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PHYSICAL, FINANCIAL, AND REHABILITATION ASPECTS OF IRRIGATION MANAGEMENT

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INTRODUCTION

Over the past few decades, irrigated agriculture in Sudan has expanded greatly to its present level of about 4.5 million feddans[1]. This development stretched Sudan's water resources to the limit. Different irrigation systems ranging from the huge Gezira Scheme irrigated by gravity to small privately owned lands irrigated by pumps, are found in Sudan.

Future expansion in irrigated agriculture is limited by two factors: the water-resources constraint; and the difficulty in securing adequate finance for new projects. Existing schemes are expected, more than ever before, to meet very demanding objectives. Among them are self-sufficiency in food, maximizing the output of export crops, maximizing government revenue and maximizing the return per unit of water. Some of these objectives were not set at the planning and design stages.

In order to meet such changing objectives, it may be necessary not only to restructure the physical component of the irrigation system to bring it to the level where it can meet the new objectives (by improved operation and maintenance, rehabilitation and/or modernization) but also to adopt management techniques and innovations.

Irrigation management includes managing the natural (water and land), "physical" (irrigation facilities, agricultural inputs, financial resources, etc.) and human (farmers, laborers, etc.) resources in order to meet the set objectives of the project. In this report almost all these facets of irrigation management are discussed in the context of the outlined themes.

IIMI has specified that its activities in Sudan should be "demand-driven." Therefore this report concentrates on the areas where the committee believes there are real and genuine needs for research and where research results are expected to have a significant impact. So the report is not meant to be exhaustive but rather thought provoking.

I. MANAGEMENT OF WATER RESOURCES FOR IRRIGATION

Water is one of the most important natural resources on earth. The readily available fresh water in the world amounts to only 0.5 percent of the total. This precious resource is sometimes scarce, sometimes plentiful, and often very unevenly and untimely distributed.

Water will continue to play the central role in Sudan's well-being and development. Competition for water among the different users is expected to become more fierce. Irrigated agriculture is currently by far the biggest consumer of water in the country. Few people realize that for a cubic metre of water we produce 0.1 kg of cotton, 0.15 kg of groundnuts and 0.4 kg of wheat; which are far below the

[1]Feddan = 0.42 hectare = 1.038 acres.

international levels of production. This in effect means that while water has become the limiting factor in new development of the irrigation sector, yet we continue to have a low water-use efficiency i.e. we are not maximizing our agricultural production per unit of water. In this respect, management of water resources for irrigation has a key role to play in improving the reliability, equity, and sustainability of our irrigation systems.

Water-resources management for irrigation involves the closely linked processes of planning, diversion, conveyance, distribution, application, and the removal of excess water. Planning of use of water resources for irrigation, though an important and pivotal process in irrigation management, lies outside IIMI's activities and hence is excluded from further consideration.

On further critical examination of these processes, it becomes obvious that conveyance, distribution, and application of water (in that order) have the greatest impact on improving the performance and sustainability of irrigation schemes in the Sudan. In the following sections, each one of these processes are discussed, delineating areas for possible improvement through management.

I.1 Water Conveyance

The main function of the conveyance system is to convey irrigation water from the source to the different parts of the irrigation scheme in order to meet the crop requirements. Conveyance is mainly affected by the system design, operation, maintenance, and irrigation practice. In Sudan, the irrigation practice of night storage is perhaps the most significant factor affecting the conveyance system.

I.1.1. Night Storage Compared to Continuous Irrigation

Night Storage is the practice of storing irrigation water by night in the minor canals and irrigating only during the day. This practice calls for larger cross-sections of minor canals than warranted. Thus such canals act as settling basins for sediment during the night when the flow velocity is very low. On the other hand, continuous irrigation (day and night) overcomes some of the night-storage problems but introduces some of its own. Table 1 shows the advantages and disadvantages of each.

Night storage is not adhered to as strictly as in the past. The practice has evolved gradually to its present position of a blend between night storage and continuous irrigation. This evolution resulted from the intensification and diversification program of Gezira Scheme, in the last two decades, which stretched the irrigation system to the limit. The mounting difficulties in operation and maintenance resulted in acute water shortages. The present irrigation practice is the result of tenants' reactions, to such difficulties.

It seems that three options are available to resolve this issue:

1) To go back to the strict night-storage practice.
2) Adopt continuous irrigation.
3) Let the present practice evolve further in a guided way as described in Annex A.

Whatever course of action is adopted, close consultation with and cooperation of farmers are of utmost importance.

Table 1. Comparison between Night Storage and Continuous Irrigation.

NIGHT STORAGE	CONTINUOUS IRRIGATION
Irrigation during the day only	Day and night irrigation
One ABU XX irrigates 90 feddans	Two ABU XXs are needed to irrigate the same area in the same time as Night Storage, or the same ABU XX requires twice the time needed for the case of Night Storage
Traps the sediment in the minor canals	The minor canals are relatively free of sediment
Frequent sediment clearance	Occasional sediment clearance
Maintenance cost is high	Maintenance cost is low
Because of the higher flow, irrigation needs attendance	Unattended irrigation is possible
Application efficiency is high because of attended irrigation	Low application efficiency

I.1.2. Canal Clearance

It is essential to keep irrigation canals well maintained in order to convey the required flow. On what basis does a decision on clearing a particular canal is made? Is it based on farmers' complaints or on performance measurements or both? And what are these performance measurements?

Since canal clearance is costly and has the most direct effect on the reliability and the equity of the irrigation system, management tools designed to answer these questions in order to optimize canal-clearance operations are most welcome.

I.1.3. Sediment Management

Sediment deposition in the irrigation canals is the biggest threat to efficient water conveyance. Every year large quantities of sediment enter the irrigation systems because of the increased water abstraction coupled with rising sediment concentration in the parent rivers due to the recent drought. The machines available for sediment clearance cannot cope with the clearing work because of the sheer size of the irrigated areas and the large quantities of sediment deposited.

Sediment control in the irrigation systems needs serious consideration. In a recent study in the Gezira Scheme it was found that most of the total sediment entering the system in a season did so in a matter of few weeks. A simple management measure to prevent this is to close the headwork gates during these weeks. But what are the repercussions on the system as a whole if this action is taken? Does a blend of management and engineering measures (e.g., settling basins) offer an optimum solution to the problem: how to control the sediment and where along the system it should be done? The answers to such questions have an immense practical value in dealing with one of the most serious problems in our irrigation systems. Some of the engineering measures are described in Annex B.

I.1.4. Optimizing Routine Maintenance

At the end of each irrigation season, maintenance of the irrigation facilities, (e.g., gates, weirs, bridges, canals, banks, etc.) is necessary in preparation for the next irrigation season. Two factors have often made this activity incomplete: the intensification and diversification program which shortened the maintenance period to two months compared to three months before the program; and lack of adequate resources and skilled laborers.

How can this routine maintenance be optimized? Is it by changing the sowing dates, or the type of crop, or the rotation, or all these together?

Routine maintenance of the irrigation facilities is so vital to sustaining the conveyance system upon which depends the reliability and equity in water supply. Therefore optimizing this activity is of utmost importance.

I.2 Water Distribution

In an irrigation project water is delivered in quantities and for durations necessary to meet the crop requirements which are variable and which depend, among other factors, on the crop variety, its stage of growth, the soil type, climatic conditions, and on field water-management practices. Hence it is a very complex activity. The mechanics of water distribution involve the following steps:

(i) Estimating crop water requirements.

(ii) Requesting water (indenting).

(iii) Processing of indents.

(iv) Diverting water from the source.

(v) Conveying water to the distributary canals.

(vi) Measuring and distributing the water at the field level.

The water-distribution process is multi-disciplinary, involving different agencies (e.g., irrigation and agriculture authorities) as well as the farmers. Close cooperation and liaison between all those involved is important. This is different to the conveyance system which has a much limited function and is therefore managed by one agency only; the irrigation authority.

Close inter-agency cooperation calls for a common language. It is important that engineers be trained on the basics of agriculture and agriculturists be trained on the basics of irrigation engineering. Also, it is important to encourage team work as far as possible so that conflicts can be resolved as soon as they arise. Research to promote inter-agency cooperation and understanding is much needed.

I.2.1. Estimation of Crop Water Requirements

The purpose of irrigation is to control the soil moisture in the root zone so as to realize targeted crop-production levels. Underestimation of crop water requirements would result not only in underdesigned and under utilized irrigation system, but also in application of less than the required amount of irrigation water, leading to reduction of crop yield. On the other hand, overestimating the crop water requirements would overburden the irrigation system, leading to water logging and decrease in yield; this is apart from the non-beneficial expenditure of water and energy resources. Therefore accurate estimation of crop water requirements is important in achieving potential crop production and in assessing the adequacy of water distribution which is an important measure of performance in irrigation management.

So far, estimation of crop water requirements by the agricultural agencies has been based on antiquated and incomplete research results as shown in Annex C. It is unclear why the results of the pioneering research work of Farbrother and Co-workers have not been put to practical use so far. Identifying the problems encountered in applying rational and scientific estimation of crop water requirements and finding ways and means of overcoming these problems are of immense practical importance.

I.2.2. Indenting

Indenting, simply defined, is a written request for a certain discharge to be let into certain minor canals for a specified time. The indent is variable due to the variable crop water requirements. Due to actual or sometimes perceived problems in the conveyance and distribution system, the maximum indent is often requested. This in turn will further exacerbate the problems of the irrigation system.

Indenting is the most basic element in water distribution. An improved estimate of crop water requirements will not, by itself, improve the indenting or the quality of response to it. How best to rationalize, improve, and integrate the indent-response process into the distribution system is fundamental to equitable and adequate water supply.

I.2.3. Equity in Water Distribution

Equitable water distribution is, perhaps, the most targeted goal in irrigation management. Critical examination of the following issues is needed in order to improve equity in water distribution:

* How best to simplify water-control operations and water-metering?
* What is the role (and limitations, if any) of farmer participation and involvement in water distribution?
* How best to get closer cooperation between irrigation and agricultural agencies at the minor head?
* How best, at the time of water shortage, to distribute the limited available water?

* Head-to-tail variation in water distribution is an intrinsic problem in irrigation systems leading to variation in yield. How best can we minimize this effect?

I.3 Water Application

The proper application of water at the field level has the biggest impact on yield and water conservation. There are immense opportunities for increasing crop production and water use efficiency, two of the most important objectives of irrigation, by improving on-farm water management. In order to improve on-farm water management the following issues need to be examined, resolved, tried, and tested and their impact on the overall objectives assessed.

I.3.1. Irrigation Extension Service

In order to improve on-farm water management, guidance, instruction through demonstrations, and training on good water-management practices need to be given not only to the farmers but also to the field staff.

I.3.2. Effective Water Use

A farmer will use water efficiently only if there is an incentive (e.g., reduction of irrigation costs) to do so. This will naturally lead to questioning of the wisdom of charging water on a flat-rate basis. Closely related to effective water use is the reliability and adequacy of the irrigation system. An unreliable and inadequate irrigation system does not encourage effective water use; farmers are compelled to apply water as much as possible whenever they can. As financing of operation and maintenance of irrigation systems comes mainly from water charges, if these charges are low, the quality of service rendered will also be low: "You get what you pay for." On the other hand, if farmers are to pay more for their irrigation water, then they will naturally ask for a better service in return. Research into such issues is of great significance.

I.3.3. Effects of Hired Labor

Some farmers hire labor to irrigate their fields. This may have serious implications on water use since hired laborers are not keen enough to irrigate efficiently. The effects of hired labor on water-application efficiency needs to be quantified. Closely related to this is the crop sharer and his influence on water management.

I.3.4. Adherence to Recommended Sowing Dates

The present rotation includes several crops -- each with its own recommended sowing dates. If farmers do not adhere to these dates, crops will overlap with an inevitable competition for irrigation water which may exceed the irrigation-system capacity.

Farmers have their own perceptions of the suitable sowing dates. It is imperative to examine such perceptions and to reconcile them with the recommended dates.

I.3.5. Effects of Soil Characteristics on Water Application

In order to apply irrigation water efficiently, it is important to study the soil characteristics which affect this process and try to manipulate these characteristics advantageously.

II. MANAGEMENT POLICIES FOR MAINTENANCE AND REHABILITATION

An irrigation system is managed generally to meet some set objectives which may include productivity, reliability, equity, adequacy, sustainability, quality of life, etc. Maintenance of an irrigation system is perhaps more directly geared towards reliability, equity, and adequacy. Like any physical system, it deteriorates with time. Sustainability comes into play with the rehabilitation of the system. If technological advances are incorporated as well, we speak of modernization. Thus maintenance is a continuous activity while rehabilitation and/or modernization are occasional and made when necessary in order to sustain the system or to improve reliability and equity. It is logical to make each of those activities an entity in its own right. Thus we can deal with each one separately.

II.1 Maintenance

Maintenance could be routine or occasional or preventive. Routine maintenance includes such activities as sediment and weed clearance, servicing of moving parts of water control facilities, etc. Renewal of protection works downstream of main regulators and the strengthening of canal banks are examples of occasional maintenance. Preventive maintenance may be defined as the precautionary measures taken in anticipation of perceived and expected problems, i.e., regular inspection, prompt attention to problems, well-stocked spare parts, etc.

Maintenance functions are often badly affected by lack of planning. The system is often managed like a fire brigade, reacting to problems as they arise. It is imperative that successful management has well-defined objectives. This is particularly true for maintenance because an irrigation system may succeed or fail depending on how well or badly it is maintained. As stated before, the prime objectives of maintenance are reliability, equity, and adequacy in water supply and distribution. The following policy issues need further investigation.

II.1.1 Responsibility for Maintenance

Maintenance of an irrigation system is complex. Assignment of maintenance responsibility is sometimes made on a functional basis, as when the one who operates the system maintains it. Or, sometimes, it is a matter of convenience based on historical precedence, as when an organization operates part of the system and another one maintains it. Operation and maintenance are closely related functions. The question, Who should maintain what and on which bases? should be answered.

II.1.2. Accountability

It is natural that in an organization someone who is responsible for certain functions is accountable to someone else higher in the hierarchy. In the case of an organization entrusted with maintenance responsibility of an irrigation system, will it be accountable to the recipient of its services which may be another organization, or a farmers' union, or both, or will it be accountable to its financier?

II.1.3. Maintenance Financing

The cost of maintenance is recurrent. In order to carry out maintenance functions properly, adequate funds should be secured. The source of funds will decide, to a large extent, the issue of accountability. Furthermore if the money is to come from the Government, maintenance has to be very satisfactory to qualify for funding.

The level of maintenance financing will reflect the quality of service rendered. It is only natural to expect good maintenance if adequate finance is provided, and vice versa. Due to mounting difficulties in securing adequate public funds for irrigation-system maintenance, maintenance needs to be very efficient to maximize the effectiveness of the limited resources. Maintenance financing is an important subject which needs thorough review and investigation in the context of maintenance-policy issues.

II.2. Maintenance Functions

Efficient maintenance involves monitoring, diagnosis, and action. The first two comprise such activities as inspection, collection of information, and analysis while action comprises the necessary intervention measures like canal clearance, gate servicing, etc.

Efficient maintenance calls for some code of practice (manual) delineating the different maintenance functions, the relations between them, and the method of carrying them out.

Maintenance performance (or efficiency) needs to be gauged against the set objectives. Preparation of maintenance manuals and measurement of maintenance performance are important subjects for further research.

II.3. Rehabilitation and Modernization

Due to financial constraints and exhaustion of "easy-option" new irrigation schemes, the emphasis has shifted towards improved maintenance, rehabilitation, and modernization of the existing schemes. The following issues are raised:

* Whether to rehabilitate or modernize or carry on with the "old" system.

* Rehabilitation needs, objectives, and priorities.

* A new look into operation and maintenance of the rehabilitated and modernized projects: the way ahead, farmers participation, and the impact on performance.

* Institutional changes and their impact on rehabilitation and modernization.

* Performance monitoring and how to evaluate it to ensure that rehabilitated and modernized projects are meeting their objectives.

* Assessment of the socioeconomic impact of rehabilitation and modernization.

* Rehabilitation sustainability.

III. MANAGEMENT OF FINANCIAL RESOURCES FOR SYSTEM SUSTAINABILITY

Among the objectives of irrigation are the generation of wealth and maximizing of Government revenue. Ideally an irrigation project is self- financing. Unfortunately irrigation projects do not live up to their expectations. Public financing of these projects has become exceedingly difficult. Irrigation has to compete with other sectors for limited financial resources.

It is generally known that performance is affected by availability and adequacy of financial resources. Quantification of the relationship between irrigation performance and finance (limited finance, in particular) is very important so as to identify the critical activities in operation and maintenance which are affected most by limited available funds.

The cost of irrigation services as well as the management cost of the agriculture corporations are supposed to be met by the water and land charges paid by the farmers. The charges are often inadequate to cover these costs. It is very likely that financial-resource limitations will persist for the foreseeable future. Four courses of action need to be considered very carefully:

(i) Increase the efficiency of rate collection.

(ii) Re-evaluate the water rates in order to encourage more efficient use of water and to reflect the true cost of providing this vital service.

(iii) Look for ways and means to optimally allocate the limited financial resources among the agencies involved in the irrigated sector. This will call for appraisal of services provided by each agency.

(iv) Make these agencies cost effective.

ANNEX A

GUIDED EVOLUTION OF THE NIGHT-STORAGE PRACTICE

The strict night-storage practice gave no role at all to the tenants in managing the field water outlet. One of the biggest advantages of the currently evolving practice is that the tenant has free access to the gate of ABU XX. This is in line with the modern concepts of irrigation management in encouraging farmers' involvement and participation. To continue this trend, it is suggested that the farmers should assume responsibility in managing the minor canal under the supervision of the agricultural administration with technical assistance from the irrigation authority. It is also suggested that operation of the minor canal be by reach-rotation and not by ABU XX rotation as in the strict night-storage practice. Details of operation of the minor canal are as follows:

1) **For a canal with an even number of reaches:**

   Half the number of reaches is considered as a rotation unit. Irrigation is then rotated between the first and second half.

2) **For a canal with an odd number of reaches:**

   The same rotation as above except that the middle reach will get half its water from each rotation.

ANNEX B

SOME EXAMPLES OF ENGINEERING MEASURES TO CONTROL SEDIMENT IN THE IRRIGATION SYSTEM

There is a multitude of engineering measures which can be made use of to control the sediment. These measures vary from massive settling basins to simple vortex tubes, depending on the sediment and flow characteristics. Two of these measures are:

1. Settling Basins

These are suitable for fine sediment in suspension which is the case in our irrigation systems. Usually the basins are located either upstream or downstream of the headwork, so as to reduce the quantity of sediment entering the system. The degree of this reduction depends on the design of the basins and their operation. It is neither desirable nor possible to get rid of the sediment completely. It is suggested that these settling basins be located immediately downstream of the headwork to make full use of the water-head difference to sluice the deposited sediment back to the parent river.

2. Sluicing of Major Canals

When it is raining, irrigation is no longer needed and the water carried by the canals has to be dispensed with. This is generally known as "rain cut." In big and extensive irrigation systems the response to the rain takes time and the excess water has to go down the drains. To make effective use of this wasted water, it is suggested that the sluice gates be built at the tail ends of the major canals which lie near the river and the excess water be used to sluice the recently deposited sediment in these canals.

ANNEX C

HISTORICAL BACKGROUND TO ESTIMATION OF CROP WATER REQUIREMENTS

Prior to large-scale cotton plantation in the Gezira Scheme, pilot farms were established at Taiba and Barakat in 1910 and 1914 respectively. In these pilot farms the viability of cotton plantations was tried and tested. Among the factors tested was the irrigation requirements. The recommendations from those tests were that the peak water requirement was 27 cubic meters (m^3) per feddan per day with a fixed irrigation interval of 14 days. It was stated, very categorically, that these recommendations "are based on limited tests and should be used only until more accurate estimates become available." Assuming an efficiency of 90 percent for large-scale water applications the peak water requirement for cotton became 30 m^3 per feddan per day.

Although the limitation of these recommendations was stated very explicitly, we continue to consider the 30 m^3-per-feddan-per-day value and the two-week irrigation interval as magic figures and we use them for all crops during all stages of their development.

Therefore what was intended as a preliminary recommendation based on limited tests for a specific crop has become entrenched, willingly or unwillingly, in our subconscious minds, as a fact of life.