Irrigation in Sudan Since Independence*

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The history of irrigation in Sudan may conveniently be divided into precolonial, colonial, and postcolonial periods. The first two have been the subject of many studies, but apart from a small mountain of consultant and donor documents, which are generally not available in libraries, little has been published on the postcolonial period. Since the British left Sudan at the end of 1955, however, there have been many important changes in this most important part of the Sudanese economy. The command or service area of the Gezira Scheme—the jewel in the crown of British resource development in Sudan-- was doubled in the first decade of independence to 2,000,000 acres, and during the 1970s the cropping intensity of the older part of the scheme was raised by 50 percent. New projects have also been undertaken, not only the 400,000 acres at New Halfa but also the 300,000 of the Rahad scheme, on the right bank of the Blue Nile, opposite the Gezira. In the past decade, almost $1 billion have been budgeted for rehabilitating and improving the country's schemes, and much more will probably be spent on this task in the future.

The Gezira

At independence on 1 January 1956, the Republic of Sudan had approximately two million acres under the command of irrigation canals. One-half of that total was in the Gezira scheme, a gravity project on the left bank of the Blue Nile; most of the remainder was in pump schemes on the Nile downstream from Khartoum and on the left bank of the White Nile downstream from Kosti. There were small spate schemes at Tokar on the Red Sea coast and on the inland Gash delta near Kassala. With the exception of some pump schemes on the main Nile, all the works had been built to generate export revenues from the sale of long-staple cotton. They were farmed by closely regulated government tenants, whose lowly rank as *de facto* sharecroppers irrigation officers stress to this day, whenever suggestions are made to give the tenants more power. Most of the pump schemes were privately owned and operated under government license. Others were operated by the government or by parastatals, of which the Sudan Gezira Board was the most important.

These irrigation schemes were hugely important to the economy of Sudan. Since the opening of the initial 300,000 acres of the Gezira in the late 1920s, cotton had provided most of the country’s export earnings, and its irrigation potential was by no means exhausted. To begin planning for future development, the British in the early 1950s hired the consulting firm of Sir Alexander Gibb and Partners to evaluate the remaining opportunities for irrigation along the Blue Nile. Gibb calculated that the irrigated command in Sudan could be doubled--as in fact it has been. It has not been doubled the

way Gibb recommended, however, because along with several pump schemes Gibb recommended construction of the Kenana Scheme, which would have been another gigantic gravity project on the scale of the Gezira. It would have reclaimed 1,000,000 acres in the southern part of the Gezira plain by canals that diverged from the Blue Nile at a new storage reservoir at Roseires, near the Ethiopian border.

With independence, however, Sudan was unable to afford the Roseires reservoir, and donors such as the World Bank were unwilling to lend or give money for the project unless Egypt agreed to a modification of the existing treaty governing Sudan's use of Nile water. The Egyptians, hoping for political union with Sudan, signed a generous treaty in 1959. It is still in force and multiplies nearly 700% the amount of water that the old agreement of 1929 allowed Sudan. There are many ways of expressing the quantum available to Sudan, but one graphic way is this: Sudan is entitled to 20 of the 80 cubic kilometers of water that the Nile carries between the two countries in an average year. With assistance from the world bank and the West German government, the Roseires reservoir was finished in 1966. Now, however, it was the Kenana canals that were dropped as too expensive. Much of the water impounded at Roseires was used instead to expand and intensify agriculture on the Gezira Scheme.

Anticipating construction of Roseires and deferment of Kenana, the Sudanese government in 1956 authorized construction of new outlet gates at Sennar Dam, the masonry structure completed in 1929 to impound the Blue Nile and divert a part of it into the Gezira's main canal. The new gates were to control the release of water to a new set of canals commanding a 1,000,000-acre western addition to the Gezira. When completed in 1963, this Managil Extension, named for the largest existing settlement in the area, doubled the command of the Gezira, whose older part has since been called the Gezira Main. The entire scheme is still managed by the Sudan Gezira Board from its headquarters at Barakat, near Wad Medani. The board operates from a two-story yellow-brick building, with green verandas and a courtyard seasonally bright with bougainvilleas.

The Managil extension resembled the Gezira Main in fundamental ways. Straight minor canals branched off major ones at intervals of 1,420 meters in parallel ranks, like teeth from the back of a comb. At intervals of 280 meters along each minor, a wrought-iron field-outlet pipe passed underneath the canal bank and led to a small ditch, called an *abu ishreen,* that ran in a straight line, generally perpendicular to the minor, for nearly 1,400 meters before stopping short of the next minor. A rectangular ninety-acre field or "number" was in this way bounded by two minors and two *abu ishreens*. Each number was subdivided into smaller plots watered from a tiny ditch, an *abu sitta,* that took water from an *abu ishreen* and carried it across the high end of each plot. Tenancies were laid crosswise across several numbers so that a tenant had

plots in a narrow rectangle parallel to a minor canal. The same distinctive layout can be found on most of the pump schemes in Sudan. From the air, it forms a very distinctive and perhaps unique mosaic of fields and streams.

Managil tenancies were much smaller than those in the Gezira Main, however. Instead of four ten-acre plots, tenants received three five-acre ones. Sudanese planners deserve credit for this change, because they were struggling to correct a scandal on the Gezira Main. Despising field labor, many tenants there had become absentee farmers by relying on hired help throughout the year, not only at picking time. By reducing the tenancy size, the planners hoped to make such arrangements uneconomic.

They failed in this effort, however, because only one-half of each tenancy on the Gezira Main was worked during any season, while at Managil it was finally decided that there would be no fallow. The cultivated area of 15 acres there, in other words, was not far short of the 20 cultivated in the Gezira Main. The case for hired labor on the Managil was actually stronger than on the Gezira Main, where most tenancies had over the years been split into 20-acre half-tenancies, as the first generation willed its property to the next. If hired labor was economic on the ten cropped feddans of a half-tenancy on the Main, it was economic on the 15 cropped ones of the Managil extension, even with allowances for the Managil's somewhat poorer soil and water conditions.

The Managil extension did not consume all the water made available at Roseires, and to use more of it the agriculture of the Gezira Main was intensified in the late 1960s and early 1970s. As early as 1951, the Gezira Board had begun a village farming experiment involving a hundred or so tenants; the hope was to test ways to diversify cropping practices under field conditions, not merely those of the Board's experimental farm. One result was the introduction of peanuts. Another was a new cropping pattern. Since the 1930s, the scheme had operated with a cropping intensity of 50 percent, with a rotation in which two numbers were fallow, one was in cotton, and one was divided between sorghum and fodder, grown for the use of tenants and their livestock. In the new arrangements, peanuts replaced the fodder and winter wheat was grown during the first of the two fallows. Cropping intensity rose from 50% to 75%.

Watering practices changed to accommodate the new pattern. Formerly, the Ministry of Irrigation had delivered enough water into the minor canals to cover the cotton numbers to a depth of ten centimeters every two weeks, with twelve waterings in the season. Like clockwork, guards released water from the minors through the field-outlet pipes into the *abu ishreens* on a schedule of seven days on and seven off. During an "on" period, during which an *abu ishreen* delivered 5,000 cubic meters of water every 12 hours, the upper tenants took water into their *abu sittas* in the first few days of the watering week; the lower tenants then took their turn. By balancing one cotton number

against the next--one taking water while the other did not--the canals could be kept running continuously, with water always flowing from the minors at a constant rate.

Fodder and grain crops, always secondary, were irrigated irregularly with unscheduled deliveries of surplus water in the system, perhaps the result of rainfall, which could suddenly reduce the irrigation requirements of the cotton. A more difficult problem arose with farmers who were unwilling to tend at night to the close work of irrigating their plots, but this was solved by closing the outlets to the *abu ishreens* at dusk. The water accumulated in the minors overnight, until the outlets were opened the next morning.

The Gezira Board expected tenants to bank their 10-acre cotton plots into nearly 200 tiny basins, to be flooded in groups of ten during the three-day irrigation period. The tenants, however, learned--without the assistance, the direction, or even the approval of the board--to instead open the bank of their *abu sittas* at six or seven places simultaneously and, using small but controlled flows, to flood their ten-acres as one basin. There were times, particularly at the first watering of wheat, when the tenants would still use the officially required but much more labor-intensive small-basin method, but the new "open plan" saved so much work that by the early 1970s it was the rule, though never officially recognized or approved.

Farmers no longer had to tend to their fields continually while irrigating, and so night irrigation became possible. The night-storage system ended, although the operating rules of the scheme were never officially revised. Rule-conscious engineers will insist that the field outlets are closed at night, but board guards long ago gave up their control of the outlets. One study reports that, if they want water, four tenants in five will open the field outlets themselves. With round-the-clock releases and only occasional closures of the outlets, the daily flow into each open *abu ishreen* inevitably declined from 5,000 cubic meters to approximately 3,000. The decline might have been far greater than that, because the outlets to numbers in wheat and fodder crops also remained open most of the time. Beginning in 1968, however, the irrigation ministry began raising the water level in the main canals some fifteen centimeters above the previous full-supply level. The volume of water actually distributed to a group of four numbers consequently increased from 5,000 cubic meters daily during a cotton-watering week, plus a variable quantity for the other crops, to almost 9,000 cubic meters every week of the season. There are times when the canals have so much water that ponds develop of waste water form at the far ends of the systems, especially they approach the White Nile: from the air, these periodic lakes are arresting.

In the midst of these fundamental changes in the Gezira's cropping pattern and water management, the World Bank sent a study mission to spend the 1965-66 season on the Gezira and find ways to increase tenant income. The motive was

simple: the bank then had an investment of $47 million in the Gezira, including a 1960 loan of $15 million to support construction at Managil (the first loan for irrigation made by the bank in Sudan) and a $32-million loan made in 1961 for the reservoir at Roseires.

The mission members conducted an unsuccessful search for alternative crops that would be more profitable than cotton. They considered introducing perennial fodder crops but worried that perennial irrigation might damage the structure of the heavy clay. They weighed conversion from extra-long to medium-staple cotton, which used less water and had higher yields. The two kinds cannot be grown close to each other, however, without increasing insect populations, and because the mission did not recommend the complete abandonment of long-staple cotton, conversion to medium-staple came only to isolated parts of the scheme. The failure to identify alternatives was sobering; indeed agronomists are still at a loss to recommend crops that would be more profitable than cotton on the Gezira.

The study mission also took the radical step of recommending abolition of the 'joint account," under which the board took a share of the cotton-crop proceeds. The mission wanted tenants to have greater incentives to maximize production and argued that tenants should receive the full value of their crop, less deductions for taxes and services provided by the ministry and the board. The proposed land-and-water charge, however, was rejected by the government. Fifteen years later, however, when the government faced low prices, reduced revenues, and deteriorating project maintenance, it requested an emergency loan from the bank. It was granted, conditional on acceptance of land-and-water charges.

New Halfa and Rahad

While seeking ways to use Roseires water, the bank in 1961 had appraised as a substitute for the Kenana scheme a 600,000-acre right-bank Blue Nile scheme known as the Rahad. The project would have taken water directly from Roseires, as Gezira does from Sennar. The outlet gates for such a canal were actually built at Roseires, but they lead nowhere, because with a cost estimated in 1961 at $140 million the project was set aside for the moment as too expensive.

At New Halfa, however, Sudan was busy with a new and unhappy project. Seven thousand Halfawi families had lost their homes, lands, and villages to the rising waters of Lake Nasser. Bitterly unhappy, they were resettled at Egyptian expense 300 kilometers east of the Gezira on the upper Atbara River. Because the Halfawis were losing freeholds at Halfa, they were given tiny freeholds at New Halfa, but this unique arrangement wasn’t as generous as it may sound, because the 7,000 families received only 24,000 acres. The Halfawis, moreover, were a tiny minority on the 330,000 acre New Halfa project, most of

which was settled by 20,000 local families, who began settling on the project in 1964. Like those at Managil, they were allocated 15-acre tenancies cultivated without fallow.

The Halfa project depends on the Khashim el Girba Dam, begun in 1959. The reservoir behind the dam silted so fast, however, that by 1977 half its storage capacity was lost. To reduce the costs of canalization, meanwhile, most of the minor canals were spaced twice as far apart as on the Gezira. This meant that the *abu ishreens* were twice as long as those of the Gezira, and that in turn meant that water did not flow to the distant or tail-end tenants.

The Halfawis felt cheated, and most of them deserted the scheme during its first decade. The other settlers, who had been cattle nomads, were also unhappy, because the New Halfa Agricultural Production Corporation wanted cotton, not cows. Assailed by physical and social problems, New Halfa actually irrigates less than 150,000 of the 400,000 acres under its command.

In the 1970s Sudan returned to a truncated, $125 million version of the Rahad scheme. The World Bank, Kuwait, and USAID together lent the country $40 million to help build a 300,000-acre project no longer fed by gravity from Roseires but by pumps taking water from the Nile and combining it with the spate flow of the Rahad River.

New Halfa had taught its planners to be cautious. Certainly they were innovative. Numbers were laid out with the geometric precision and the tenancies that were the legacy of British irrigation in Sudan, but the project planners sought replace the old methods with mechanized production of medium-staple cotton, to be irrigated by long furrows. Tenants were expected to take water through batches of siphons feeding furrows 280 meters long across each ten-acre plot.

Long furrows had been advocated in the Gibb report of 1954, which had proposed the Kenana scheme. Although the choice was not explained, presumably the authors believed that long furrows were a good way to apply water quickly and efficiently, without waterlogging. Long furrows function best on precisely leveled land, however, and leveling is costly. In addition, the heavy clays of the Gezira do not absorb water except through the deep cracks that open when the soil is dry, so long-furrow irrigation may not water the soil thoroughly. Indeed, water may run down a furrow, vanish into a crack, and reappear from a crack in a neighboring furrow, disrupting the even application of water across the field.

In 1975, with inflation and energy costs soaring, the Rahad was reappraised at a cost of $320 million. The world bank added another $20 million, and the Kuwaitis contributed an additional $40 million. Approximately $4 million was budgeted for leveling, but by 1983 estimates of levelling cost had risen to $50

million. Only a tenth of the project, or 30,000 acres, was finally leveled. Long furrows were abandoned even there, as the tenants discovered the difficulty of getting uniform water application on the clay soils. The technology was finally condemned as an "inappropriate technology choice" in the world bank's own project-completion report.

Rahad was finished in 1983 at a total cost of $400 million. Development of an additional 300,000 acres of a Rahad II Project was indefinitely postponed. Mechanized harvesting had meanwhile proved uneconomic, and tenants returned to the irrigation and cultivation methods of the Gezira. Medium-staple cotton prices fell, however, and many tenants found themselves in debt to the Rahad Corporation for service charges. From the outset, the corporation had adopted the land-and-water charges prescribed by the world bank's study mission, but the corporation soon fell into chronic debt because it dared not bill tenants for more than half its actual costs and overheads.

Rehabilitation

Despite this woeful history, the Ministry of Irrigation in the late 1970s still hoped to start construction not only of Rahad II but of a 500,000-acre project on the Atbara River above New Halfa. Most of all, perhaps, it wanted to raise the crest of Roseires Dam, whose reservoir, like the one at New Halfa, was rapidly silting. The ministry's enthusiasm was sustained by a massive study undertaken by the consulting firm Coyne and Bellier. Funded by the world bank's Rahad I credit, this study said that Sudan's most economical choice was further intensification of the Gezira, but the consultants rejected this path because Gezira tenants had already benefited from public investment. New projects should instead be started.

The world bank came to a different conclusion. Conducting its own review of Sudanese agriculture in 1979, it called for a halt to construction of new irrigation works, and it advocated instead the rehabilitation of existing ones. From any other source this recommendation would have been ignored, but since 1979 no major new irrigation project has been begun in Sudan.

At the time of the study, New Halfa was operating with a cropping intensity of 30%, one-third of the 90% for which it had been designed. Most of the country's pumping schemes were in equally bad condition. Low cotton prices had caused the abandonment of half of them by 1968, and most of the ones still operating were nationalized—one of the few cases that come to mind of landowners actually welcoming a government takeover. The government duly bought 439 schemes on the White Nile, 314 on the Blue Nile, and 100 downstream from Khartoum—in effect, it bought all but the smallest schemes. The owners invested the proceeds in more profitable ventures, and the tenants became dependent on state corporations whose debts continued to rise.

An old spate system on the Gash delta was suffering badly. This primitive system comprised 180,000 acres crossed by several parallel canals that operated only during a month-long annual flood. Water was allowed to flow through each outlet in a fan-shaped lobe, but water was generally so limited that only a third of the outlets were used. In a reorganization similar to that for the pump schemes, the Gash was taken over in 1967 by the new Gash Delta Agricultural Corporation, but it was unable to irrigate even a of the project command. It abandoned cotton and shifted to drought-tolerant castor.

Worst of all, cotton production on the Gezira during the second half of the 1970s had been cut in half, as low prices and high costs left tenants with little interest in cotton and left the board with reduced means to provide necessary production services. Morale was low; a World Bank staff member working in Sudan at the time reported that "a sense of helplessness pervades the once dynamic Sudan Gezira Board."

It was at this point that the government acceded to the bank's long-frustrated desire for land-and-water charges. In turn, the bank lent $65 million in 1980 for imported spare parts, fertilizers, and pesticides; the European Community added $10 million to the first of three agricultural rehabilitation projects. Strikes by tenants in 1979 and again in 1980 protested the new arrangement. This delayed planting so long that cotton yields those years were severely depressed.

The tenants grudingly accepted the new system, and by 1984 production had returned to its 1975 levels. Yet the new system still depended on tenants receiving substantially more for their cotton than they were charged for services. To sustain farmer interest, the land-and-water charge for cotton was initially set at $30 an acre, even though the board was spending about $20 for fertilizer and $60 for pesticides—let alone the costs of operating the canal system. Since then, the charges have tripled, but so have input costs. Should the tenants be forced to bear them in full, enthusiasm for cotton would decline again.

The annual bill to Sudan for such imported inputs is approximately $130 million, or one-half the value of the cotton crop. To pay the bill, Sudan turns to foreign donors. In 1983 the World Bank advanced $50 million, while the European Community gave an additional $10 million. West Germany gave the Gezira Board $70 million worth of herbicides and pesticides in 1985. Still the demand was not satisfied, and in 1987 a loan of $85 million was offered by the bank and the European Community. Sudan is relatively lightly burdened by these debts, which at most charge low interest rates over a long term, but donor patience may not be infinite. There is a widespread conviction among the aid agencies in Khartoum that more fundamental changes must come to the schemes, so that help can eventually be discontinued.

To that end, the World Bank between 1980 and 1983 made a series of loans for rehabilitation of individual schemes, with funds for new equipment and vehicles and for improved buildings, roads, and water-distribution facilities. New Halfa came first in 1980, with a loan of $40 million. The next year the bank made two loans of approximately $30 million each for the Blue Nile and White Nile pump schemes. In 1983 a $260-million package was put together for the Gezira, with a bank contribution of $80 million and large additional sums from Saudi Arabia, Japan, and the United Kingdom. The British undertook to rehabilitate a group of northern pump schemes schemes whose original construction costs they had subsidized a decade earlier. In 1986 the Rome-based International Fund for Agricultural Development lent $10 million for others still farther downstream. A 1987 rehabilitation plan for the Gash delta has yet to be funded. The Rahad, though new, is the focus of a bank loan of $22 million to improve farming practices on Sudanese irrigation schemes. Research is a principal component of the project, along with the introduction of the bank's "train and visit" method of agricultural extension.

There's a lot of money wrapped up in these rehabilitation projects, but their results have disappointed everyone with expectations of change. Consider the rehabilitation of the Blue and White Nile pump schemes, scheduled for completion in 1986, when the loans expired. By then, only a third of the $30 million in the White Nile loan had been disbursed. The bank canceled the rest, except for $2 million to be spent on studies and $11 million for works that were to be completed within a year. At the end of the rehabilitation period, the amount of land producing cotton on these schemes had actually fallen from 63,000 acres to 54,000 acres, and the foreign-exchange cost of production inputs exceeded earnings from cotton sales. The Blue Nile rehabilitation project fared about as badly, and several million dollars of that credit were canceled. By 1987 the British were seriously considering cutting off their support for northern pump-scheme rehabilitation, because the Sudanese government refused to guarantee that it would implement a program to recover full operating and maintenance costs.

Of all the rehabilitation projects, the largest was for the Gezira. It was the most important project in another sense, too, because innovations on it were likely to be adopted elsewhere. Work on it was to start with rehabilitation, followed by modernization. The rehabilitation phase, covered by the 1983 loan, included new vehicles, equipment, and buildings for the Sudan Gezira Board, replacement of the hydraulic-control works on the canal system, improvements to the scheme's unpaved roads and light railway, and installation of a wireless, solar-powered telephone system donated by Japan for canal operations. To ensure that work proceeded on schedule, a special project-management unit was created, and the bank employed an irrigation engineer who was assisted by a bank economist already working at the Ministry of Agriculture. The modernization phase was left undefined, but funds were included in the

rehabilitation project for pilot farms where experiments in modernization could be performed on actual tenancies.

It is absurd to evaluate a project that has yet to be prepared, let alone executed, but doubts are already in order about the modernization program. There is a certain perversity in installing more than 30,000 new field-outlet pipes in the name of rehabilitation, when there is no clear idea how water should be managed in a modernized Gezira. The new outlets are designed, as the British ones were, to release an adjustable quantity of water, with a peak equal to that of the replaced outlets. Yet research from the pilot farms might show that this amount of water is not needed or that a valve should be installed that operates only at full discharge. The choices of a smaller outlet or one differently controlled are now effectively foreclosed.

The urgency of rehabilitation, it may be stated in defense of the program, did not allow a logical progression from research to the development of standards for a modernized scheme, yet it is doubtful that conditions on the scheme were so dire as this implies. The old telephone system had ceased to function in the 1960s, but canal operations continued without interruption. Gatekeepers at branching points no longer released measured quantities of water, but they released quantities proportional to the size of the downstream irrigated areas. Maintenance was so inadequate that emergency dredging was necessary to clear silt from the heads of minor canals, but water deliveries to *abu ishreens* were astonishingly close to the amounts that farmers needed, or so it appears from the few studies of system performance that are based on water measurements.

Unfortunately the rehabilitation project was more than precipitous: it brought such a heavily top-down approach to research on the pilot farms that modernization is likely not only to be constrained by the results of rehabilitation but also to ignore the wishes of tenants and laborers. The situation might not be so bad if the ideas of the bank and the Sudanese authorities were suited to actual farming conditions on the Gezira, but they are not. They are reminiscent of nothing so much as the failed mechanization, leveling, and long-furrow irrigation approach tried and abandoned at Rahad.

The intellectual atmosphere in which the work of the pilot farms is proceeding was well illustrated in 1987, when DEVCO, an Irish consultanting firm, submitted the first of several immense studies that were commissioned as part of the preparation for the modernization project. The DEVCO report was devastating in its criticism of tenant-laborer relations on the scheme: it estimated that some 85% of the labor on the entire scheme was done by hired hands, not by tenants and their families, half of whom no longer did any field work. Most of the laborers on the scheme were seasonal, arriving for the cotton harvest early each year, but there were also some 630,000 permanent residents of the scheme who are either landless laborers or their dependents. They

constitute a population more than half as large as the 1.1 million members of tenant families. Although tenants live in villages of mud-brick houses, with schools, electricity, and domestic water pumped from wells into overhead tanks, laborers live in grass huts erected in separate, canal-side villages without schools or electricity. Their domestic water comes from canals infested with schistosomes, and the group is disregarded by officials, who assert that these workers are much wealthier than they appear.

DEVCO examined livestock on the Gezira, an important subject because the average tenant derives a surprising one-third of his income from animals. Nearly two-fifths of the livestock on the scheme belong to laborers, however, not to tenants, so efforts to improve animal husbandry had to include laborer-owned livestock. The study recommended more attention to breeding programs, fodder development, dietary supplements, veterinary services, and marketing. There is no evidence that in the development of these recommendations tenants were asked what they thought.

Similarly, tenants on the new pilots farms do not participate in the development of experiments, yet they are required to participate in them. They are told that fields are to be leveled, in some cases with laser-guided equipment; that peanuts are to be planted by machine, not by hand; and that selected numbers are to be irrigated with long furrows and night storage. They are not asked if these are good ideas, and nobody tells them that they will bear the cost of leveling. No thought has been given to the effect of mechanization on the livelihood of laborers. There is no intention even of measuring performance on the current project to determine how open-plan, continuous-flow irrigation compares with the proposed improvements.

By the start of the 1987-88 crop year, the 11 cotton numbers in the 44 numbers of one pilot farm had been equipped with new field outlets that were to be closed at night, not because night storage was demonstrably better than continuous flow, but because the authorities were dogmatically convinced that the Gezira should have night storage. Leveling was being done. The contractor was certain that the benefits of leveling would not justify its cost, although approximately 10% of the land was too high to be properly watered, largely because of silt deposition over the decades. The peanut planters arrived so late that manual planting had to be allowed. Irrigation had not yet begun, but engineers were planning to cover each tenant's plot with ninety furrows and, by precise measurements, to calculate required timings to meet soil-moisture requirements.

A visitor might have predicted trouble: tenants refusing to observe night storage and resorting to open-plan irrigation when long furrows did not function, or simply losing interest in their crops when yields appeared to be low. The season was finally a complete failure, and the crops were abandoned. The Gezira Board blamed the Ministry of Irrigation for failing to deliver the

needed quantity of water. The Ministry replied that the location of the pilot farm at the tail end of a canal was unsatisfactory. If more water was available there, it suggested, there would be no need for a rehabilitation project at all.

Despite this failure in working out a set of ideas about how to modernize the Gezira, important changes has been introduced by the Board. It decided in 1986 that the high cropping intensity at Managil was the cause of consistently low and declining yields and, in an amazing demonstration of its power over tenants who had been settled for thirty or more years, the board induced all tenants to shift from three plots of five acres each to four plots each of 3.75 acres, one of which was to be fallowed each year. Most tenants found themselves cropping entirely new fields, in some cases at considerable distance from their old fields. Cropping intensity and tenant income were reduced, yet the change was accepted, seemingly without protest. Meanwhile, trials are being conducted on the Gezira Main to raise intensities there to 80% with five-plot tenancies of four acres each, one fallow and one fodder. It seems extraordinary that such immense changes were made without considering their relation to project modernization.

Outlook

A top-down orientation is by no means unique to the Gezira: the scheme typical of the way by which agricultural research is handled in many countries. The Initial plans of the bank's agricultural-improvement program for Sudan suggest that the work will be based on experiment stations, with extension agents sent to promote practices that farmers may admire but find irrelevant to their own needs. In the same way, the pump-scheme rehabilitation program in the far north, sponsored by the International Fund for Agricultural Development, intends to organize farmers into water-user groups, but it ignores the informal cooperatives that farmers long ago formed to operate water wheels, or *sagias*; it ignores the larger organizations that farmers worked out when those wheels were largely replaced in the 1930s by pumps.

One might have hoped for more from all this effort, but judging from the work to date, modernization of Sudan’s irrigation works, including the historic Gezira Scheme, are likely to be a fiasco, perhaps with leveling costs absorbed by a government that cannot afford to bear them or with machinery quickly failing for lack of spare parts. All the while, additional agricultural-rehabilitation loans and grants will be required to avoid total collapse of the systems.

Raising the crest of Roseires Dam is still on the agenda, especially because low flows on the Blue Nile have cut cropping intensities on the Gezira about 15%. Instead of 1,500,000 irrigated acres, the total irrigated area is closer to 1.2 million, while the cotton crop covers 385,000, not 500,000. As the storage capacity at Roseires declines, these figures may be expected to fall further. The dam could be raised enough that Sudan could finally use all 20 of the cubic

kilometers of water to which it is entitled, not the 17 it presently diverts. Egypt has severe water shortages, however, which is why some Sudanese irrigation planners are convinced that the work will be indefinitely delayed. The prospect is for modernization to call for increased cropping intensities concurrently with decreased water supplies.

Such a combination may be possible with very efficient irrigation methods, but those methods are probably unsuitable to Sudan. A British irrigation engineer working on pump-scheme rehabilitation notes that the small, old-fashioned pumps crudely set up along the Nile are inefficient, but he predicts that Sudanese farmers will keep them running long after the efficient, aid-funded pumps that he installs will have broken down for lack of replacement parts and proper maintenance.

The logical but utopian recommendation is for a genuinely cooperative relationship between reearchers and tenants. Such cooperation is a truism, and the board, ministry, and bank would insist that it already exists, just as it did at the time with the British and their village-farming experiment. Yet this cooperation in fact is little more than ritualistic meetings of board officers and tenants gathered in the shade of a tree. In this setting, tenants have little to say about modernization. What's needed is a sustained working relationship. Building it will be a huge challenge, with tenants rightly skeptical about genuine collaboration and scientific researchers necessarily pursuing their own priorities, focused on professional advancement and the publication of scientific papers.

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