by a special study on farmer- and agency-managed small-scale systems in the Maggia Valley of Niger, sector assessments in Kenya and Chad, an assessment of small-scale and small-holder irrigation in Zimbabwe, and design guidance for the Shebelli Water Management Project in Somalia.[1]

WMS-II investigations show that irrigation conditions vary widely throughout the region and that irrigation systems may be indigenous or introduced, with technologies ranging from calabash hand-lift and flood recession systems, to large diversion works and deep tubewells. The gamut of institutional arrangements runs from individually owned and operated shallow dug wells serving mango groves and onion gardens to immense agency-controlled schemes devoted to cotton production.

While the large-scale irrigation tradition in sub-Saharan Africa may be less venerable than that in the Near East or Mesoamerica, some indigenous systems are precolonial. Others,

[1]Water Management Synthesis II publications on African irrigation include the following:

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

WMS Report 37. *African Irrigation Overview* (3 vols.).

WMS Report 40. *Watering the Shamba: Current Public and Private Sector Activities for Small-Scale Irrigation Development (Kenya).*

WMS Report 41. *Strategies for Irrigation Development: Chad.*

WMS Report 48. *Small-Scale and Smallholder Irrigation in Zimbabwe: Analysis of Opportunities for Investment.*

WMS Report 51. *Pre-Feasibility Study of Irrigation Development in Mauritania.*

Goldring, L., *Social and Economic Influences on Perimeter Management and Operation: Findings from Research in the Maggia Valley, Niger.* WMS II Working Paper, Cornell University, 1987.

Wells, J.C., and W.R. Norman, *Sahelian Irrigated Agriculture: A Review of French Literature Sources.* WMS II Working Paper, Cornell University, 1984.

constructed during the colonial period, reflect British, French, and Italian influences in design and administration. If international donors are to make a meaningful contribution to the development of irrigation in Africa, they must recognize both the rich and varied history of small-scale systems and the European colonial legacy. They must also build upon the research and development efforts of Africans and Europeans who have been examining irrigation issues in Africa for quite some time.

For this reason, the WMS-II Forum on Irrigation Systems Research and Applications, held at Cornell University in May 1986, devoted two sessions to African irrigation. The intent was to learn what is already known about irrigation in Africa, key questions for research and development, and the methodologies employed in irrigation research. The four papers included in this volume were presented at the Forum. Researchers addressed irrigation issues and research methodologies used in Mauritania, Senegal, Kenya, and Zimbabwe.

Two of the papers examine specific water management problems; the others address broader irrigation policy issues. Koita and Bernsten compare rice production costs on small- and large-scale irrigation perimeters in the Fleuve region of Mauritania and offer recommendations for improving perimeter performance. Horst discusses the methodology employed by the WARDA/Wageningen Project in the Middle Valley of the Senegal River, which was designed to sensitize engineers to social and institutional issues, to identify indigenous water management institutions and rules, and to explore the effect of ethnicity on water management practices. Ssennyonga and Rukuni trace the history of small-scale irrigation development in the context of the changing policy environments of colonial and postcolonial Kenya and Zimbabwe.

A key theme that emerges in the papers is the ongoing transition from local to governmental management of irrigation schemes. Motives for governmental involvement in irrigation management include a desire to promote the production of specific crops, famine and drought relief, and the resettlement of displaced populations. Closely related to the issue of governmental involvement in irrigation is that of the tension between agency and local control. Rukuni's review of irrigation policy in Zimbabwe shows that government intervention in the 1930s both restricted farmers' latitude in water use and committed the government to subsidizing system capital, operation, and maintenance costs. While current policy calls for elimination of these subsidies, mechanisms for devolution of control to farmers have not yet been developed.

Another issue is that of the economic viability of irrigation schemes. Food shortages will hit hardest marginal lands that do not enjoy reliable rainfall. The cost of irrigating such lands is generally high and returns low. The task of turning schemes that were built in marginal environments for noneconomic reasons into self-supporting enterprises is formidable at best.

A factor affecting the performance of new schemes in marginal areas is the unfamiliarity of intended project beneficiaries with irrigation. Ssennyonga notes the difficulties of incorporating irrigation activities into household production strategies that are primarily pastoral. The MIP minor schemes in Kenya, undertaken to assist drought victims, required a rapid transformation of nomadic pastoralists into irrigation farmers. Predictably, these schemes required substantial government investment but contributed almost nothing to the national economy. Similarly, the development of large-scale systems in the Fleuve region of Mauritania disrupted household economies by denying farmers access to productive nonirrigated lands.

Despite these constraints, agencies have sought to make perimeters self-sustaining and economically viable. This goal is even more elusive because so often systems in sub-Saharan Africa are planned and built not only with imported technologies, but engineers are also imported to design systems and to supervise construction. They, in turn, require expensive housing and domestic accoutrements that must also be imported. According to Koita and Bernsten, expatriate personnel account for between 13 and 20 percent of total rice production costs.

The papers presented in this volume offer some tentative solutions to the problem of economic viability. Koita and Bernsten recommend the construction of medium-sized perimeters to augment returns to rice schemes in Mauritania. All four papers emphasize farmer involvement in system planning and maintenance and increased attention on the part of planners to social factors that are likely to affect perimeter performance.

KENYA'S TRANSITION FROM THE WITTFOGELIAN LEGACY TO COMMUNITY-MANAGED IRRIGATION

Joseph W. Ssennyonga

INTRODUCTION

Until recently, the instigation of irrigation policies was driven by the Wittfogelian (1957) model. In this paper, the historical, agronomic, and organizational factors that led to a radical break with this model are analyzed. Wittfogel's basic contention is that centralized bureaucratic forms of government are associated with the growth of large-scale irrigation systems. In the case of oriental societies, he contends, despotic political systems were requisite for the maintenance of irrigated agriculture.

Another goal is to demonstrate that although the recent shift in policy from emphasis on large-scale, high technology, and centrally managed private systems was precipitated by disaffection with poor agricultural returns, managerial bottlenecks, and high costs of public irrigation, the transition is not simply one of scale, rather it demonstrates a fundamental change in concept. Put differently, it is not a mere linear reduction in the physical size and costs of irrigation systems, but is a qualitative change involving restructuring of three key aspects of irrigation: management planning, goals, and organization. Further, it is suggested that the pioneers of this new policy got their inspiration from indigenous irrigation models.

The bulk of this paper draws on material taken from a study, "Indigenous Irrigation Systems in the Kerio Valley, Kenya," under preparation by this writer. Research (1979-83) was financed by the University of Nairobi. Complementary material was derived from a consultancy study, "An Analysis of Small Scale Irrigation in Kenya," commissioned by the USAID, Kenya. The study covered twenty small-scale schemes in November/December 1985. This writer is indebted to these organizations for their support.

Research and writings on irrigation in Kenya are not only fragmented and scattered, but also lack focus mainly because most of the work is commissioned by a congeries of agencies involved in irrigation development with no clear direction or coordination. Another contributing factor is that irrigation has not yet been recognized as a discipline by the social science faculties at any of the universities in Kenya. As far as indigenous irrigation goes, authors often dispose of it in less than a paragraph. For example, according to Palutikof (1979:66), the era of indigenous irrigation came to an end in the 1950s. As will be shown, there are numerous instances of indigenous irrigation in the country. Furthermore, we do not even know its full extent as more schemes are still being "discovered."

Almost every major European and North American country has commissioned one or two short-term consultancy reports on Kenyan irrigation. However, comparative or analytical writings are both few and far between; among these are Kortenhorst (ed.), 1983; Post, 1982; Walker, 1982; Underhill, 1982; and Arao, 1984. There are also several conference papers that have never been published.

Work on indigenous systems only emerged in recent years. The best researched systems are those of the Kerio and Rift valleys. This writer has completed a study that analyzes the history of furrow construction, water and land rights, and demographic and ecological aspects of the Kerio Valley systems. A portion of this study appears in a publication including Soper's (1983) study of the physical aspects of forty-three furrows in the Upper Kerio Valley (Kipkorir, B. et al., 1983). Cappon (1984) provides engineering, agronomic, and demographic data for forty-eight furrows in an unpublished paper. Dube and Kwaasteniet (1983), in an unpublished consultancy report on female labor, provide useful information on farmer organization.

Anderson's (1981) historical account of the nineteenth century Il Chamus systems contrasts sharply with Little's (1985) analysis of contemporary indigenous irrigation, which has reemerged during the last twenty years but under changed ecological conditions and organizational forms.

Fleuret (1985) portrays the Mwatate systems in Taita. This qualitative material is complemented by Rugenyi's (1982) quantitative survey of 143 furrows in the same highlands.

Unfortunately, these data have not yet been analyzed. The Vanga systems in Kwale District have also not yet been systematically studied.

A brief outline of the role of agriculture in Kenya's social and economic development opens the discussion. This is followed by an examination of the country's land, irrigation, and employment potential. A resume of the historical development of irrigation opens the way for a detailed analytical account of irrigation development based on three criteria: goals, organization models, and agro-economic performance. This is followed by an outline of the characteristics of current small-scale irrigation systems that are being promoted by the government.

THE ROLE OF AGRICULTURE IN THE ECONOMY

The pivotal role of agriculture in the Kenyan economy is demonstrated by its contribution to five important sectors: GDP, food, employment, income, and foreign exchange earnings. For the period 1964-72, agriculture contributed 30 to 40 percent of the GDP; by 1982, it had declined to 33 percent. Since independence, except in a few drought years, Kenya maintained self-sufficiency in the production of basic foodstuffs such as maize, wheat, dairy and meat products, etc. However, the severe droughts in 1979 and 1980 served warning about future prospects for chronic deficits in all the major foodstuffs. For example, maize production grew at 4.6 percent per year between 1964 and 1972, but by 1972-81 growth had declined to only 2.7 percent annually.

A government food policy paper (Republic of Kenya, 1981) set food production targets that are much higher than the rates achieved in the past decade when population growth was slower than today. Apropos of this, it stipulated that the strategic food reserve be increased by one-half.

Agriculture also provides most of the jobs in the economy. According to the ILO, 62 percent of the jobs are in the agricultural sector, with 20 percent in the nonagricultural sector, leaving 18 percent unemployed. About 85 percent of the agricultural jobs are in the small-holder sector (with less than 8 ha of land). At most, the nonagricultural sector will absorb 62 percent (8,829,190) of laborers by the year 2003---merely to maintain the status quo.

Agriculture is also the main source of rural income. Small-holders account for 75 percent of agricultural produce and 55 percent of marketed output from which they derive their incomes. But sales should not be interpreted as necessarily reflecting surplus production. Even deficit producers must sell food to meet other needs such as those for health, education, etc.

Agriculture is the main contributor of foreign exchange earnings to the Kenyan economy. In 1982, the percentage was 52, and the combined share of coffee and tea, important export crops, was 40 percent (Republic of Kenya, Economic Survey, 1983). Agriculture also indirectly supports manufacturing through its contribution of raw materials to agribusiness (food processing, tobacco, textiles, etc.), which accounts for 40 percent of manufacturing.

Significantly, while food crop output recorded lower growth rates than population growth, cash crop rates were always higher. In 1972-81, coffee production grew at 5 percent a year, cotton at 6.7, sugar cane at 11.3, and tea at 9.3.

CONSTRAINTS TO AGRICULTURAL AND FOOD PRODUCTION

Major constraints are periodic droughts, land scarcity, land tenure problems, falling value (currency devaluation and price slumps), and inadequate marketing and pricing institutions.

Only about 7 percent of the country receives adequate and reliable rainfall, another 5 percent has good soils, but rainfall is not so reliable. Optimistically, arable land can be estimated at only 18 to 20 percent of the total surface area. The rest is suitable for livestock production only. The distribution of arable land is also uneven; the three most densely settled provinces occupy only 6 percent of the country, but their share of arable land is almost 30 percent. Furthermore, the 44 percent population share in these provinces exceeds their proportion of arable land.

Land use and tenure arrangements reveal the following pattern. There is no land ceiling or bottom, no zoning system, or land tax. In the absence of these regulatory mechanisms, land speculation or mismanagement cannot be prevented or curbed; similarly excessive land fragmentation or misallocation cannot be controlled either. Instead, land is transacted on the "willing seller, willing buyer" basis. This has brought about a distribution pattern whereby 75 percent of the small-holders have less than 2 ha of land, and 54 percent have less than 1 ha.

The problems of currency devaluation and the falling value of export crops are equally crippling. In December 1981, the exchange rate of US $1 was KShs 7.54, a year later it increased to 12.5, and in 1986 it was 16.0.

IRRIGATION AND DRAINAGE POTENTIAL

Estimates of irrigation and drainage potential vary widely depending on sources and distinction between drainage and irrigation. Here, separate figures are presented for irrigation and drainage, but wherever appropriate, the discussion for both activities will be integrated. One feature of the figures, regardless of their source and refinement, is that revisions upward occur frequently as the country's capacity for data gathering on soil and water expands. In the mid-1970s, the potential was estimated at about 250,000 ha of irrigable land by the Ministry of Agriculture and Livestock Development (MALD). Later, this was revised to 500,000 ha; more optimistically, others put the potential between 600,000 and 900,000 ha (Toksoz, 1981). Irrigation potential as a percentage of arable land (7.5 million ha) is 7 to 12 percent. Another way of interpreting this statistic is to say that arable land can, through irrigation, be increased by a margin of 7 to 12 percent.

In terms of resource (investment and research) allocation, drainage has received negligible attention, even though it offers greater potential at less cost. Estimates also vary;

MALD estimates that 600,000 ha of land could be reclaimed via drainage, but others give a figure of up to 1 million ha (Ruthenberg, 1978). As a proportion of arable land, drainable land accounts for 8 to 13.3 percent.

Drainage and irrigation therefore offer an additional 15 to 25 percent of crop land potential. How much of this potential has been realized so far? The answer is again variable. For example, it is virtually impossible to separate the irrigated land figures from those for drained areas as provided by the National Irrigation Board (NIB), which also gives figures on an annual basis. As a result, total irrigated area of each scheme varies from one year to the next. In addition, the Irrigation and Drainage Board (IDB) within the MALD is gradually taking over schemes previously run by private organizations. Table 1 summarizes some of the estimates of the area actually under irrigation, but in fact some of the schemes are on drained land (e.g., Bunyala, West Kano, etc.).

If the figure of 1,200,000 ha is taken as the combined potential for irrigation and drainage, then only 2 to 5 percent of this has so far been developed.

EMPLOYMENT POTENTIAL IN IRRIGATION ACTIVITIES

No work has yet been done on the labor force currently involved in irrigation and drainage activities. One can only attempt to make rough estimates from some of the published material. The reports of the NIB give only the number of tenant farmers on the schemes and their dependents (some of whom provide labor) while hired labor is not included. For illustrative purposes, let us use the NIB figure of 5,289 in 1979-80 as a basis for estimating the labor force.

For each farmer, five dependents are assumed (in 1979, the average household size was 5.2 in Kenya), and, if the NIB's share of 30 percent of irrigated area is also valid for population, a total population of 105,780 is involved in irrigation activities.[1] Nationally, 48.3 percent of the population was, according to the 1979 census, aged 15 to 64 years. If this

[1]The figure of 30 percent is calculated from Palutikof (1979:74, Table 1).

ratio is also assumed for the smaller population, we get 51,092 persons. At the rate of 22 percent decline, the labor force is 39,852 in an area of 58,000 ha.[2]

As will be shown shortly, the public and private commercial sectors use high and capital-intensive technology. Toksoz (1981) developed a model that assumes labor-intensive methods for an accelerated program starting in 1979 and continuing to 2003. Under this plan, only 200,000 ha of irrigated and 200,000 ha of drained land (representing about one-third of the combined potential) would be developed by the public sector. Labor would account for 60 percent of the budget, and the multiplier effects of the program would also create a cumulative total of 722,000 jobs for the period 1979-2003.

THE HISTORY OF IRRIGATION DEVELOPMENT IN KENYA

Palutikof (1979) divides the history of irrigation in Kenya into three broad phases: traditional (up to 1950), colonial (1950-1960), and present-day irrigation. Arao (1984) divides it into five stages: slave, traditional, wartime (1930-1950), postwar, and current irrigation. This paper traces irrigation development along three broad phases---precolonial, colonial, and independent irrigation, but within each of these phases there are important subcategories as indicated below.

PRECOLONIAL IRRIGATION

Precolonial systems were installed prior to 1880 and can be subdivided into clan-based systems and slave labor dependent systems.

Clan-based Irrigation

The largest concentration of indigenous systems are found in the Rift Valley. Irrigation has existed along the Elgeyo Escarpment for more than 300 years and serves a command area of about 20,000 ha. The Il Chamus of the Lake Baringo lowlands developed

[2]These calculations leave out the labor force in the indigenous irrigation areas.

the basin system and became so successful that Arab caravans traveling to Uganda used to stop over to buy foodstuffs. However, when the parent river changed its course in 1918, the inhabitants reverted to their former nomadic pastoralist economy (Anderson, 1981).

Other documented systems are found in the Taita Hills (Fleuret, 1985; Rugenyi, 1982). This writer was also informed about irrigation systems along the slopes of Mt. Kilimanjaro and Mt. Kenya. The Pokomo of Lower Tana River grew rice under tidal irrigation for several centuries, as did the Turkana of northern Kenya.

Slave Labor Dependent Irrigation

This form of irrigation is associated with the colonization of Kenya's coastal belt by Arabs about 3,000 years ago (Taylor, 1984). The Arabs developed irrigation systems using slave labor to grow mostly arboreal crops, such as coconuts and cashew nuts. The region also originally exported rice, but with the abolition of the slave trade, the area later became a net importer (Cooper, 1981). Vestiges of Arab feudalism still exist. The Wavumba, a people of mixed Arab and Bantu races, inherited the land. They rent it to the Digo, who divert water from the Umba River to grow rice and maize on a command area of about 400 ha. This, therefore, was the first instance of an irrigation system maintained through coercion with a centralized polity.

COLONIAL IRRIGATION

Prewar Colonial Irrigation

These systems may be divided into prewar, wartime, and postwar colonial periods. Some of the Indians brought to work on the Uganda Railway were allocated plots in the Kibwezi/Makindu area. The plots were used to produce horticultural crops for the work force on the Uganda Railway. At the completion of the rail line, the accompanying irrigation schemes disintegrated. In the 1930s, the central government drafted several blueprints for irrigation development: the Parkerra River irrigation scheme (1929), the Yatta

Canal (constructed in 1936), and the rehabilitation of the Il Chamus systems. With the exception of the Yatta Canal, these plans were never completed because of funding constraints.

Wartime Colonial Irrigation

The Second World War greatly increased food demand, and as a remedial measure, irrigation systems were constructed in Karatina (Central Province) and the Lake Victoria Basin where, of the 8,000 ha suitable for rice production, 28 percent was actually cultivated. Coercion is reported to have been used in the construction of the 45 km-long canal at Agembo. Most of the schemes constructed during this period such as Obange, Awach Kano, Gen-Rae, K'Opudo, Kore I and II, and Wasare were rehabilitated by the government.

Postwar Colonial Irrigation Activities

The postwar years were characterized by three major bottlenecks to the development of irrigation. First, the productivity of African agriculture progressively deteriorated because of intensive land use without accompanying fertilizers. In 1945, the administration set up the African Land Development Program (ALDEV) to revive agriculture. This program included an irrigation development component. Seven new schemes were started at Ishiara, Perkerra, Makajini, Kimorigo-Kamleza, Mwea-Tabere, Hola, and Kiboko.

Second, according to the 1948 national census, the annual crude rate of natural increase (CRNI) was a high 3 percent. Third, the combined strains of population pressure and the attendant increase in food demand and land needs, coupled with declining yields, led to armed rebellion by the Africans in the early 1950s. The colonial administration tried to quell the rebellion through the instigation of the Swinnerton Land Reform of 1953. The aim of the policy was to create an African middle class with vested interests in the colonial system. For the first time, Africans were allowed to grow lucrative high-value crops such as coffee, tea, and pyrethrum. They also qualified for credit facilities and farm inputs, provided they had individual title deeds, and land became legal collateral. To facilitate these arrangements, a new system of individual land tenure was introduced, replacing customary law.

The colonial administration also deployed African prisoners captured during the rebellion to work on public irrigation schemes. This was the most decisive move to establish Wittfogelian irrigation.

INDEPENDENT IRRIGATION

Large-Scale Irrigation

Initially, official policy was ambivalent. Although the government verbally stressed the goal of resettling the landless, it actually gave more prominence to economic goals (contribution to the GDP, generation of incomes, and high yields). There was to be no room for inefficient producers on irrigation schemes. This was the essence of the legal instrument enacted by parliament in 1966 to regulate the operations of the National Irrigation Board (NIB), which manages public schemes.

Soon after the establishment of the NIB charter, disaffection with large-scale schemes surfaced. Costs were very high, yields were poor, the schemes were seen as too wieldy to manage, and social analysts criticized scheme planners for ignoring social problems, such as the rights of tenants and their dependents who had no legal recognition.

Small-Scale Irrigation Schemes

The disillusionment with large-scale schemes gave impetus to diversified irrigation development. Small-scale, government-assisted schemes were started as early as 1967. This was followed by a series of reorganizations within the MALD, culminating in the creation of various structures to cater to small-sized irrigation schemes.

Small-Scale, NGO-Sponsored Irrigation Projects

Several Christian churches started irrigation schemes, mainly in nomadic pastoralist regions, with the goal of helping to alleviate the traumas of periodic droughts. This form of irrigation departs from all others in that the sponsors and assisted communities often have no prior experience with irrigation.

Private Commercial Schemes

There are two types: large and small systems. The former are organized by large-scale farmers growing high value crops. Ninety percent of farms over 50 ha are believed to be served by supplementary irrigation (Palutikof, 1979:72). These constitute about 20,000 ha of land. Small schemes are rapidly mushrooming, especially in the Lake Victoria Basin and parts of the montane range of Mt. Kenya. It is not easy to estimate their combined size as many of them are now being taken over by the Provincial Irrigation Unit (PIU) program.

This historical survey illustrates the varied circumstances under which irrigation development has taken place in the country. The section below takes up some of the analytical issues briefly touched upon above.

CAUSAL FACTORS FOR THE TRANSITION TO COMMUNITY-MANAGED IRRIGATION

The transition to community-managed irrigation in Kenya is explained by the convergence of five factors during the 1970s. These are phenomenal population growth; declining agricultural production; the response of missionaries to the prolonged droughts of the 1970s; the expatriate factor within the MALD; and the shift from centralized to district development planning. Each of these processes is briefly outlined.

1. Population Pressure

In Kenya, very high and rising birth rates are now combined with relatively low and declining death rates. As a result, the country is experiencing an unprecedented annual growth rate of 4 percent. At this rate, population doubles in just seventeen years. When surveys in 1973 and 1978 revealed these alarming rates, the impetus for seeking accelerated food production through greater land use intensification gained momentum.

2. Declining Agricultural Production

At the beginning of the 1970s, the outlook for the agricultural sector looked very grim. Yields fell at the same time as world export markets declined or disappeared. Further, the value of the Kenyan shilling dipped drastically. This forbidding background forced planners to reexamine agricultural strategies including irrigation.

3. Church Initiatives

The early 1970s were also marked by prolonged droughts that had a devastating effect on Kenya's pastoralists, who form about 25 percent of the population but occupy 75 percent of the land area. Missionaries tried to help but lacked basic technical skills in agriculture and irrigation. However, they were not deterred but learned by trial and error. Because capital was scarce, they relied on low-cost technology and encouraged community participation in irrigation organization and management. In 1981, the National Christian Council (NCCK) organized a national conference on irrigation development for its workers. Speaker after speaker advocated small-scale, community-managed irrigation. However, like the expatriate group in the MALD, they had no conceptual framework for modeling 'small-scale' irrigation. It may well be that the presentation of the Marakwet irrigation scheme (Ssennyonga, 1983) at the conference provided a useful referral model for future planning.

4. The Impact of Expatriates in the Ministry of Agriculture

During the 1970s, a group of articulate expatriates, notably Toksoz (1981), Post (1982), and Cnoops (1978), initiated a vigorous debate within the MALD and strongly criticized public irrigation policy (or lack of it). Among the expatriates, the Dutch group deserves special mention as they pioneered the reorganization of the MALD, culminating in the creation of the Provincial Irrigation Units (PIUs). Incidentally, some of these workers at one time or another also served under church schemes.

5. The Shift from Centralized to District Focus for Development

In the 1970s, government planners began to discuss decentralizing development planning to the district level. As a side effect, the effort to scale down the operation of irrigation to lower levels met with more success. By 1984, when the "district focus policy" was implemented throughout the country, irrigation decentralization had already reached the district level.

PUBLIC IRRIGATION

Perhaps the basic feature of Kenyan public irrigation schemes is the peculiar circumstances out of which they originated. They were not designed to fulfill either the general or specific goals of increased agricultural output and food production as outlined earlier. According to Chambers and Moris (1973), the first three schemes, Mwea, Perkerra, and Hola, were initiated by the colonial government as work camps for the captured freedom fighters and other landless Kikuyu who were forced out of the Rift Valley Province during the Mau Mau War in the early 1950s. They worked on the construction of the water canals and were later resettled on the schemes to produce export cash crops such as rice, cotton, and sugar. They worked and lived under highly regimented conditions. For example, the tenants had to obey rules stipulating what and when to plant and were on yearly tenancy contracts under which failure to comply with the rules led to dismissal from the scheme. To this day, the NIB charter still retains the long litany of hard-line rules. Today the NIB is operating eight irrigation and drainage schemes (Table 2).

The NIB charter gives mandates to open up new schemes on condition that they are on a sound financial footing, that tenants earn high incomes, and that yields of the selected cash crops remain high. As the figures in tables 2 and 3 indicate, growth in area stagnated while tenant incomes were above the average for small-holders elsewhere in the country. As the figures in Table 3 show, however, there is considerable variation among the various schemes. Despite the high income performance of tenants, the schemes are a drain on public funds, only Mwea pays its costs.

In 1977, the government launched a new irrigation venture, the Minor Irrigation Programme (MIP) within the MALD relief program to alleviate the plight of drought victims in pastoral areas. By introducing irrigated agriculture as an alternative to pastoral agriculture, planners hoped to reduce the strain on public funds spent on famine relief. Schemes were started along the Turkwell River at Katilu in Turkana, at Amolem in West Pokot, in Isiolo, and elsewhere. By 1979, there were ten such projects covering a area of 920 ha with 1,975 families at an average of 0.5 ha per family. The NIB programs, notably Mwea, Hola, Bunyala, and Perkerra, involved a fundamental change in land use from arid, unimproved to intensively farmed and irrigated. MIP schemes sought to change nomadic pastoralists into farmers and irrigators. These schemes were an economic drain on the national treasury and contributed virtually nothing to the national or local economy.

In 1970, the government launched yet another program, the Small Scale Irrigation Unit (SSIU), within the MALD. Its task was to initiate small, district-based projects. The five-year district development plans in the Kerio Valley Basin, for example, were replete with irrigation projects, but like virtually all the other SSIU schemes, the results were very disappointing (Post, 1982).

In 1977, recognizing the need to coordinate the various small-scale programs and to decentralize irrigation planning and management as well as to develop appropriate policies, the MALD formed the Small Scale Irrigation Development Project (SSIDP). PIUs were also started. The main driving power behind this program was the expatriate staff seconded to the MALD by the Dutch Government.[3]

[3]Officers also stated that the program included research within the MALD and training at the University of Nairobi.

It may be useful to pause here and outline some of the constraints encountered in public irrigation development. It has already been shown how spatial and employment expansion stagnated. These and other problems raised serious doubts about the future of irrigation development in Kenya.

According to officials in the MALD, the most crippling bottleneck is the prohibitively high cost of schemes. The MALD estimates that the MIP and SSIDP or SSIB schemes cost US $7,700 per ha, while NIB costs range between US $10,500 (Tana Delta) and US $26,900 (Bura). Bura scheme alone accounts for 25 percent of the development budget of the MALD, which estimates that to irrigate and drain 20,000 more hectares from 1984-2000 will cost 50 percent more than MALD's current development expenditure. The big question is can the government continue to spend money on irrigation at this rate?

This high level of expenditure is not inherent to irrigation as such, it is largely due to the capital-intensive technology used. Other budget inflators include the management style and high consultancy fees. For Bura, consultancy fees amounted to KShs 133,500,000 and accounted for 9 percent of the budget. Toksoz (1981) estimates that a mere 1 percent of the consultancy and engineering fees (earmarked for expatriates) in the government's 1980-2000 irrigation program is enough to meet the training needs of 100 Kenyan engineers abroad. The accelerated model for irrigation development formulated by Toksoz (1981) and referred to earlier needs only 34 percent of the current expenditure incurred by the NIB (per hectare). The program could be made more cost-effective if the process of decentralization were to be speeded up and accompanied by other measures.

Even with the establishment of the SSIB, it remains doubtful if the problems of lack of coordination and policy can be resolved. One of the stiffest hurdles is institutional; there were and still are far too many government bodies participating in irrigation development without an institutional channel for streamlining activities. Apart from the MALD, the Ministry of Water Development plays a key role (engineering survey work, granting permission to private organizations/individuals to use water sources for irrigation), there is the NIB, the Kenya Soil Survey, and the three river basin development authorities. Without some form of legal modification in their charters, coordination is impossible.[4]

PRIVATE IRRIGATION SCHEMES

The schemes discussed under this heading include a diverse range of technologies, crops, sizes, and goals. Therefore, they are logically categorized by management organization into commercial/large-scale schemes, church run, and finally, small-holder irrigation works.

Large-scale commercial irrigation covers only a small fraction of the total land area of farms. Palutikof (1979:72) estimates that 22,000 ha, of which 20,000 ha are in the high potential zone, are under irrigation. If the total area of large farms in the country is 2,500,000 ha, then irrigated farms constitute only about 1 percent of the total area. Irrigation on these farms supplements rainfall during periods of drought or dryness in high potential areas. The goal is to increase cash earnings from high-value crops such as coffee and vegetables, which are primarily grown for overseas markets.

The choice of high-value crops and international markets makes it economically feasible to use capital-intensive methods. The cost per ha of these schemes is about the same as those under the SSIB, but much lower than the NIB. Critics of this form of irrigation point out that it is a drain on foreign exchange because it uses expensive imported machinery and that it is successful because of special fiscal advantages afforded capital-intensive schemes.

The label "church" denotes a congery of churches with uncoordinated irrigation schemes. The presentation here is based on papers presented at the NCCK conference on

[4]Dube and Kwaasteniet (1983) report that the Nakuru-based Provincial Irrigation Unit had to shelve an irrigation project (for which money had already been spent) when they discovered that another irrigation project was already planned in the same area (Sangat/Weiwei), West Pokot District. Besides these government institutions, there are numerous donor agencies sponsoring irrigation schemes. These include the Netherlands, Denmark, Norway, West Germany, Belgium, Italy, Great Britain, the EEC, the World Bank, FAO, Japan, and Christian churches.

irrigation in Nairobi (1981). This is complemented by information collected during interviews with officials at the headquarters of the NCCK.

Church schemes share at least two characteristics in common with the government's earlier MIP ones; the goal of alleviating food problems among pastoralists in arid lands, and the fact that they are small-scale operations covering a total land area of about 350 ha with an average family holding of only 0.5 ha. Costs per ha are much smaller than even those of the revised SSIB projects, at KShs 4 to 5,000 (1982, US $365-453).

Cost-effectiveness is the direct result of the choice of so-called appropriate technologies, e.g., ox-ploughs and the absence of consultancy fees as many of the schemes are not preceded by feasibility studies or elaborate planning. They usually bear the stamp of the personality of the individual pragmatic missionary. According to the NCCK officials, government officers refer to church schemes as "primitive."

Another area of contrast between church and public schemes is the organization and management of the scheme. Church schemes generally place the responsibility of running the schemes on the community. Beneficiaries are made to understand from the beginning that they, and not the church, will be responsible for system operation. Although the church provides funds and technical staff, the community fixes the irrigation turns, organizes the maintenance work, including the imposition of sanctions to defaulters. The NCCK officials stated that this was in sharp contrast to the nearby FAO and government schemes where the people expected that the schemes would be run on their behalf by the outside agency responsible for initiating them.

Church programs also include a welfare component. For example, pastoralists are given a general education to help them to adapt to the new sedentary way of life, including instructions in food preparation, nutrition, childcare, etc. But herein lies the potential for ambivalence. The missionaries declare that they do not intend to change the pastoralists radically to the extent that they have to abdicate pastoralism. This is why holdings are small, and allowance is made for retaining family herds. The problem is, where? When herds are kept near the scheme as in Isiolo, Rapsu, etc., problems of overgrazing are observed. Where herds are kept further afield, families cannot cope with the dual demands of the agricultural and pastoral economics.

Another dimension of ambivalence in church policy is illustrated by an account of the Amolem scheme in West Pokot by Schwarz (1982). Choice of farmers to participate in the scheme was principally on the basis of physical ability to work, hence young, able-bodied males were selected, even though they were not the most destitute. They were given ownership and managerial rights over the plots, although their aged parents accompanied them. At harvest time, severe conflicts erupted between the young men and their fathers over the right to crop disposal.

Pastoralist production and property ideology distinguishes between management and ownership. The son often manages the herd, but it is his aged father who exercises ownership and disposal rights. At the scheme, the otherwise destitute senior elders tried to exercise their 'rights' by deciding what proportion of the harvest was to be sold and by demanding to keep the money. When the young men protested, they were branded rebellious. Ironically, where the elders still had some stock left, they also had a bargaining chip. The young men need stock because bridewealth is not payable in crop equivalents.

These observations illustrate the myriad of factors that can cause problems, especially where systems are initiated by an outside agent with an inadequate understanding of the irrigators' systems of organization and production. It is this awareness, together with the agronomic and economic constraints discussed, that finally led the government to adopt an altogether new irrigation policy in the 1980s.

CURRENT IRRIGATION POLICY

Current irrigation policy is divided along two lines. The original Wittfogelian model--typified by public schemes emphasizing export substitution/cash crop/hard-line control of farmers---still widely persists. The only measure taken recently has been to remove the costliest scheme, Bura, from NIB control and give it autonomy. The newer policy orientation is reflected in assistance to small-scale irrigation schemes belonging to communities with an *a priori* irrigation organization and at their express request. More importantly, at the completion of the rehabilitation projects, scheme management is returned to the communities, which maintain them with minimal technical assistance from the government.

This is not a mere linear scaling down of irrigation operations, it is a radical break from past trends. This willingness on the part of government to work with water users' organizations was matched by a dynamic response from the people. This is anchored in Kenya's strong tradition of working together, symbolized by the term harambee (pulling together). It is estimated that about 10 percent of national development revenue is mobilized through self-help projects that local communities identify, plan, and implement. This tradition allows localities to take the initiative in planning community projects. Already the IDB and its PIUs admit that they can only assist about one-half the number of water users' groups requesting help.

CHARACTERISTICS OF PRESENT-DAY SMALL-SCALE SCHEMES

As noted from the foregoing account, present-day, small-scale schemes can be envisioned as a mosaic composed of several parts and patterns. On the basis of seven criteria, a dual typology of schemes, namely clan-based and bureaucratic systems, is developed below. The criteria are origin, goals, organization and management structures, technology, ownership of water, land and physical structures, and finally, functions of water users' organizations (allocation of water, maintenance of conveyance structures, enforcement of discipline, resolution of conflict, etc.). However, no formal study of the organization and management of these schemes was made. This effort relies on fragmentary information collected by this writer. As a result, the framework and the generalizations based on it can only be taken as provisional.

CLAN-BASED IRRIGATION SYSTEMS

Such systems were largely initiated in the nineteenth century, are organized and managed according to clan-based principles, and operate with rudimentary technology. The communities construct and own them; they also own the land communally. The central government owns all water resources by law and requires systems to obtain permission to remove water. Precolonial systems, however, predate this law, and the communities do not even know of its existence, nor do they have water permits. Water uses (domestic consumption, irrigation, and livestock production) are, by design, integrated. The communities allocate water and mobilize communal labor by egalitarian principles.

BUREAUCRATIC SYSTEMS

Many of the systems categorized under this heading were started during the colonial era, e.g. Mitungu, Ishiara, Awach-Kano, Kore I & II, and Taveta; but an even larger number came into existence in the post-independence period. All of these are organized on bureaucratic principles, including formalized roles and affiliation to modern institutions such as banks and government ministries. In many cases, the physical structures were designed and constructed by outsiders; some use modern technology such as pumps and sprinkler systems. In most cases, land ownership is problematic. Irrigation is principally for cash crop production---cotton, vegetables, rice, etc. Water serves exclusively one goal---irrigation. In general, all government-assisted schemes approximate this model.

MAJOR CONSTRAINTS TO THE DEVELOPMENT OF SMALL-SCALE SCHEMES

Government/donor assistance permitted the rapid expansion of the number and complexity of tasks that water users' organizations (WUOs) assumed. Most of these organizations came into existence during the last five years, so performance of WUOs has not been tested.

Both the IDB/PIU bureaucrats and farmers concede that marketing is a bottleneck for WUOs. Complicating the matter is the fact that most of the schemes are cash crop oriented.

Some depend on overseas markets that are notoriously unstable. Thus, it may be a case of ill-placed optimism to expect village farmers to cope with year-to-year instability.

Irrigation goals should, on the one hand, be consistent with both the stated national objectives of economic and social development, and on the other, the specific goals of agricultural production. The Kenyan government is determined to achieve self-sufficiency in the production of principal foodstuffs; it also recognizes the grave unemployment problem in the country. Viewed against this backdrop, the policy of encouraging cash crops at small-scale, government-assisted schemes does not appear to be in accord with the priority order established by the government itself.

At most of the small-scale schemes, irrigators either do not own the land or have insecure land rights. Given the current policy objective of handing the schemes back to the communities at the completion of the rehabilitation programs, there is need to ensure that present land use arrangements do not disintegrate.

In areas where land is not yet registered under individual title holders, a whole range of new issues emerges. As has been the case elsewhere in the country, land registration is accompanied by severe social and family conflicts because of insufficient land resources. Land registration also circumvents communal ownership of areas used to obtain fuelwood, house construction materials, and grazing resources. In many cases, perceived equity may be lost.

The position of women, who provide the bulk of labor, is even more precarious because women do not traditionally own land. Male chauvinism may lead landlords to demand lease renewal at terms unfavorable to women.

No concrete measures have been taken to strengthen WUOs. This is partly because the IDB/PIUs have no properly trained personnel to offer this service. The danger is to envision this problem as an extension issue, solved by training more extension staff. Actually, a new worker, ideally with social science training and versatile in irrigation organization, is required. Unfortunately, at the moment none of the existing training institutions in the country offer this type of education. At the same time, the present staff structure in the government has no room for social scientists in the MALD. There is, therefore, a need to restructure the staff establishment.

PECULIAR PROBLEMS OF CLAN-BASED SYSTEMS

Clan-based schemes pose challenges peculiar to their cultural, environmental, and agronomic circumstances. For example, the systems at Vanga and in the Kerio Valley have the disadvantage of being located in isolated geographical settings. The Kerio Valley suffers from extreme physical and economic isolation. Engulfed between two steep highland ranges, it has no reliable roads, no means of private or public transportation in the entire 160 km-long valley. Under these conditions, it is futile to promote production beyond household subsistence needs because there is no outlet for surplus production.

There are, nonetheless, cases that call for immediate assistance just to sustain production at subsistence level. At Vanga, the erection of a permanent headweir is a case in point. A weir would considerably reduce the large labor budget.

Although there are catalytic agents at work (a need for cash to finance school education, pay health bills, and purchase processed foodstuffs such as cooking oils, maize flour, sugar, etc.), there is a need to raise the people's perceptions and aspirations to levels beyond their current subsistence life styles. This is, no doubt, a subtle and long-term problem.

STRENGTHS AND POTENTIAL FOR BUILDING EFFICIENT WUOs

The lively harambee movement is itself a glowing tribute to Kenyan leaders who transformed traditional African values for cooperation in productive activities into a dynamic force for modern development. The observed willingness by farmers to work together owes a lot to this tradition. Two measures are singled out for praise. These are the willingness to work with existing WUOs, making the presence of farmer organizations a precondition for assistance; and the decision to give all the responsibility for O&M back to the farmers at the completion of the project phase. This contrasts sharply with government policy for public irrigation systems, where the state owns the systems and runs all the O&M functions.

CONCLUDING REMARKS

The peculiar historical, political, organizational, and agronomic circumstances were analyzed that have, since the 1900s, shaped the development of irrigation in general and the transition from authoritarian systems to small-scale, community-managed schemes in Kenya. Right now, there are three irrigation traditions: (1) indigenous irrigation; (2) large-scale, public schemes; and (3) small-scale, community-managed systems assisted by government or donor agencies. These were shown to operate on entirely different principles of organization and management; they pursue different goals and play different functions.

Indigenous irrigation has an organizational basis in clan-based principles. It emphasizes subsistence production and is complementary to other equally important economic activities. Colonial irrigation, like agriculture and the economy in general, was subservient to broad colonial objectives. It was developed in an uncoordinated, ad hoc manner to serve expedient needs as they arose---to feed the workforce on the rail line, to produce food for world war needs, and to contain and absorb disaffected and landless freedom fighters.

Independent government policies have been ambivalent. There was a reluctance to dismantle colonial irrigation, mainly because the state redefined the goals of irrigation. On the one hand, irrigation schemes served as a means to resettle the landless and create employment, on the other, the emphasis on import substitution forced the government to promote cash crop production and retain hard-line regimentation to ensure high output and incomes.

In the meantime, the initial high performance of the economy and agriculture in particular (1963-70) began first to stagnate and later to decline at the onset of the 1970s. At the same time, some of the pressures that initial post-independence success kept at bay started to get out of hand. One of these was the realization that unprecedented population growth was narrowing the gap between the capacity for resource development and population growth. This in turn raised serious doubts as to whether the economy and agriculture would be able to meet the major challenges of achieving broad self-sufficiency in food production, creation of employment, and generation of rural incomes and foreign exchange. It also became more difficult to establish a priority order among these goals.

More specifically, the expansion of public schemes after independence created problems. With the attainment of independence, coercive elements could not be replicated in the new schemes, management from afar made it difficult to achieve efficiency, and yields began to decline. Disaffection set in, resulting in a lively debate led by expatriates, particularly the Dutch group within the Ministry of Agriculture. This created a favorable atmosphere for introducing alternative irrigation systems---MIP, SSIB, etc. Finally, the government undertook the monumental step of rejecting large-scale schemes in favor of assistance to existing small-scale, community-owned systems. At the completion of the assistance program, the schemes will be turned over to the communities, which will assume full responsibility for their organization, management, and maintenance activities. Currently, there is an undisguised sense of euphoria among government and donor agencies that finally the right formula has been found. This raises the question of whether this hope is well-founded.

The fundamental issue is whether or not the change in emphasis to small-scale has resolved the problems associated with large-scale systems. Because of the fact that this policy change has been in force for a very short time (less than three years), most of the crucial issues cannot be answered one way or the other. There is no evidence, for example, to show that agricultural output at small-scale schemes is greater than it is at large ones. There is, however, ample evidence to show that costs were drastically reduced. These schemes also appear to be easier to manage, although formal evidence is needed to demonstrate this claim. There is also a need to show whether small-scale systems are always and everywhere more efficient in engineering and economic terms.

Questions have been raised about the capacity of water users' organizations to perform the increasing number and complexity of functions under their responsibility. Related to this is the current inability on the part of the government to assist or strengthen them simply because there are no qualified resource persons in the ministry to do this. The inability of government to build its manpower fast enough to meet the rapidly growing demand by water users for assistance is going to be a grave constraint to irrigation development.

There is evidence, albeit fragmentary, that small-scale schemes are creating employment much faster than large-scale systems, mainly because farmers are asked to contribute labor in the construction phase, and there is less reliance on motor energy. More importantly, the willingness of the government to work with water users' organizations is a crucial step in the right direction. Finally, the enthusiasm and commitment of the farmers to schemes they regard as theirs, coupled with the indigenous harambee spirit (working together), is sure to benefit future development.

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Table 1. Estimates of Irrigated Area by Public and Private Sector.

Source and date	Total ha.	Public irrigation ha.	Public irrigation percent	Private irrigation ha.	Private irrigation percent
Toksoz (1981)	26,000	10,000	38.5	16,000	61.5
Palutikof (1979)	58,600	27,300	46.6	31,300	53.4
Post (1982	26,000	10,000	38.5	16,000	61.5
IBRD (1983)	35,600	12,600	35.4	23,000	64.6

Table 2. Estimated Area Under Irrigation and Drainage in the NIB Programs.

Scheme	Irrigated area in hectares 1973	1980	Percentage change
Mwea	5,700	6,300	+ 10.5
Bunyala	380	258	- 32.1
West Kano	900	1,180	+ 31.1
Ahero	850	1,361	+ 60.1
Perkerra	415	205	- 50.6
Hola	860	892	+ 3.7
Yala	-	600	-
Bura	-	-	-
Total	9,105	10,796	18.6

Source: Compiled from the National Irrigation Board Annual Report 1979-80 and from interviews with NIB officials.

Table 3. Percentage Distribution of Tenants by Net Income Classes, 1978-79.

Net return	Mwea	Perkerra	Hola	Ahero	Wikano	Bunyala	Total
KShs							
0-1,000	1	21	7	27	50	37	12
1,001-2,000	1	12	30	15	22	16	9
2,001-3,000	2	17	48	14	9	17	10
3,001-4,000	3	10	14	9	4	17	6
4,001 +	93	40	1	35	15	13	63

Source: Calculated from NIB Annual Report 1979-80, Table VI, p.8.

THE EVOLUTION OF IRRIGATION POLICY IN ZIMBABWE; 1900-1986

Mandivamba Rukuni

INTRODUCTION

When Zimbabwe attained independence in 1980, it inherited a dual irrigation structure. The larger subsector is composed of commercial, large-scale production based on producing mainly cotton, wheat, tobacco, and soybeans. The small subsector is composed of small-holder schemes scattered over the Communal Areas of Zimbabwe, where the majority of small farmers live. These schemes are largely based on food crops for home consumption, as well as vegetable production for 'local' and urban markets.

The devastating drought of 1981-1984 refocused the government's policy of reducing dependency on rainfed agriculture where this is feasible. One of the key issues is the role of small-holder irrigation, and how small-holders can reduce their dependency on the government by managing their own schemes. Problems related to achieving this overall objective stem from the historical process and evolution of the schemes.

This paper traces the historical process of government intervention in irrigation development since the beginning of the twentieth century to date. This process was accompanied by the dynamic and ever-changing nature of multiple policy objectives.

We will examine how farmers closely identified with earlier developments and how government intervention, starting in the 1930s, reversed this process over a long period. So, while current government policy emphasizes farmer participation and management of small-holder irrigation schemes, there are obstacles to overcome. The obstacles have resulted in little meaningful investment in the small-holder irrigation sector since independence in 1980.

HISTORICAL REVIEW OF SMALL-HOLDER IRRIGATION IN ZIMBABWE

The literature indicates that the history of small-holder irrigation in Zimbabwe can be analyzed within the context of the government's policy over the past six decades (tables 1 and 2).

The period 1912 to 1927 has been described as the period of "incorporation into indigenous agriculture" (Roder, 1965). The Manicaland Province schemes were the first to be developed, and they dominate the history of small-holder irrigation up to the end of the Second World War.

Settlers started to irrigate crops by the beginning of the century in the Manicaland area of Eastern Zimbabwe. In 1980, Mutambara Mission was opened by missionaries, and an irrigation furrow was dug by the missionaries. Subsequent involvement by local peasant farmers can be summed up from the following quotation (Roder, 1965):

> *African irrigation at Mutambara had its beginnings in 1912. This was a year of severe famine. . . . The people near Mutambara Mission took inspiration and encouragement from the example before them and built new ditches to irrigate new gardens. The missionary aided their efforts by supplying wheat seed and sweet potato vines.*

Famine is given as the first major reason why peasant farmers engaged in irrigation in Manicaland Province. As a result, farmers were active participants in the construction and running of their irrigation schemes.

The first active involvement by government in irrigation development is linked to Emery Alvord's appointment as agriculturalist for the Instruction of Natives in 1927. Alvord shaped the development of irrigation in Manicaland starting in 1932 until he was appointed director of the Department of Native Agriculture in 1951. In his new capacity, Alvord became responsible for irrigation development in black areas (now Communal Areas) throughout the country.

When Alvord became actively involved in irrigation development, he was interested in aiding existing projects where local farmers had a significant measure of control (Roder, 1965). Farmers developed small irrigated plots of about 1 hectare or less in size, but they continued to rely heavily on rainfed farming. The main justification for this government aid was famine relief. For a number of decades, Alvord reported that irrigation was a success in famine relief, although this was difficult to substantiate. The important point is that the government did not interfere with the farmers' use of irrigated land.

In 1933, however, this liberal policy began to fade when the government took over the management of the Mutambara project in Manicaland from local farmers. A number of other schemes in Manicaland were also reorganized along authoritarian lines. A water rent of 5 shillings per acre was imposed in 1932 and subsequently doubled to 10 shillings per acre in 1942 (Hughes, 1974). Restrictions were introduced to stop rainfed cultivation by farmers. The government agriculturalists introduced compulsory crop rotations, but these measures were unpopular with the farmers.

Before government intervention in the 1930s, irrigation schemes were built by the communal efforts of local people. The government justified their increased control over the schemes by the fact that they were committing more funds and resources to the irrigation schemes. After the government took over the task of constructing schemes, less consultation and cooperation of local farmers was sought in the development process.

After the Second World War, there was a government drive to expand Manicaland irrigation schemes in order to settle peasant farmers from designated white areas to African Reserves (Reservations). The Land Apportionment Act of 1930 demarcated the country into black and white areas. This act was amended in 1950 to force black farmers to move to designated areas within a five-year period. A number of new irrigation projects were conceived as a means of absorbing the displaced and expanding black population. For example, the Director of Irrigation in Southern Rhodesia reported that (Director of Irrigation, Annual Report, 1950):

> *. . . to accommodate the growing native population every available acre will have to be put to maximum use. There are extensive dry areas particularly in the Southern and South-Western parts of the Colony where the only means of bringing land to proper use will be by large-scale gravity, or where gravity is not possible, by large-scale pumping. These schemes will be very costly, and by ordinary standards, uneconomic, but it may well be found*

that any other solution to the population problems will be still less economic and far more desirable.

The political expediency of settling black farmers, following the amended Land Apportionment Act of 1950, led to the establishment of a number of new schemes that did not meet standard social and economic criteria. This also led to expansion of projects, development of new projects into sandy soils, and the introduction of pumping projects that were more costly to operate than gravity schemes.

The reduced popularity of schemes, combined with rising construction and operation and maintenance costs, led to the Department of Native Agriculture reviewing its irrigation development program. In 1957, the department employed an economist for the first time to look at profitability of small-holder irrigation schemes. The economist came to the conclusion that the small-holder schemes were all uneconomic (Hunt, 1958). An Irrigation Policy Committee was set up in 1960 to examine the strategy of using irrigation as a means of settling black farmers. The recommendations of this committee were as follows (Irrigation Policy Committee, 1961):

(a) Irrigation was not the best way of settling displaced farmers. The population pressure in black areas was temporary and would slacken as more found employment on white farms.

(b) It would be more productive for government to invest in the industrial sector than irrigation.

(c) Future projects should be based on voluntary agreement where settlers will be able to meet the costs of construction and operation and maintenance.

As a result of these deliberations on the irrigation policy, construction of irrigation projects was stopped during most of the 1960 to 1968 period.

After the Unilateral Declaration of Independence (UDI) by the Smith government in 1965, there was a new commitment to developing irrigation projects in Communal Lands (then Tribal Trust Lands) as part of the philosophy of developing rural growth points in black areas to facilitate separate development from white areas. The government set up a parastatal, the Tribal Trustlands Development Corporation (TILCOR), to develop growth points in what are now known as Communal Lands, where small-holder farmers are concentrated.

The growth points based on irrigation were designed to have a large 'core estate' to provide services to settlers. The core estate operates like a large-scale commercial farm, is heavily mechanized and uses high levels of inputs. The existence of a core estate and the settlers would therefore justify further investment into other commercial and industrial ventures. Other social services like markets, schools, clinics, and postal services were also incorporated. In summary, the government's political commitment to developing black areas separately from white areas justified investment into irrigation-based growth points.

After the independence of Zimbabwe in 1980, moves were made to merge TILCOR and Sabi Limpopo Authority (SLA) into the Agricultural and Rural Development Authority (ARDA). Until 1981, The Sabi Limpopo Authority was responsible for the development of large-scale commercial and white settler irrigation in the Sabi Limpopo catchment area. The Government of Zimbabwe has indicated that irrigation will play an important role in transforming the rural sector in the Communal Lands. Government has broader plans in establishing growth points and rural service centers, some of which are, or will be based on irrigation.

As a result of the 1981 to 1984 drought, government decided to encourage irrigation and has set up a fund, the National Farm Irrigation Fund, for this purpose. A total of 12 million of the 18 million dollars is earmarked for large-scale farmers to produce wheat, tobacco, and other cereals. Six million dollars has been earmarked for small-holder schemes on Communal Lands. Government policy has explicitly and implicitly encouraged small-holder farmer involvement in these new efforts. However, substantial problems still exist in trying to implement new schemes in Communal Areas. Before discussing these, the current scope of small-holder irrigation development will be reviewed.

SMALL-HOLDER IRRIGATION DEVELOPMENT IN ZIMBABWE

Zimbabwe has an estimated 151,000 hectares of land under irrigation, as shown in Table 3. Approximately 62 percent of this area is farmed by large-scale commercial farmers, who collectively farmed approximately 93,000 hectares of irrigated land in 1984. About 16,000 hectares of irrigated land are farmed by 6,000 families in eighty-one schemes on Communal Lands. There are, in total, seventy-two government-supported schemes totaling 4,269 hectares farmed by 5,825 families (Table 4). These are under the Department of Agricultural, Technical, and Extension Services (AGRITEX) in the Ministry of Lands, Agriculture, and Rural Resettlement. ARDA has nine schemes totaling 5,320 hectares of which 761 hectares are farmed by 529 settler farm families. The rest of the 4,559 hectares are ARDA 'core estates' operated on a state farm basis.

ORGANIZATION AND MANAGEMENT OF SCHEMES AND FARMER INVOLVEMENT

In 1985, AGRITEX, the national agricultural extension service, took over the management of all small-holder irrigation schemes in Communal Areas (Table 2). Meanwhile, ARDA schemes continue to contain a few small-holders. As is the case with AGRITEX schemes, policy objectives stress the need to increase economic viability and involvement of small-holders in management. ARDA schemes are, however, organized on different lines from AGRITEX schemes. A typical ARDA scheme is split between a large core-estate (state farm) and a small settler section. The core-estate is farmed as a large unit by an ARDA management team. A Settlement Officer, a member of the ARDA management team, is responsible for small-holder settlers. The objective is for the core-estate to provide land preparation, water supplies, credit, and other services to the settlers. The ARDA team, through the Settlement Officer, provides the extension service. ARDA controls the settler accounts and recovers credit through a stop order system in commodities sold by the settlers. However, sometimes farmers are paid late. Also, this system makes it more difficult to effectively involve farmers in decision making. The involvement of farmers in management has therefore become an important policy issue.

Since independence in 1980, Irrigation Management Committees (IMC) have emerged as a type of "water users' association." On both AGRITEX and ARDA irrigation schemes, the committee members are elected by the plot-holders. The main role of these committees is o liaise and assist in the management of the irrigation schemes. It is a government policy objective that farmers ultimately will take over the management and maintenance of irrigation schemes. All present schemes are heavily subsidized by government. The IMCs are viewed as a starting point in a process whereby these subsidies can be steadily eliminated in a fashion equitable to the farmers. The development of this policy is an issue that needs to be given more policy and planning guidance. Existing AGRITEX schemes have IMCs that function closely with the AGRITEX staff on the same aspects of management and farmer discipline, though AGRITEX has the ultimate responsibility for the functions, and subsidizes operation and maintenance costs.

OBSTACLES TO SMALL-HOLDER PARTICIPATION IN NEW IRRIGATION SCHEMES

The government subsidizes about 89 percent of the operation and maintenance costs of all AGRITEX small-holder schemes and does not recover any of the capital costs (Rukuni, 1984b). This level of subsidy is justified on the grounds that most of these schemes on Communal Lands are financially unattractive yet socially desirable for household food security purposes. Present plans are for farmers to increase their contribution towards operation and maintenance to about 25 percent through water charges.

The government is committed to the continued development of existing and new schemes. The existing schemes are developed to about 20 percent of their potential area (DERUDE, 1983). New schemes are being identified. The government strategy is to give priority to rehabilitation of existing schemes and expand those with potential before construction of new schemes. The policy is to encourage small irrigation schemes that are constructed and run by local communities. However, little investment in small-holder irrigation has taken place since 1980. With the policy placing more importance on financial viability, most potential schemes fail to meet the criteria for funding.

The National Farm Irrigation Fund has earmarked approximately 6 out of the 18 million dollars for funding small-holder schemes where these are appraised as financially viable. However, because of the traditional communal land tenure system operating in these areas, farmers can only borrow funds as a group for developing in-field works.

Group borrowing is necessary as a means of securing loans and also, equally important, to ensure that a cohesive group of irrigators is formed. The group is then expected to take over most of the government's present activities on existing schemes, including management and paying for water, operation, and maintenance. Under these conditions, which are significantly different than those on existing schemes, none of the 6 million dollars has been borrowed by small-holders from the National Farm Irrigation Fund and other similar sources of funds.

The basic contradiction seems to be that, whilst most of the existing schemes were developed for famine relief and other political reasons irrespective of financial viability, the same schemes, when appraised by new economic criteria, fail. Farmers on existing schemes have found it attractive to continue paying the modest operation and maintenance costs. This seems to be the precedent negating more active farmer involvement in new schemes, especially as it means they end up paying for capital costs, operation, and maintenance.

This is the present policy dilemma in the development of small-holder irrigation in Zimbabwe. No short-term solutions are obvious. An intensive process of policy development, new schemes identification, and action-oriented research is required to complete the long lesson to get farmers into cohesive groups willing to invest funds and labor into schemes they will run themselves, thereby relieving the government of the burden of subsidizing costs of capital, operation, and maintenance.

SUMMARY

Irrigation history in Zimbabwe dates back only to the beginning of the twentieth century. Whilst the bulk of irrigation is under large-scale, commercial agriculture, it is the small-holder irrigation subsector that faces problems with more challenging policy questions. This paper shows that the process of getting small-holder irrigators to fully participate in capital financing, operation, and maintenance of irrigation schemes has suffered setbacks in the Zimbabwean experience. This has become a long costly lesson that has taken more than eighty years and is not yet complete.

Small-holder farmers fully participated in early schemes developed for famine relief. Government intervention in the early 1930s brought more restrictive use of irrigation by farmers in an attempt to achieve economic viability. Government has since borne the burden of subsidizing capital, operation, and maintenance costs. Present attempts to organize farmers for purposes of borrowing funds for irrigation and reducing government assistance have not yet materialized. It is now government policy for small-holder farmers to fully participate in financing and management, but the long lesson has not yet been completed.

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Table 1. **Zimbabwe: Evolution of Government Irrigation Policy and Effects, 1986.**

Period	*Policy objectives and effects*
1912-1927	Missionaries introduce irrigation into indigenous agriculture.
1928-1934	Government provides services and helps farmers develop irrigation schemes, but farmers retain control.
1935-1945	Government takes over and manages schemes, introducing restrictive regulations.
1946-1956	Land Apportionment Act of 1930 is amended and blacks are moved to Native Reserves. New irrigation schemes were created to help resettle black farmers.
1957-1965	Government investigates economic viability of schemes, and this slows down development of new schemes.
1966-1980	Government policy of separate development for blacks and whites and introduces the strategy of rural growth points, mostly based on irrigation.
1981 to date	Policy moves towards decreasing government subsidies on existing schemes, and financial viability for new schemes.

Source: Adapted from Roder (1965) and Rukuni (1984b).
NB: These policy objectives tend to overlap. Table 2 gives the corresponding organizational history of small-holder irrigation development.

Table 2. **Zimbabwe: Government Agencies Responsible for Managing Irrigation Schemes and Providing Extension Services, 1932 to 1986.**

Period	Government agency	Functions
1932-1944	Ministry of African Affairs	Extension & management
1945-1963	Department of Native Agriculture	Management
1951-1963	Department of Native Agriculture	Extension
1964-1968	Department of Conservation and Extension (MOA)	Extension & management
1969-1978	Ministry of Internal Affairs	Extension & management
1978-1981	Department of Agricultural Development (DEVAG), Ministry of Lands, Resettlement and Rural Development (MLRRD)	Extension & management
1981-1985	Department of Rural Development (DERUDE), MLRRD, Department of Agricultural, Technical and Extension Services (AGRITEX), MOA	Extension
1985 to date	Department of Agricultural, Technical and Extension Services (AGRITEX), Ministry of Lands, Agriculture and Rural Resettlement (MLARR)	Extension & management

Source: Rukuni (1984a).

Table 3. **Zimbabwe: Area Under Irrigation by Type of Farmers, 1984.**

Type of farmer	Hectares
Commercial farms	93,000
Company estates	30,000
Commercial settler	11,500
ARDA estates and settlers	11,000
Communal lands: schemes	4,400
Communal lands: private	700
Total	150,600

Table 4. **Zimbabwe: AGRITEX Irrigation Schemes on Communal Lands, 1983.**

Province	Number of schemes	Area (ha)	Number of plot holders
Manicaland	11	2,189	2,149
Matebeleland South	18	1,161	1,173
Mashonaland West	1	5	16
Mashonaland Central	5	48	-
Matebeleland North	8	79	220
Masvingo Province	15	418	1,062
Midlands	14	369	1,205
Total	72	4,269	5,825

Source: Derived from DERUDE (1983).

COMPARATIVE ANALYSIS OF RICE PRODUCTION COSTS IN SMALL- AND LARGE-SCALE IRRIGATED PERIMETERS, UPSTREAM ZONE OF THE FLEUVE, MAURITANIA

Toka Koita and Richard Bernsten

INTRODUCTION

Today, Mauritania faces a food security crisis. Cereal production has declined sharply since the 1960s, when Mauritania produced an average of 90,000 metric tons per year---over three times the current average level of about 27,000 tons. In 1984-85, total food requirements were estimated at 280,000 tons of cereals. Even in normal rainfall years, local cereal production supplies only 21 percent of total needs, but in 1984-85, domestic production accounted for a mere 7 percent of total requirements (Cilss, 1985). Without adequate resources to generate foreign exchange, the country has been highly dependent on food aid to fill the current food gap.

Mauritania's fourth economic and social development plan (1981-85) placed priority on 1) achieving national food self-sufficiency by the year 2000; 2) increasing rural incomes; and 3) stopping the process of environmental degradation as a first step to gradually restoring the natural environment. To achieve these goals, the government sought to progressively reduce the food deficit by dramatically stimulating local production. After the last drought (1973-74), the government decided to rely heavily on irrigation as a major component in its strategy to achieve food security. The third plan (1976-80) proposed to develop irrigation on 93,000 additional hectares in order to satisfy cereals needs in the year 2000, with rice production alone occupying 65 percent of the land developed. To date, more than $U.S. 30 million has been invested in irrigation. As only about 6,500 hectares are currently under irrigation, the government will have to accelerate land development to achieve the year 2000 target (Ministère Du Développement Rural, 1976).

Given the severity of the food security situation in Mauritania and the shortage of foreign exchange, it is critical that development resources are allocated in the most efficient manner. Since the government has decided to expand the irrigated sector, current policy debate focuses on the most appropriate strategy to achieve this goal. This study contributes to this debate by 1) estimating the comparative rice production costs in the large- and small-scale perimeters in the upstream zone of the Fleuve region; 2) highlighting the advantages and disadvantages of large- and small-scale perimeters; and 3) drawing policy recommendations for future land development.

Related issues explored include Mauritania's comparative advantage in rice production: Is locally produced rice competitive with imported rice? If not, in what proportions should Mauritania produce and import rice to maximize food security? For example, rice produced and consumed in the same zone may be competitive with imported rice delivered to this zone. Finally, this study analyzes rice policies used by the Mauritanian government to increase real rural income. In particular, are existing incentives adequate to motivate farmers to continue to produce under the current rice policies?

HISTORY OF IRRIGATED FARMING

Efforts to develop irrigated agriculture were first initiated on the Senegal side of the Senegal River and later in Mauritania. Both small- (25 ha) and large-scale (greater than 500 ha) schemes have been developed.

SENEGAL RIVER VALLEY

While flood recession agriculture was practiced along the Senegal River for several centuries, French colonists undertook the first attempt to develop irrigation in the Senegal River Valley in 1822. This project, an attempt to adapt European crops to the environment of the Senegal River Valley, failed because of factors such as soil salinity, problems with the irrigation technique, and climate. It was terminated in 1831.

A century later, the Mission d' Aménagement du Sénégal introduced "controlled submersion" techniques on 1,000 irrigated hectares at Guede. While earlier initiatives focused on growing cotton for export, this project concentrated on producing rice to reduce the colony's shortages during World War II.

In the 1960s, Senegal experimented with water control techniques modeled on the controlled flooding polders of Indochina. This model, developed in monsoon Asia, proved totally inapplicable for semiarid agriculture and the conditions of the Senegal River Basin during drought years. As a result of these problems, investments in irrigation were reoriented toward total water control systems involving pumping and leveling. While these systems are more reliable, they are also expensive to construct and operate.

MAURITANIAN SIDE OF THE FLEUVE

The history of locally irrigated schemes goes back to the mid-1960s when the French Office of Agricultural Development (BDPA) constructed small perimeters (Figure 1). This first generation of small perimeters (up to 1972) represented an attempt to test and adapt modern rice production technology to the local environment. Consequently, paddy yields were low, ranging from 1.5 to 3.5 mt/ha.

A second generation of small perimeters, financed by European Economic Community Funds (FED), underwent construction from 1973 to 1979. The FED introduced a new approach to perimeter building and operation. In addition to training farmers, the FED assumed responsibility for leveling and plowing and provided free inputs to farmers during the first two years of perimeter operation.

In the 1980s, a third generation of small perimeters was implemented involving a new approach that required farmer participation. Farmers were responsible for building their perimeters themselves and for bearing all operating costs. This strategy was introduced to combat the "dependency mentality" of farmers created by the FED's perimeter management approach. This strategy also included plans for the gradual transfer of management and support functions, initially assumed by the state, to the perimeters' cooperative.

Farmers are unhappy with this most recent approach because they previously received all inputs free of charge. Yet, the Mauritanian government cannot continue to follow the FED's approach for both economic and political reasons. Subsidizing investment and operating costs for the first generation of perimeters was justified because it encouraged farmers to quickly adopt the new technology package. However, rural development policy makers made a mistake by failing to revise this approach earlier---before farmers came to expect the subsidies as a right.

Large-scale perimeters were also implemented in the Fleuve region. The first scheme, the Farm State of Mpourie located at Rosso, was developed in 1967 with technical assistance provided by the People's Republic of China. Approximately 1,800 ha of land were developed, but salted and sandy soils reduced the total cultivable area to 1,500 ha. Salt water, coming from the sea during the dry season, made it impossible to grow a second rice crop on this perimeter. Subsequently, the Gorgol perimeter (700 ha) in Kaedi, the Boghe perimeter (4,000 ha), and the Gorgol Irrigation Project (3,600 ha) in Foum Gleita were constructed. After completing the Diama and Manantali dams on the Senegal River, the Mauritanian government plans to develop 5,000 hectares annually.

Modern small- and large-scale irrigation schemes in Mauritania utilize a complete water control system (Figure 2). This system involves four components: a) peripheral diking and pumping water for complete water control down to the quaternary canals; b) leveling of interior paddy land; c) construction of numerous small dikes, ditches, and bunds to separate parcels and to allow for internal water control; and d) pumping water up from the river and accumulating it in a cement stilling basin. From there, water is channeled through an earthen canal system. Minor ditches divide the system into 100 square meter sections.

TYPE OF IRRIGATION SCHEME

Irrigation systems are administered under the authority of the Société Nationale de Développement Rural (SONADER). Rice production schemes can be divided into two classes:

1) small-scale, village-level irrigated perimeters covering an average of 25 ha each; and 2) large-scale, irrigated perimeters with a command area of over 500 ha. However, these two types of irrigated schemes are designated and managed differently.

SMALL-SCALE, VILLAGE-LEVEL IRRIGATION PERIMETERS

SONADER uses two approaches to establish village perimeters. In one approach, SONADER selects the site, undertakes all preliminary perimeter preparation, and provides the necessary equipment and supervisory personnel. A contract binds villagers to SONADER, stipulating the duties of the two partners. SONADER is required to supply all the services, including inputs, during a growing season. After harvest, the villagers are required to reimburse SONADER for these services. This contract is generally renewed before each growing season. The other approach, called the private village approach, refers to village perimeters established without prior feasibility studies. Under this alternative, SONADER and other international organizations provide the technical assistance and occasionally material equipment. This study focuses on perimeters designated using the first approach.

Small-scale perimeters are labor-intensive schemes. Villagers must provide an average of 4,500 man-days per perimeter (180 md/ha). Farmers are responsible for land clearing, small dike and canal construction, and leveling. To compensate for their effort, SONADER gives farmers food ("food for work"), generally drawn from food aid reserves.

The qualifier "village-level" is frequently used in discussing a small-scale scheme to specify that the perimeter is located close to a village, worked primarily by that village's farmers, and is established on elevated land (fonde). This approach is feasible where 1) the water supply (river) is near the village, making long water supply routes unnecessary (Figure 3); 2) the soil is relatively light so that it can be easily worked by hand or with draft animals; 3) the topography is relatively flat, which minimizes the need for extensive leveling; and 4) the land is elevated---reducing the labor requirements for building flood protection dikes and providing natural drainage toward the river of the neighboring basins.

The government's strategy to create small-scale irrigated perimeters has two fundamental objectives. First, it is designed to provide an individual irrigated plot to the maximum possible number of peasants located in the Fleuve. This explains why family plots are only 0.1 to 1.0 ha. Production from this plot represents a complementary food supply in good rainy years and a unique source of food supply during a drought period. Second, the schemes are designed to train peasants in the Fleuve region to use new agricultural technology before implementing intensive land development---planned for after completing the Diama and Manantali dams.

Small perimeters are built on fonde soils (less than 10 to 30 percent clay) that are too porous for efficient paddy rice irrigation. While drainage is good, subsurface leakage and percolation have resulted in large water losses. Canal leakage was excessive in many perimeters because of sandy soils, which resulted in a low water retention capacity.

A better pumping system needs to be developed and leveling improved. These operational problems are beyond farmers' control. Pumps often break down at critical periods when paddy rice needs more water, causing yield reduction. Pump breakdown is more due to bureaucratic constraints that result in an unreliable supply of spare parts than to poor pump maintenance.

The major constraint to expanding the area in small-scale perimeters is the availability of suitable land. If land development is to be done manually by villagers, these perimeters can only be constructed on light fonde soils (Figure 4), which represent a small percent of the total arable land in the Fleuve. In addition, small-scale perimeters can only be constructed in zones that do not require villagers to perform major leveling work. Alternatively, small-scale perimeters could be developed on hollalde soils (heavy soils with more than 60 percent clay), but this would require constructing a peripheral dike against flooding and drainage canals---operations that can only be completed using heavy construction equipment.

As noted earlier, irrigated plot size varies from 0.1 to 1.0 ha per family, with an average of eight to ten individuals, including three active members. Thus, production from this plot is insufficient to meet family food needs. This is why small perimeter farmers still engage in rainfed and flood recession agriculture. Many agricultural projects analysts recommend that plot size should be expanded. But, if plot size is increased without introducing mechanization, labor shortages could constrain perimeter maintenance.

In the case of the small-scale perimeter, the major handicap is the "common propriety resource" issue. Without strong perimeter cooperative leadership and a great commitment by all the cooperative members, the perimeter will be maintained poorly. Improper maintenance at critical periods results in canal erosion and the failure of the physical works.

LARGE-SCALE IRRIGATED PERIMETERS

In contrast to the small-scale perimeter approach, large-scale perimeters are designed by the government without any initial association with or commitment from the peasants. After completion, plots are distributed to producers who fulfill certain criteria. Producers assigned a plot are required to pay for SONADER's services and are not allowed to sharecrop their plot. Plots, which range from 0.5 to 3.0 ha, are grouped into 10 ha hydraulic units to facilitate irrigation and the mechanization of field operations.

Large-scale perimeters are constructed with the extensive use of heavy earth-moving equipment. Infrastructure and equipment for irrigation and drainage include 1) dike works to protect against river flooding; 2) an irrigation network---ranging from primary channels to tertiary and water diffusion channels---with mechanisms to control water levels and distribute flows; and 3) one or several pumping stations that supply irrigation water and provide drainage.

The major objective of large-scale perimeters is to increase production at minimum cost. Their size is expected to lead to economies of scale. The major advantage of this type of scheme is that it favors investment in equipment and a better diffusion of technical packages.

When project analysts design large-scale perimeters, they focus on technical rather than sociological problems. The Gorgol pilot project showed that sociological factors are one of the most important determinants of a large-scale scheme's success. This scheme was implemented in very rich walo soils that were partly flooded---even during drought periods. Thus, farmers can expect to harvest sorghum from these lands in low rainfall years. Developing these flood recession lands into irrigated perimeters directly conflicted with the landowners' interests because it deprived them of access to productive nonirrigated land.

The Gorgol perimeter experiences also illustrate that farmer participation at all the stages of perimeter design significantly contributes to successful implementation at later stages. National agricultural projects analysts have, since the Gorgol case, advised against designing very large and compact block perimeters without farmer participation. Instead, they now recommend developing medium-size perimeters that are irrigated by separate pumping stations. Each perimeter includes many different villagers, and each village corresponds to a hydraulic unit. This makes it easier to manage the whole system since each hydraulic zone is cultivated by a homogeneous group of individuals. The goal is to develop a prototype production system perimeter that combines the economies of scale involved in the large perimeter with the more effective incentives offered by the small perimeter.

METHODOLOGY

The primary objective of this study is to estimate the economic and financial costs of rice production in small- and large-scale irrigated perimeters in the upstream regions of the Fleuve. For this comparative analysis, data representing the average small perimeter and the Pilot Gorgol large-scale scheme were used. This analysis used secondary data that were derived primarily from SONADER reports and West African Rice Development Association (WARDA) studies on irrigated rice in Mauritania. Complementary data were found in information obtained from the World Bank and in graduate student theses related to rice irrigation in the Senegal River Valley.

OPPORTUNITY COSTS

The World Bank estimates that in the 1980s the Mauritanian ougouia (U.M.) was overvalued by 16-20 percent. Therefore, this study used 18 percent as the currency premium. The shadow exchange rate approach was used to convert the value of traded goods into a domestic equivalent. The market prices (in domestic currency) of traded goods were multiplied by the shadow exchange rate (1.18) to make traded goods relatively more expensive---in terms of domestic currency---by the amount of the foreign exchange premium.

Unskilled labor was valued at 100 U.M. per man-day in both economic and financial analyses. We assumed that family labor is available and willing to work at this wage rate. This assumption is revised in the sensitivity analysis.

"In most instances, skilled labor in developing countries is considered to be in rather short supply and would most likely be fully employed even without the project being considered" (Gittinger, 1982:259). Hence, wages paid to workers, such as mechanics, extension agents, and perimeter managers, were assumed to represent the true marginal value product of these workers. Thus, in the economic analysis, these wages were entered at their values. In the case of foreign labor---such as expatriate technicians employed in the perimeters---their economic value to society is the sum of their salary, housing, per diem, and other perquisites. Yet, the cost of these expatriates must be shadow priced because they are paid in foreign currency (at least most of their salaries).

In an economic analysis, traded goods must be shadow priced to reflect their opportunity cost. This was taken into account by multiplying their domestic prices by the foreign exchange premium. On the other hand, domestic goods were valued at domestic market prices. This adjustment allowed us to compared traded and non-traded goods in equivalent value terms (real domestic value).

DIVISION OF COSTS INTO FOREIGN EXCHANGE, UNSKILLED LABOR, AND DOMESTIC GOODS COMPONENTS

The cost components (foreign exchange, unskilled labor, and domestic goods) for each cost category considered in this study are shown in tables 1 and 2. For all goods and services used to construct and operate the irrigated rice perimeters, the economic costs were calculated by subtracting government taxes from, and adding subsidies to, the financial costs.

COMPUTATIONAL SIMPLIFICATIONS

Three discount measures are commonly used to evaluate agricultural projects: the benefit-cost ratio, net present worth, and internal rate of return. However, when sufficient times series data are not available, a static comparison of costs and benefits for a given year is acceptable. Data for 1980 were used in this analysis as these are the only available data.

Forty years was assumed as the expected useful life for large-scale experiments and twenty for small perimeters. In the economic analysis, 8 percent was assumed as the opportunity cost of capital funds to the economy---regardless of the source---because this rate most accurately reflects the commercial interest rate.

In computing annual fixed costs, the annualized depreciation, interest charges on the average annual investment, and annual maintenance costs were used. Since no information is available on either the procedures used in repaying the invested funds or the successive annuities, we calculated the average annual investment and computed the annual interest on it.

The average annual depreciation over the life of the asset was calculated in the following way:

$$Dep = \frac{A\,Q - S\,V}{N}$$

Where:

Dep = depreciation
A Q = acquisition or initial investment
S V = salvage value
N = life of the asset

The coefficients assumed in estimating depreciation and maintenance costs for both large- and small-scale perimeters are presented in Table 3.

A SONADER report (SONADER, 1984) estimated the average cropping intensity (total ha cultivated per year divided by the perimeter's total ha) in 1980 to be 1.25 for both large-and small-scale perimeters in the upstream zone of the Senegal River Valley. Thus, all fixed costs per ha were divided by 1.25 to reflect the costs borne by the rice component.

To compare rice production costs among different types of perimeters, we estimated the "average cost" of growing rice in 1980 in small perimeters in the upstream zone of the Fleuve. This "average small perimeter" was assumed to represent a typical small perimeter. Costs of production in the Gorgol Pilot perimeter---both by SONADER and by farmers---were used to represent large-scale perimeters.

RESULTS

In this analysis, small and large perimeters were compared for investment costs, operating costs, farm-level production costs, post-farm production costs, and total costs of producing rice domestically compared to imported rice. Sensitivity analysis was performed to assess the impact of changes in several critical assumptions on these results. The following are the results of the data analysis.

1. Investment Cost. The financial and economic costs of establishing 1 ha of irrigated land were approximately U.M. 800,000 ($US 17,400) each for the large-scale and U.M. 200,000 ($US 4,350) each for the small-scale perimeters, respectively (Table 4). Thus, large-scale perimeters required almost four times greater capital investment than did small perimeters. Table 5, which compares annual fixed costs per ha for small- and large-scale perimeters, also indicates a similar magnitude of difference in fixed costs between the two types of perimeters. However, in the large-scale perimeter, SONADER did not charge all the fixed costs to farmers. It is significant to note that the small perimeters, with substantial peasant participation, required far less investment than the large, more centrally controlled perimeters.

2. Operating Costs. Total financial operating costs ranged from about U.M. 12,000-50,000 ($US 260-1,087) per ha, depending on the type of perimeter (Table 6). This represents

a ratio of 4 to 1. In the large-scale scheme, SONADER's operating costs per ha were four times as high as those of the farmers. Surprisingly, in small-scale irrigated perimeters, farmers' financial costs were twice as high as those of the large perimeter farmers. This difference was mostly due to high pumping costs in small perimeters, which include all costs---whereas in the large perimeter, farmers only paid for subsidized electric power to run their pumps. On the other hand, the substantial difference in operating costs (U.M. 49,200 versus U.M. 25,400) between the large (SONADER management) and small perimeters was largely because of SONADER use of mechanical means for most production operations, including land preparation, seeding, fertilizing, and threshing.

3. Farm-Level Production Costs. The total financial cost per ha of producing paddy rice varied from U.M. 76,000-140,000 ($US 1,652-3,043), as shown in Table 7. Producing rice in the large-scale perimeter (SONADER's management) cost almost one and one-half times as much as in small-scale perimeters. Farmers' production costs in the large-scale perimeter were 46 percent less than those of farmers in the small-scale perimeter. This was due to the higher transfer payments made to large-scale perimeter farmers (Table 8).

Table 8 also shows that income transfers to the large perimeter farmers were twice as large as those to the small perimeter farmers---indicating significant discrimination against small perimeter peasants. In the large-scale perimeter, farmers' financial costs were only 33 percent of their economic costs. In contrast, in the small-scale perimeters, farmers' financial costs equaled 82 percent of their economic costs.

The portion of total financial costs per ha---by type of perimeter, divided between farmers and SONADER, net of payments from farmers to the SONADER---is given in Table 9. This analysis clearly shows that the costs per ha were lower in small perimeters, but farmers bore a larger portion (40 percent) of the total cost. In contrast, in the large-scale perimeters, farmers bore only 24 percent of the total rice production costs.

4. Post-Farm Cost of Paddy Production. To estimate the financial cost of producing 1 kilogram of paddy rice, total costs per ha (Table 8) were divided by 3,200 kg/ha (exclusive

of post-harvest losses)---the assumed yield level in both small- and large-scale perimeters. As shown in Table 10, the farmers' production costs per kilo of paddy varied from U.M. 12-13 (US \$.26-.28) per kilogram. The paddy price, fixed by the Mauritanian government and paid to farmers, was U.M. 10 (US \$.22) per kilo in 1980. This means that the 1980 paddy price did not cover farmers' total production costs.

The distribution of financial rice production costs between farmers and the public sector (Mauritanian government) are shown in Table 11. **This analysis indicates that farmers in both small- and large-scale perimeters earned negative profits---when family labor is valued at farmers' opportunity cost of U.M. 100 per man-day.** Consequently, in the upstream zone of the Fleuve, to repay credit received for agricultural inputs at the beginning of the growing season, farm households had to accept a return to their own labor input below its opportunity cost.

5. Total Costs of Producing Rice. The financial cost per kilo of paddy produced in the upstream zone of the Fleuve and consumed locally was estimated by adding total marketing costs per kilo to the production costs per kilo (Table 12). Total costs varied from U.M. 33-53 (US \$.72-1.15 per kilogram). The cost per kilo of rice produced in the large perimeter was one and one-half as high as in the small perimeters. Expatriate personnel costs represented 20 and 13 percent of total rice production costs in the large and small perimeters, respectively.

To determine if it is cheaper to produce rice in the upstream zone of the Fleuve or to import it, the economic and financial costs of rice produced in the different irrigation schemes and consumed within the production zone were compared to the average cost per kilo of imported milled rice delivered to the upstream zone of the Fleuve. The average CIF price of U.M. 13.8 (US \$.30) per kilo was assumed as representative of imported rice costs.

Table 13 shows that the average cost per kilo of imported milled rice delivered to the upstream zone of the Fleuve was U.M. 24.5 (US \$.53). By comparison, the financial cost per kilo of rice produced in large- and small-scale irrigated perimeters and consumed at the production zones varied from U.M. 33-53 (US $.72-1.15) per kilogram (Table 12). This means that, in financial terms, domestically produced rice from irrigated perimeters cost 36 to 116 percent more than imported rice (Table 14).

The economic cost to Mauritania, per kilogram produced, was U.M. 40.8 and U.M. 67.8 (US $.89 and 1.47) for the large- and small-scale perimeters, respectively; versus U.M. 24.5 (US $.53) for imported rice. Thus, in economic terms, rice produced in the upstream zone of the Fleuve was from 66 to 177 percent more costly than imported rice. These results confirm that Mauritania is a high cost rice producer.

Sensitivity Analysis

The objective of the sensitivity analysis was to look at the effects of yield and cropping intensity variations on domestic rice production costs. In addition, we looked at the effect of the revised wage rate assumptions on domestic rice production costs.

The opportunity cost for unskilled labor varies among references. In the initial analysis, we used U.M. 100 per man-day, but the alternative assumption of U.M. 200 per man-day was later introduced. Table 15 shows the cost per kilogram of producing rice, after adjusting the unskilled market wage rate from U.M. 100 to U.M. 200. At the higher wage rate, the financial cost of rice production varied from U.M. 57.6-39.1 (US $1.25-.85) per kilogram. Large-scale perimeter production costs were about 50 percent higher than those for small-scale perimeters.

Table 16 compares the financial costs of imported rice in the upstream zone of the Fleuve to rice produced domestically and consumed in the production zones. In financial terms, domestic rice produced in small and large irrigated perimeters cost 59 to 135 percent more, respectively, than imported rice. In economic terms, rice produced in the upstream zone of the Fleuve was from 92 to 168 percent more costly than imported rice.

Table 17 shows the total financial cost per kilogram of rice at various cropping intensities and yields in large- and small-scale perimeters. Increasing both cropping intensity and yield simultaneously reduced rice production costs per unit of output. In the large perimeter, domestic rice production was competitive with imported rice at a cropping intensity and milled yield (on-farm paddy yield) of 1.75 and 6.0 t/ha (7.2 t paddy/ha), respectively. In contrast, in the small perimeter, domestic rice production was competitive with imported rice at a cropping intensity and milled yield (on-farm paddy yield) of 1.5 and 5 t/ha (6.0 t paddy/ha), respectively.

Table 18 presents farmers' costs per kilogram of rice produced at various intensities and yields (exclusive of post-harvest losses) in the large- and small-scale perimeters. It shows that, in the small-scale perimeters, farmers had to achieve at least a cropping intensity of 1.5 and a real milled yield (on-farm paddy yield) of 4.0 t/ha (4.8 t/ha) to break even at the government paddy price (U.M. 10 per kilogram) prevailing in 1980. In contrast, in the large-scale perimeters, farmers had to achieve at least a cropping intensity of 1.25 and a real milled yield (on-farm paddy yield) of 4.0 t/ha (4.8 t/ha) to break even at the prevailing paddy price (U.M. 10 per kilogram) in 1980.

CONCLUSIONS

Our analysis indicates that the economic cost of rice produced in irrigated perimeters and consumed in the production zones was from 92 to 168 percent (small and large perimeters, respectively) higher than for imported rice in the upstream zone of the Fleuve. In financial terms, locally produced rice cost 59 to 135 percent (small and large perimeters, respectively) more than imported rice. In the large perimeter, 70 percent of the costs were borne by SONADER (government), while only 30 percent were paid by farmers. In contrast, in the small perimeters, 44 percent of total costs were borne by farmers and 56 percent by SONADER.

The comparison between domestic and imported rice costs shows that Mauritania was producing rice at a high cost. Thus, in simple terms, Mauritania should import rice rather than produce it. However, we need to consider the political and strategic cost to Mauritania of being dependent on food imports and international food aid. What would happen if riceexporting countries decided to raise prices or were no longer in a position to export? More important, what will be the long-run impact of rising energy prices on commodities transported over long distances?

Although the small-scale perimeters were more cost-effective than the large one; neither the large nor the small perimeters' production costs were competitive with imported rice delivered to the upstream zone of the Fleuve. At present, the high domestic cost of rice production is simply part of the price to be borne in achieving partial food security. However, present costs could be substantially reduced by implementing several changes.

1. Construction of Medium-Size Perimeters. Efforts should be directed at developing a prototype perimeter that will combine the economies of scale involved in the large perimeter, with more effective incentives offered by small perimeters. Perimeters should be large enough to provide at least .75 ha/farm family, so that plots can generate acceptable returns to family labor. This would encourage farmers to concentrate only on irrigated farming, thereby improving management. The total command area of the medium-size perimeters may be quite large and could include many villages. Yet, each village hydraulic unit should include 50 to 100 ha and be irrigated by a separate pumping station.

Enlarging existing small perimeters to medium-size perimeters would require that hollalde soils be brought into production. Therefore, SONADER would have to provide heavy machinery services to perform tasks that cannot be completed manually, such as construction of peripheral dikes, principal canals, and land plowing.

2. **Improved Perimeter and Pump Maintenance**. The leadership of the collective organization should require all members to help maintain the irrigation system. Members absent during perimeter maintenance workdays should be required to pay a fine.

National companies should be established to provide pump repair and spare parts services. The Mauritanian government should support local firms by providing credit and possibly subsidies during the first few years to help defray start-up costs. The companies should establish branches at the irrigation perimeter level so that they can immediately intervene when breakdowns occur. Pump repair costs should be subsidized during the first two years of perimeter operation, with gradual elimination in the following years.

3. Improvement of Water Management. Farmers should adhere to the rotational water schedule. An OMVS survey (1977) indicated that failure to adhere to the parcel watering schedule was a major problem for both small- and large-scale perimeters. The survey showed that 22 percent of the parcels sampled in the 1977 rainy season experienced water shortages, and 17 percent had excess water. This disregard for water scheduling led to inefficient water use, yield losses, and higher than necessary pumping costs.

4. Supervisory Personnel and Farmers' Training. First, additional supervisory personnel should be trained to replace foreign technical advisors engaged in implementing government land development plans. This would substantially reduce domestic rice production costs. Second, SONADER extension agents should be retrained so that their expertise corresponds to farmers' needs. Training should be oriented to practical tasks, including water management and cooperative organization management. Third, some of the farmers most interested in modern rice production techniques should also receive training and be used as extension agents. Finally, leaders of collective production organizations must be trained to gradually assume the management and support functions initially undertaken by SONADER. This would reduce SONADER management and logistical support responsibilities, making it possible for the parastatal to focus on development expansion and productivity improvement.

5. Reduction of Production Costs. After the completion of the dams on the Fleuve, it will be possible to grow three crops on irrigated perimeters. Increasing cropping intensity will reduce the high fixed cost per kilo of production in larger perimeters, making large-scale perimeters more financially and economically viable. Yet, if crops other than rice are to be produced (sorghum, maize, and cowpeas), the marketing system must also be strengthened. Also, when more water becomes available, it will be possible to plow hollalde

soils when completely saturated. This will make land plowing easier and reduce the cost. In addition, the National Research Center should supplement on-station screening of disease-resistant, high-yielding varieties with on-farm trials. This effort should help to identify new high-potential varieties that can be made available to farmers. Finally, SONADER's production costs on the large perimeters are too high. Land in these perimeters should be turned over to farmers---with SONADER retaining only enough land to test new varieties for future use by farmers.

6. Reducing Perimeter Construction Costs. Short-term contracting with foreign firms has resulted in high costs because there is minimal incentive to these firms to establish local facilities. Multiple-year contracting in which a large volume of construction is specified, along with the requirement that the foreign contractor establish permanent on-site facilities, would reduce costs in the long run. Also, the government should promote the extensive participation of national companies (subcontractors) to assist in perimeter construction.

Grouping calls for bids and announcing them far in advance permits more firms to tender bids, thereby increasing the competition and reducing costs. To facilitate this recommendation, it would be necessary for the different financing sources to agree to forego conditions that limit participation to companies of a specific national origin. This would permit companies that establish themselves in the field to have a chance to have regular work and, as a consequence, improve the competitiveness of their prices.

Farmer participation in carrying out perimeter construction, wherever feasible, should be required. This would reduce construction costs for work such as land clearing, stump removal, earth leveling, digging small dikes, etc.

7. Resolution of Sociological Problems. The government should obtain a consensus from farmers on perimeter location prior to construction. This would alleviate problems with compensation, which have plagued previous projects.

8. Pricing Policies. Adequate paddy prices, covering at least production costs, should be paid by the government to farmers involved in irrigated perimeters. In addition, paddy rice floor prices should be announced to farmers before each growing season.

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Table 1. Foreign Exchange, Unskilled Labor and Domestic Cost Components Used for Economic Analysis in the Large-Scale Perimeter in the Upstream Zone of the Senegal River Valley, Mauritania, 1980.

	Foreign exchange		Unskilled labor		Other dom. costs	
	SONADER	Farmers	SONADER	Farmers	SONADER	Farmers
			(percent)			
Investment costs						
Dikes	62.0	62.0	25.0	25.0	13.0	13.0
Roads	62.0	62.0	25.0	25.0	13.0	13.0
Sluice gate	62.0	62.0	25.0	25.0	13.0	13.0
Pumping station	62.0	62.0	25.0	25.0	13.0	13.0
Irrigation canal	62.0	62.0	25.0	25.0	13.0	13.0
Drainage canal	62.0	62.0	25.0	25.0	13.0	13.0
Leveling	62.0	62.0	25.0	25.0	13.0	13.0
Electric exchange	75.0	75.0	12.5	12.5	12.5	12.5
Perimeter buildings	75.0	75.0	12.5	12.5	12.5	12.5
Hydromechanical devices	75.0	75.0	12.5	12.5	12.5	12.5
Technical supervision	90.0	90.0	0	0	10.0	10.0
Consultant services	90.0	90.0	0	0	10.0	10.0
Farmers' training	46.0	46.0	46.0	46.0	8.0	8.0
Interest on capital	0	0	0	0	100.0	100.0
Perimeter maintenance	33.0	33.0	50.0	50.0	17.0	17.0
Operating costs						
Seeds	25.0	25.0	50.0	50.0	25.0	25.0
Farmers' share of land development	0	0	0	0	0	100.0
Fertilizer	80.0	80.0	12.0	12.0	4.0	5.0
Electric power costs	33.0	50.0	0	33.0	34.0	50.0
Bags	80.0	80.0	12.0	12.0	8.0	8.0
Machinery services	84.0	58.0	16.0	13.0	0	29.0
Small equipment	35.0	35.0	56.0	56.0	9.0	9.0
Labor (family)	0	0	100.0	100.0	0	0

Source: WARDA, Analyse economique de la culture irriguée du riz en Mauritanie, 10 Mars 1980.

Table 2. Foreign Exchange, Unskilled Labor, and Domestic Cost Components Used for Economic Analysis in the Small-Scale Perimeter in the Senegal River Valley, Mauritania, 1980.

Cost component	Foreign exchange	Domestic unskilled labor	Other domestic costs
		(percent)	
Investment costs			
Farmers' training	60	24	16
Perimeter establishment	0	100	0
Motor pump and other equipment[a]	90	10	0
Perimeter supervision costs for expatriates	90	0	10
Cooperative fee	0	0	100
Perimeter maintenance	0	100	0
Interest on capital invested	0	0	100
Car	100	0	0
Food for work[b]	100	0	0
Operating costs			
Family labor	0	100	0
Seeds	25	50	25
Fertilizer	80	15	5
Small equipment	35	56	9
Water supply costs[c]	80	16	4

Source: WARDA, Analyse economique de la culture irriguée du riz en Mauritanie, 10 Mars 1980.

[a]Other pump equipment includes floating ferries, spare parts, flexible pipe, aluminum tubs, joinings, and accessories.

[b]Food for work comes from food aid.

[c]Includes fuel, pump operator salary, maintenance, and spare parts costs.

Table 3. Coefficients Assumed for Estimating Depreciation and Maintenance Costs for Large- and Small-Scale Irrigated Perimeters in the Upstream Zone of the Senegal River Valley, Mauritania, 1980 (thousands of ouguias).

Investment	Estimated life	Estimated maintenance (percent)
Large perimeter		
Dikes	40.	2.
Roads	40.	2.
Building for perimeter	20.	5.
Sluice gate	40.	2.
Irrigation canal	25.	2.
Leveling	20.	4.
Pumping station	10.	10.
Electric exchange	10.	10.
Perimeter establishment control costs	40.	0.
Engineering services	40.	0.
Cars and trucks	5.	15.
Drainage canal	25.	2.
Small perimeter		
Construction and perimeter	20.	2.
Pump and pumping equipment	10.	10.

Source: OMVS, Étude socio-economique du Bassin du Fleuve Sénégal, 1980.

Table 4. Summary of the Financial and Economic Capital Investment Required for One Hectare of Irrigated Land in the Upstream Zone of the Senegal River Valley, Mauritania, 1980 (thousands of Ouguias).

Cost category	Large perimeter		Small perimeter	
	Financial	Economic	Financial	Economic
Perimeter establishment	491	549	56	62
Agricultural equipment	145	163	47	54
Building costs	101	114	101	114
Total costs for all crops	737	826	204	230

Source: Koita, 1986, tables 5.1, 5.4, 5.6a, and 5.7.

Table 5. **Annual Fixed Costs per Hectare: A Comparison Between Large-Scale and Small-Scale Irrigated Perimeters in the Upstream Zone of the Senegal River Valley, Mauritania, 1980 (thousands of Ouguias).**

Cost component	Large perimeter*		Small perimeter	
	Financial	Economic	Financial	Economic
1) Perimeter establishment				
Depreciation	15.9	18.7	2.8	3.1
Maintenance	10.0	11.8	1.1	1.2
Interest	0.6	19.6	0.1	2.4
Subtotal	26.5	50.1	4.0	6.7
2) Equipment and building				
Depreciation	19.9	22.2	7.3	8.4
Maintenance	19.2	21.6	9.6	11.0
Interest	0.6	22.1	0.3	13.4
Subtotal	39.7	65.9	17.2	32.8
Total costs for all crops	66.2	116.0	21.2	39.5
Total costs for rice component	53.0	93.0	17.1	31.8

Source: Koita, 1986, tables 5.3, 5.5, and 5.8.
US $1 = U.M. 46
*Farmers pay only U.M. 10,400 per hectare per growing season, which represents about 20 percent of the rice component total fixed costs and corresponds to the financial cost for farmers.

Table 6. **Operating Costs on a Per Hectare Basis for Large- and Small-Scale Perimeters in the Upstream Zone of the Fleuve, Mauritania, 1980 (thousands of Ouguias).**

Cost category	Large-scale perimeter				Small perimeter	
	SONADER		Farmers			
	Financial	Economic	Financial	Economic	Financial	Economic
Fertilizer	6.8	7.7	3.4	7.7	3.4	6.7
Seeds	1.2	1.3	1.2	1.5	1.2	1.3
Machinery services	5.2	5.9	1.1	1.4	0.0	0.0
Water supply fuel	3.8	4.4	3.6	4.4	6.9	8.0
Bags	1.3	1.3	1.3	1.3	1.3	1.3
Manual equipment	0.5	0.5	2.1	2.2	2.9	3.0
Other costs	0.5	0.6	0.0	0.0	1.1	1.2
Personnel	29.9	33.3	0.0	0.0	8.6	9.5
Total for rice	49.2	55.0	12.7	18.5	25.4	31.0

Source: Koita, 1986, tables 5.11, 5.12, and 5.13.
US $1 = U.M. 46

Table 7. **Cost of Producing Paddy Rice per Hectare in the Large- and Small-Scale Perimeters in the Upstream Zone of the Senegal River Valley, Mauritania, 1980 (thousands of Ouguias).**

	Large-scale irrigated perimeter				Small perimeter	
	SONADER		Farmers			
Cost category	Financial	Economic	Financial	Economic	Financial	Economic
Fixed costs	53.0	92.9	10.4	92.9	17.4	33.0
Operating costs	49.5	55.0	12.7	111.8	25.3	31.0
General adm. costs	37.8	37.8	37.8	37.8	37.8	37.8
Family labor	0.0	0.0	15.0	15.0	20.8	20.8
Total costs	140.3	185.7	75.9	257.5	101.3	122.6

Source: Koita, 1986, tables 5.10, 5.14, and 5.16.
US $1 = U.M. 46

Table 8. **Distribution of the Financial Cost of Producing Paddy Rice between Farmers and the SONADER (Government) in the Upstream Zone of the Senegal River Valley, Mauritania, 1980 (thousands of Ouguias per Hectare).**

	Large-scale irrigated perimeter				Small-scale irrigated perimeter			
	Financial costs			Economic costs	Financial costs			Economic costs
Cost category	Farmers	SONADER[c]	Total	Total	Farmers	SONADER	Total	Total
Fixed costs[a]	10.4	42.6	53.0	92.9	5.1	12.0	17.1	33.0
Operating costs								
Fertilizer[b]	3.4	3.4	6.7	7.7	3.4	3.4	6.7	6.7
Seeds	1.2	0.0	1.2	1.3	1.2	0.0	1.2	1.3
Machinery services	1.1	4.0	5.2	5.9	0.0	0.0	0.0	0.0
Water supply fuel	3.6	0.2	3.8	4.4	6.9	0.0	6.9	8.0
Bags	1.3	0.0	1.3	1.3	1.3	0.0	1.2	1.3
Manual equipment	2.1	0.0	2.1	2.3	2.9	0.0	2.9	3.0
Personnel	0.0	29.9	29.9	33.3	0.0	8.6	8.6	9.5
Other costs	0.0	0.5	0.5	0.6	0.0	1.1	1.1	1.2
Subtotal Operating costs	12.7	38.0	50.7	56.8	15.7	13.1	28.6	31.0
Administration	0.0	37.8	37.8	37.8	0.0	37.8	37.8	37.8
Family labor	15.0	0.0	15.0	15.0	20.8	0.0	20.8	20.8
Total costs	38.1	118.4	156.5	202.5	41.6	62.9	104.3	122.6

Source: Koita, 1986, tables 5.16 and 5.17.
[a]SONADER's share of the total fixed costs include only personnel, food for work, and the subsidy for farmers' first motor pump in the case of the small perimeter.
[b]This corresponds to the real quantities of fertilizer used by farmers.
[c]SONADER represents the government or the public sector.
US $1 = U.M. 46

Table 9. Portion of the Financial Cost of Producing Rice Borne by Farmers and SONADER (Government) in the Large- and Small-Scale Irrigated Perimeters in the Upstream Zone of the Senegal River Valley, Mauritania, 1980 (thousands of Ouguias).

		Farmer share		SONADER share	
Type of perimeter	Cost/hectare	Value	Percent	Value	Percent
Large perimeter	156.5	38.1	24	118.4	76
Small perimeter	103.4	41.5	40	62.9	60

Source: Koita, 1986, Table 5.18.
US $1 = U.M. 46

Table 10. Production Costs per One Kilogram of Paddy Rice in Large- and Small-Scale Irrigated Perimeters of the Upstream Zone of the Senegal River Valley, Mauritania, 1980 (Ouguias).

Perimeters	Farmers	SONADER	Financial	Economic
Large perimeter	11.9	37.0	48.9	63.3
Small perimeter	13.0	17.7	30.7	38.3

Source: Calculated from Koita, 1986, tables 5.18 and 6.1.
US $1 = U.M. 46

Table 11. Farmers' Profit and Public Sector Subsidies per Kilogram of Paddy Rice Produced in the Upstream Zone of the Senegal River Valley, Mauritania, 1980 (Ouguias).

Perimeter	Total cost of production per kg A	Official prices/kg B	Farmer cost/kg C	Farmer profit/ kg D	Subsidies A-C
Large perimeter	48.9	10.0	11.9	-1.9	37.0
Small perimeter	30.7	10.0	13.0	-3.0	17.7

Source: Calculated from Koita, 1986, Table 6.2.
US $1 = U.M. 46

Table 12. Total Cost of One Kilogram of Rice Produced in the Upstream Zone of the Senegal River Valley, Mauritania, 1980 (Ouguias).

	Large-scale irrigated perimeter				Small-scale irrigated perimeter			
	Financial costs			Economic	Financial costs			Economic
Cost category	Farmers	SONADER	Total	cost	Farmers	SONADER	Total	cost
Fixed costs	3.3	13.3	16.6	29.0	1.6	1.8	3.4	10.3
Operating costs	4.0	11.9	15.9	17.7	4.9	4.1	9.0	9.7
Administrative costs	0.0	11.8	11.8	11.8	0.0	11.8	11.8	11.8
Family labor costs	4.7	0.0	4.7	4.7	6.5	0.0	6.5	6.5
Marketing costs[a]	4.0	0.0	4.0	4.6	2.5	0.0	2.5	2.5
Total costs	16.0	37.0	53.0	67.8	15.5	17.7	33.2	40.8
Percentage	30.0	70.0	100.0		47.0	53.0	100.0	

Source: Calculated from Koita, 1986, Table 5.18.
[a]It is assumed that 80 percent of the SONADER milling costs are for imported machinery. Thus, marketing economic costs are U.M. 4.6 for the large-scale perimeter.
US $1 = U.M. 46

Table 13. Average Cost per Kilo of Imported Milled Rice Delivered to the Upstream Zone of the Fleuve, Mauritania, 1980 (Ouguias).

Cost component	Amount
Average CIF price	13.8
Buying cost	0.5
Shipping and handling	1.5
Taxes	0.5
Margin	0.3
General costs	2.9
Total average cost in Nouakchott	19.5
Transport cost to the Fleuve Zone	5.0
Total average cost in the Fleuve Zone	24.5

Source: RAMS, June 1981 and Koita, 1986, Table 5.6.
US $1 = U.M. 46

Table 14. Comparative Costs Between Imported Rice and Rice Produced in the Upstream Zone of the Senegal River Valley, Mauritania, 1980 (Ouguias).

		Locally produced rice			
Type of Scheme	Average imported rice cost	Financial cost/ kilo	Percent ratio of imported to domestic cost[a]	Economic cost/ kilo	Percent ratio of imported to domestic cost[b]
Large perimeter	24.5	53.0	216.3	67.8	250.7
Small perimeter	24.5	33.2	135.5	40.8	150.6

Source: Koita, 1986, tables 6.4 and 6.6.
[a]Percent ratio = financial cost divided by average cost for imported rice.
[b]Percent ratio = economic cost divided by CIF price * SER + domestic costs (w/o taxes).
US $1 = U.M. 56

Table 15. Total Cost of One Kilo of Rice Produced in the Senegal River Valley under Revised Wage Rate Assumptions, Mauritania, 1980 (Ouguias).

	Large-scale irrigated perimeter				Small-scale irrigated perimeter			
	Financial costs			Economic	Financial costs			Economic
Cost category	Farmers	SONADER	Total	cost	Farmers	SONADER	Total	cost
Fixed costs	3.3	13.3	16.6	29.0	2.4	3.8	6.2	10.3
Operating costs	4.0	11.9	15.8	17.7	4.9	4.1	8.9	9.7
Administration costs	0.0	11.8	11.8	11.8	0.0	11.8	11.8	11.8
Family labor costs	9.4	0.0	9.4	9.4	9.7	0.0	9.7	9.7
Marketing costs[a]	4.0	0.0	4.0	4.6	2.5	0.0	2.5	2.5
Total costs	20.7	37.0	57.6	72.5	19.5	19.7	39.1	44.0
Percentage	30.0	70.0	100.0		44.0	56.0	100.0	

Source: Calculated from Koita, 1986, Table 6.4.
[a]It is assumed that 80 percent of the SONADER milling costs are for imported machinery. Thus, marketing economic costs are U.M. 4.6 for large-scale perimeters.
US $1 = U.M. 46

Table 16. Comparative Costs between Imported Rice and Rice Produced in the Upstream Zone of the Senegal River Valley under Revised Wage Rate Assumptions, Mauritania, 1980 (Ouguias).

Type of scheme	Locally produced rice: Financial cost per kilo	Percent ratio of imported to domestic cost[a]	Economic cost per kilo	Percent ratio of imported to domestic cost[b]
Large perimeter	57.6	234.1	72.6	268.1
Small perimeter	39.1	159.3	52.0	192.0

Source: Koita, 1986, tables 6.8 and 6.6.
[a]Percent ratio = Domestic financial cost divided by average cost for imported rice.
[b]Percent ratio = Domestic economic cost divided by CIF price * SER + Domestic costs (w/o taxes).
Cost of imported rice = 100.
US $1 = U.M. 46

Table 17. Farmer costs to Produce One Kilo of Rice at Various Cropping Intensities and Yields (Real) in the Large- and Small-Scale Perimeters, Upstream Zone of the Fleuve, Mauritania, 1980 (Ouguias).

Milled yield (tons/ha)	Cropping intensity per year: 1.25 Small	1.25 Large	1.5 Small	1.5 Large	1.75 Small	1.75 Large	2.0 Small	2.0 Large
4	10.4	9.5	8.7	7.9	7.4	6.8	6.5	6.0
5	8.1	7.4	6.8	6.2	5.8	5.3	5.1	4.6
6	6.8	6.3	5.7	5.2	4.9	4.5	4.3	3.9

Source: Koita, 1986, Table 6.3.

Table 18. Total Financial Cost to Produce One Kilo of Rice at Various Cropping Intensities and Yields (Real) in the Large- and Small-Scale Perimeters, Upstream Zone of the Fleuve, Mauritania, 1980 (Ouguias).

Milled yield (tons/ha)	Cropping intensity per year							
	1.25		1.5		1.75		2.0	
	Small	Large	Small	Large	Small	Large	Small	Large
4	31.4	46.1	26.1	38.3	22.3	32.9	19.6	28.8
5	24.4	36.0	20.4	30.0	17.5	25.7	15.3	22.5
6	20.6	30.3	17.1	25.3	14.7	21.7	12.9	18.9

Source: Koita, 1986, Table 7.1.

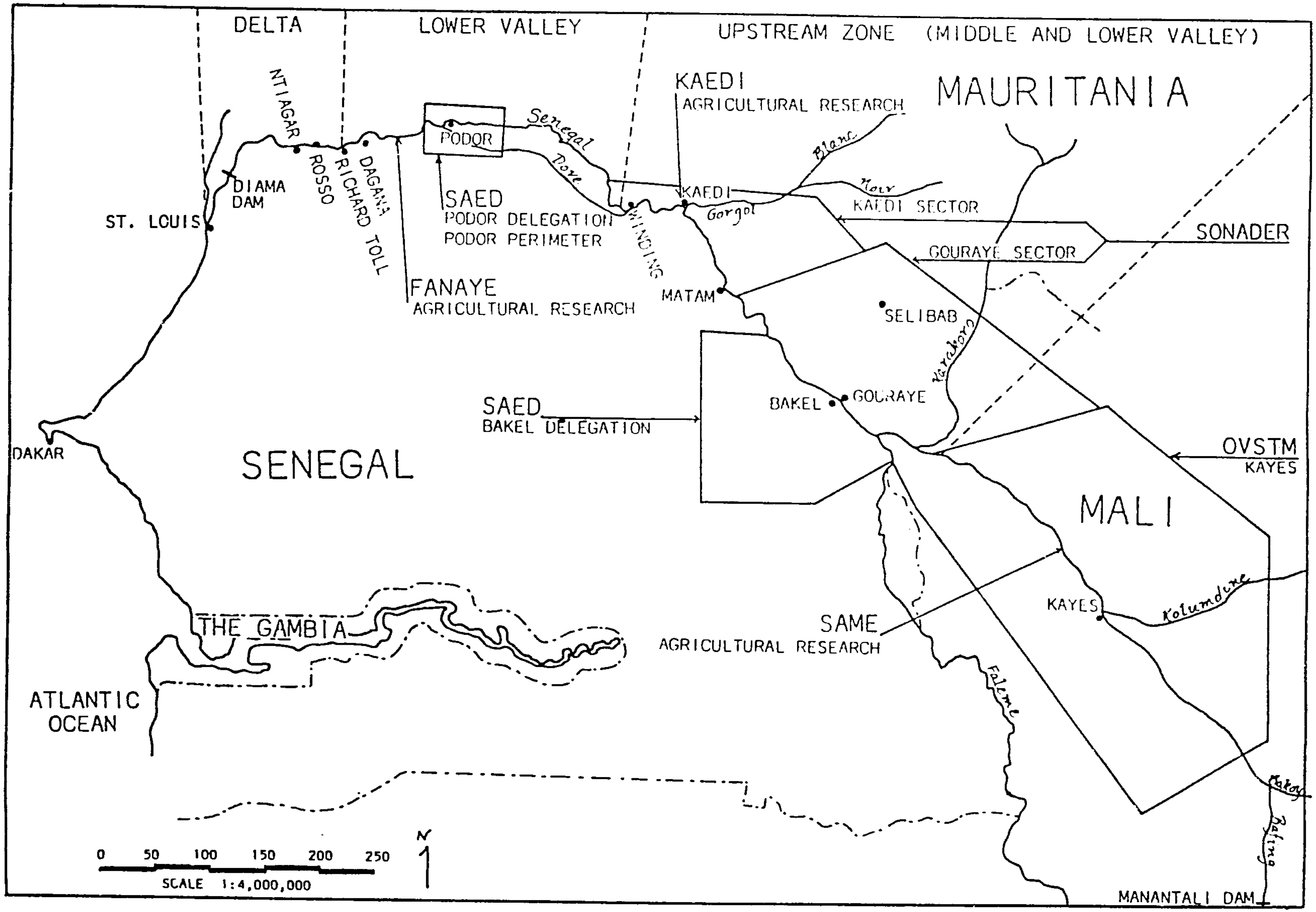

Figure 1. Perimeter Location Map

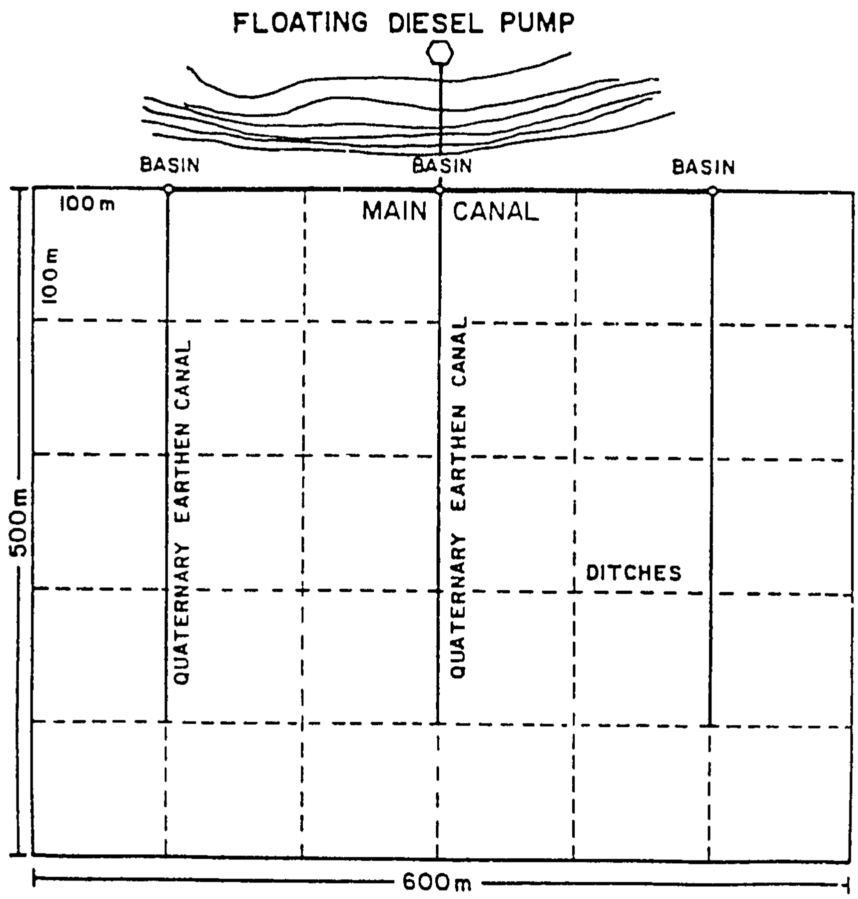

Figure 2. Complete Water Control (Tertiary Development).

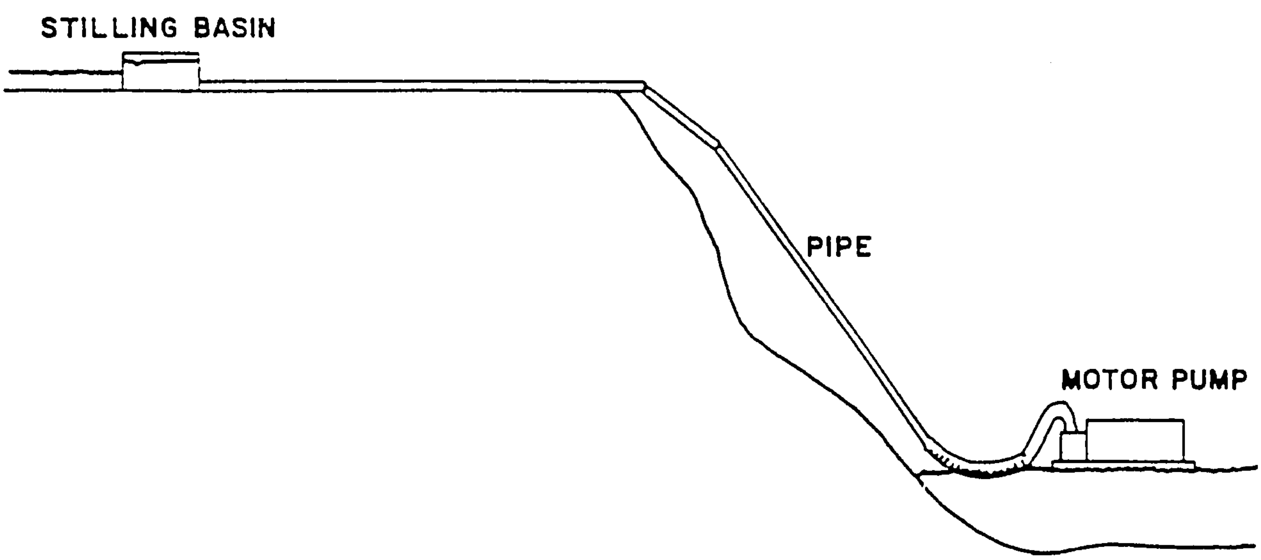

Figure 3. Pump Float on the River (Small-Scale Perimeter).

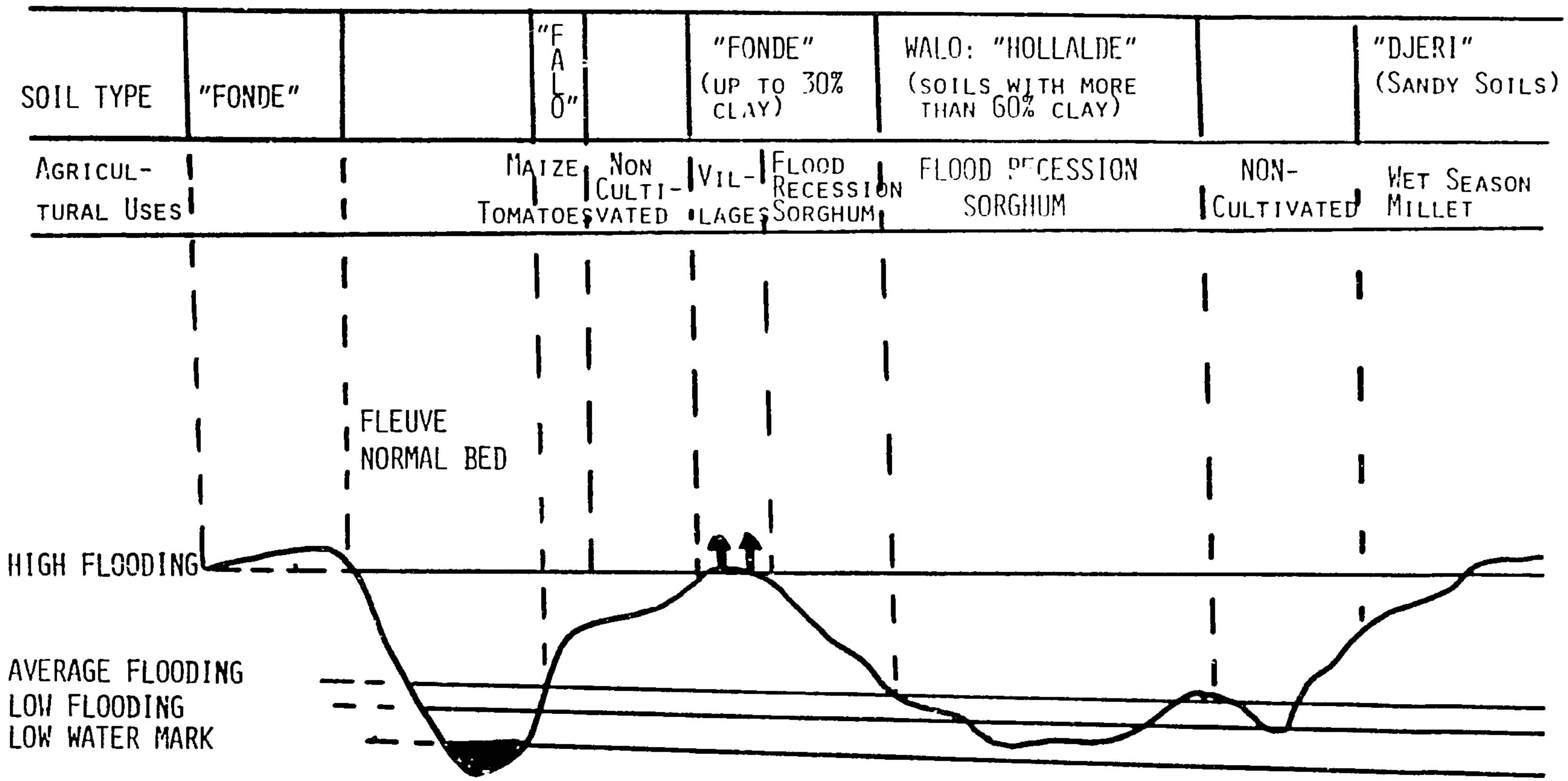

Figure 4. Spatial Representation of Different Soils in the Senegal River Valley.

Source: RAMS (1981).

MANAGEMENT OF IRRIGATION WATER IN THE MIDDLE VALLEY OF THE SENEGAL RIVER: THE WARDA/WAGENINGEN PROJECT

Lucas Horst

The West African Rice Development Association (WARDA), to which fifteen West African states belong, started research on management of irrigation water on the small schemes in the Middle Valley of the Senegal River in July 1982. A preliminary phase ended July 1984, and a second phase was started in November 1985. Research during the preliminary phase was designed both to help answer policy and practical, field-related questions and to form a foundation upon which to base future research priorities in the field of water management. This paper describes the design and implementation of the preliminary phase and presents research topics to be considered during the second phase.

THE GEOGRAPHICAL SETTING

The Senegal River Valley extends over 800 kilometers, and its Middle Valley covers approximately 400 kilometers. The slope is gentle; at 800 kilometers from the ocean, the riverbed is only 25 meters above sea level. The Middle Valley is characterized by a relatively wide flood plain used for flood-recession cultivation of sorghum. Average rainfall was approximately 350 millimeters between 1930 and 1960 and dropped to about 200 millimeters during the 1970s. Rainfed cultivation of millet is unreliable, even in the upper reaches of the Middle Valley where average annual rainfall used to amount to 600 millimeters but has now dropped to approximately 450 millimeters.

The Middle Valley is essentially inhabited by four peoples: the Halpulaar (known in ethnographic literature as the Tokolor), Soninke (also called Sarakolle, after their language), Wolof, and Arab-speaking Moors. In response to a steady increase in population density, the effects of which were aggravated by the sudden drop in rainfall and river discharge in the 1970s, the inhabitants have started to construct irrigation schemes, which now cover about 20 hectares. Since the schemes are physically quite similar, a study of system management can help to identify the social dimensions of the management of irrigation water.

THE CONTEXT OF IRRIGATION DEVELOPMENT

The Senegal River Basin includes land in four countries: Senegal, Mauritania, Mali, and Guinée-Conakry. The former three are members of the Organization pour la Mise en Valeur du fleuve Sénégal OMVS (Guinée-Conakry is a founding member but withdrew in the 1960s). Under the aegis of OMVS, a river basin development plan, including the construction of two dams--one upstream at Manantali--one at 26 kilometers from the mouth at Diama, was formulated. The purpose of the dams is to

1) develop the huge potential for irrigated farming,
2) make the river navigable up to Kayes in Mali,
3) produce electricity, and
4) ensure the drinking water supply for Dakar and other cities.

State efforts aimed at developing the basin's potential for irrigated agriculture date back to 1817 and have continued intermittently until today, although with little success. Problems included an inadequate understanding of various physical concepts with respect to characteristics of the annual flood and lack of incorporation of farmer objectives, local political relationships, and organizational linkages in the physical design of the schemes. During the 1960s, irrigated areas were successfully used for two main farm types. On the classical sugar cane plantation, Senegalese farmers were employed as "factory" workers rather than as independent cultivators. The other grew out of experiments by farmers with unsuccessful schemes designed by engineers and based on controlled flooding. In one of the Mauritanian villages, farmers constructed a canal network on sandy soils near the river. Both construction and cultivation were carried out by hand, and a pumping facility was installed by the Mauritanian state. Other Mauritanian villages rapidly imitated this small scheme, and in 1974, FAO started a program to disseminate the schemes on the left bank. In 1984, there were more than 500 small schemes in the Middle Valley, each covering on average 20 hectares, which were subdivided into 30 to 120 plots used for subsistance cultivation of rice and corn.

THE DESIGN OF THE PRELIMINARY PHASE

Based on anthropological reasoning, it could be hypothesized that the four valley societies would manage their schemes in different ways in spite of the physical similarities among them. A study of these differences could more clearly delineate the social dimensions of irrigation management in Sahelian Africa. More specifically, it was felt that the use of anthropological fieldwork techniques by (student) irrigation engineers would yield data with respect to water distribution and resolution of conflict that would

(1) clarify the differences between engineering and user concepts of water management and distribution, and

(2) help planners view irrigated agriculture in a broadly social rather than narrowly organizational phenomenon.

To aid in constructing irrigation development policies, objectives of the preliminary phase consisted of gathering sociological data of use to agricultural engineers involved in expansion of irrigated agriculture in the Middle Valley and, on a more academic level, of comparing Halpulaar, Soninke, and Moorish water distribution system maintenance and conflict resolution.

For each ethnic group, a student irrigation engineer and a student sociologist studied neighboring villages and their respective schemes. Wolof villages were not included in the study because of their relatively smaller numerical sizes, and two student irrigation engineers were sent to Halpulaar schemes because two anthropologists from the African Studies Center in Leiden had just completed twenty months of anthropological fieldwork on Halpulaar irrigated farming.

SOME RESULTS OF THE PRELIMINARY PHASE

As data from the Soninke fieldwork are not yet fully analyzed, no definite results can be given. We can, however, summarize some of the work dealing primarily with Halpulaar schemes.

To an engineer not acquainted with water distribution practices on Halpulaar schemes, 'chaos' is the first word that comes to mind. Closer observation shows, however, that rules formulated by the users, do exist. The rules govern such things as the order in which plots are watered, the number of sectors and plots that can simultaneously be irrigated, the volume of water that one is authorized to take, situations in which users are or are not entitled to supplementary irrigation water, the need for a user to be present when his/her plot has its turn, pumping hours, the right to use leaking water, and the watering of seedbeds.

The pattern of water delivery is the result of decisions made by the ever-changing user group who will shortly receive water. These users determine when the operator will start his pump, and hence the water will flow by making an appointment with him or by arriving on the scene. (The pump is only started when the person whose turn it is has arrived.) Those who will shortly have their turn decide upon possible deviations from the established order and whether to accommodate requests for supplementary irrigation. Prior users also help determine the duration of the irrigation interval by using more or less water on their plots.

Of course the plant water requirements vary over the season and the growing cycle. Users react to increased water needs by starting to irrigate earlier in the morning, and to plentiful water supplies by not watering. As a result, irrigation intervals vary over the season. On some schemes, users increase the pumped flow by turning the engine to a higher speed when more water is needed. Often, however, this is not possible because canals already transport the maximum flow.

Irrigation intervals, therefore, result from an interaction between (the user perception of) plant needs and organizational rules for water distribution. These rules can be likened to sociological norms in the sense that they express for a given situation at the specific moment in history certain values. For Halpulaar users, one fundamental value is the apparent social equality of all participants. As far as access to irrigation water is concerned, this equality is embodied in the rule that any user can take as much water as wanted during his or her turn. Turn order is reversed every season without regard to social status, and irrigated plots are awarded by lottery. Fuel and repair and maintenance costs for the pumpset are divided equally among users irregardless of harvest volume. In a sense, the irrigation scheme can be seen as what in Euro-American society is regarded as a public convenience. Of course, many other values find their way into the water distribution practices, some of which stress the hierarchical nature of the relationships among freeborn persons and people of slave descent, but space lacks here to discuss these.

On Halpulaar schemes, every household waters its own plot. On Soninke schemes, however, users are assembled into 'irrigator groups' of approximately fifteen people. On an average scheme, between three and five of such groups are formed. The groups take turns in watering the plots when the scheme is being irrigated. As a result, a plotholder may find that at the end of the growing season he has never watered his own plot, although some or all of the other groups or even members of his own group may have irrigated it.

On Halpulaar schemes, water distribution is relatively free from conflicts, but such is not the case on the Moorish schemes. Here also, the user must be present during his/her turn. However, where collective decision making and enforcement are internalized in the Halpulaar groups, among the Moorish villagers they are not. Many users are recently emancipated slaves who are fearful that if they obey others they will slip back into their socially inferior position. As a result, water distribution on the two Moorish schemes studied often resulted in deadlocked situations that lasted for days. Ironically, the only people capable of untying the social knot were "white" Arabs, members of the slave-owning class.

RESEARCH TOPICS FOR THE SECOND PHASE

The second phase of the water management research in the Senegal Valley started in November 1985 and will last until 1989. The project is financed by the Dutch Government and executed by WARDA. Scientific backstopping is carried out by the Irrigation Department of the Agricultural University of Wageningen. The research team consists of an irrigation specialist, a sociologist, junior scientists, graduate students, and observers. The objectives of the second phase are

- provide technical and socioeconomic support to help improve existing and newly created small-scale irrigation systems;
- provide empirical knowledge to guide the evolution of irrigated agriculture at the peasants' level;
- identify and translate the needs and interests of the farmers as well as those of the government with regard to irrigation development.

Four research topics are

a) Improvement of concepts related to and management of small-scale systems;

b) development of criteria for measuring the performance of irrigated agriculture that satisfy both the government and farmers (medium-scale projects);

c) improvement of communication among government and farmers; and

d) development of a research methodology that can be applied in other parts of Sahelian West Africa.

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WATER MANAGEMENT SYNTHESIS PROJECT REPORTS

WMS 1 Irrigation Projects Document Review

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

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

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

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

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

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

WMS 7 General Asian Overview.

WMS 8 Command Area Development Authorities for Improved Water Management.

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

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

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

WMS 12 Ecuador/USAID: Irrigation Sector Review.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

WMS 31 Training Consultancy Report: Irrigation Management and Training Program.

WMS 32 Small-Scale Development: Indonesia/USAID.

WMS 33 Irrigation Systems Management Project Design Report: Sri Lanka.

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

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

WMS 36 Irrigation Sector Assessment: USAID/Haiti.

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

WMS 38 Diagnostic Analysis of Sirsia Irrigation System, Nepal.

WMS 39 Small-Scale Irrigation: Design Issues and Government Assisted Systems.

WMS 40 Watering the Shamba: Current Public and Private Sector Activities for Small-Scale Irrigation Development.

WMS 41 Strategies for Irrigation Development: Chad/USAID.

WMS 42 Strategies for Irrigation Development: Egypt/USAID.

WMS 43 Rapid Appraisal of Nepal Irrigation Systems.

WMS 44 Direction, Inducement, and Schemes: Investment Strategies for Small-Scale Irrigation Systems.

WMS 45 Post 1987 Strategy for Irrigation: Pakistan/USAID.

WMS 46 Irrigation Rehab: User's Manual.

WMS 47 Relay Adapter Card: User's Manual.

WMS 48 Small-Scale and Smallholder Irrigation in Zimbabwe: Analysis of Opportunities for Improvement.

WMS 49 Design Guidance for Shebelli Water Management Project (USAID Project No. 649-0129) Somalia/USAID.

WMS 50 Farmer Irrigation Participation Project in Lam Chamuak, Thailand: Initiation Report.

WMS 51 Pre-Feasibility Study of Irrigation Development in Mauritania: Mauritania/USAID.

WMS 52 Command Water Management - Punjab Pre-Rehabilitation Diagnostic Analysis of the Niazbeg Subproject.

WMS 53 Pre-Rehabilitation Diagnostic Study of Sehra Irrigation System, Sind, Pakistan.

WMS 54 Framework for the Management Plan: Niazbeg Subproject Area.

WMS 55 Framework for the Management Plan: Sehra Subproject Area.

WMS 56 Review of Jordan Valley Authority Irrigation Facilities.

WMS 57 Diagnostic Analysis of Parakrama Samudra Scheme, Sri Lanka: 1985 Yala Discipline Report.

WMS 58 Diagnostic Analysis of Giritale Scheme, Sri Lanka: 1985 Yala Discipline Report.

WMS 59 Diagnostic Analysis of Minneriya Scheme, Sri Lanka: 1986 Yala Discipline Report.

WMS 60 Diagnostic Analysis of Kaudulla Scheme, Sri Lanka: 1986 Yala Discipline Report.

WMS 61 Diagnostic Analysis of Four Irrigation Schemes in Polonnaruwa District, Sri Lanka: Interdisciplinary Analysis.

WMS 62 Workshops for Developing Policy and Strategy for Nationwide Irrigation and Management Raining. USAID/India.

WMS 63 Research on Irrigation in Africa.

WMS 64 Irrigation Rehab: Africa Version.

WMS 65 Revised Management Plan for the Warsak Lift Canal, Command Water Management Project, Northwest Frontier Province, Pakistan.

WMS 66 Zimbabwe Joint Field Workshop.

WMS 67 Variations in Irrigation Management Intensity: Farmer-Managed Hill Irrigation Systems in Nepal.