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Gezira Scheme Irrigation System Performance after 80 Years of Operation

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ABSTRACT: Gezira Scheme (GS) is considered one of the oldest irrigation systems in Africa and the Arab region. Moreover, it's the largest scheme (0.90 million ha) in the world under a single management. The length of the irrigation network is 11000 km, in addition to 29000 field channels. This paper is seeking to evaluate the irrigation GS system performance after more than 80 years of operation, especially if it is realized that serious deterioration was experienced in the last decade, where the system failed to meet the crop water requirement. This may be attributed among many other reasons mainly to: the huge amounts of sediment entering the scheme each year and the mismanagement of the irrigation system. The impact of this is water shortage in wide areas of the scheme and flooding in others, i.e. inequity in the water distribution and hence reduction in crops production and returns of the scheme. In this context a critical review of the irrigation system is discussed. The concept and procedure for designing and remodeling of the silted canals to restore the original section are highlighted, based on the rich experience and performance of this irrigation system. It is found that aquatic weeds aggravated the sedimentation rate and the deposited sediment enhances the aquatic weeds growth, which leads to canal capacity reduction. The impact of this on the socio-economic development of the scheme is explained. The paper finally examines the possibility of having canals with stable regime condition. It also reports on the future of the irrigation system management and the possibility of having an efficient and effective system for better crop production.

Keywords: Gezira Scheme, Canal, Regime, Design, Water Discharge, Irrigation, Management, Sediment, Crop Production, O&M, Socio-Economic, Mitigation.

INTRODUCTION

Following the construction of Sennar dam in 1925 on the Blue Nile, the British designed the Gezira Scheme (GS) based on their experience in India and Egypt. It was established in the Central Clay Plain (CCP) between the Blue and While Niles. GS is the largest irrigation system in the world under a single management (2.2 million feddans ~0.9 million ha). Therefore, its operation and maintenance are very complex and represent quite a challenge. The irrigation system comprises twin Main Canals running from the head-works at Sennar Dam to a common pool at the cross-regulator at km 57. Beginning of the sixties of the last century, the Managil Main Canal of 186 m^3/sec (16.0 million m^3/day) design capacity was constructed in parallel to the old Gezira Main Canal of 168 m^3/sec (14.5 million m^3/day) design capacity, to serve the Managil extension. The two Main Canals of total length of 261 km and the conveyance capacity ranging reduces towards the tail end to 10 m^3/sec. Figure 1 and Table 1 give a clear idea about the irrigation system in the GS.

Downstream of the first common cross-regulator at km 57 the main canals are divided into reaches, which vary in length from 5 km to 22 km, by further cross-regulators. These regulators are the control points for the Branch and Major Distribution canal off-takes. The branch canals are similarly divided into reaches by cross-regulators and major distributor canals are grouped at these regulators. The Main, Branch and Major canals are designed as regime conveyance channels, with water flowing continuously day and night. The Minor canals had been designed to irrigate day and night. However, during the thirties after few years of operation for practical reasons facing irrigation during the night, the system operation was changed to irrigate only during the day light. Therefore, the Night Storage System (NSS) was introduced. The control structures are designed to maintain a constant upstream level. The system of water control throughout the distribution system relies on knowledge of the discharge characteristics of the regulator gates. The flow through the sluice gates is estimated from calibration charts requiring readings of gate opening and upstream and downstream levels.

Table 1: Detail Information of the Irrigation System in GS

Canals	*Number*	*Capacity (m^3/sec)*	*Length (km)*	*Av. Width (m)*	*Area (ha)*
Main	2	354	261	50	1315
Branches	11	25 to 120	651	30	1953
Majors	107	1.2 to 15	1652	20	3304
Minors	1500	0.5 to 1.5	8119	6.0	4872
Subtotal	**1068**	–	**10683**	–	**11444**
Abu XXs	29000	0.116	40000	1.0	4000
Abu VIs	350000	0.05	100000	0.5	5000
Total	**380068**	–	**150683**	–	**20444**

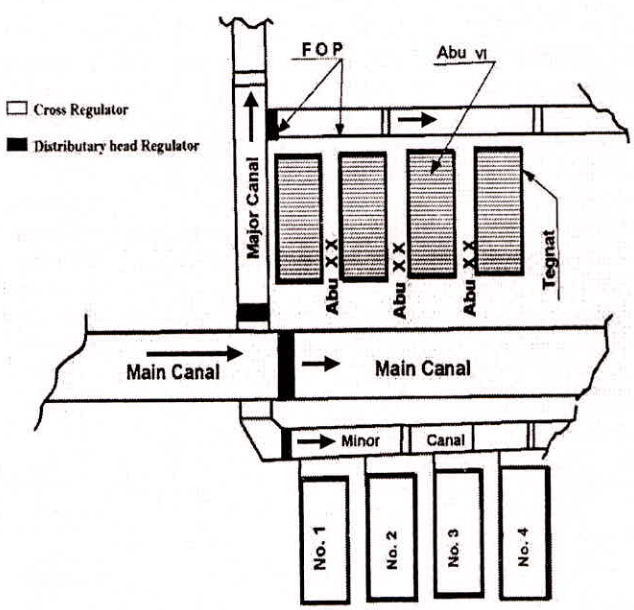

Fig. 1: General Layout of the GS Canalization System

The standard distance between two successive Minors is 1.42 km. The total length of a minor canal can be as much as 20 km, width 6.0 m and depth 0.8–1.3 m. Each Minor is divided into reaches; with a length varying from 1 to 4 km depending on the slope of the land. The reaches are separated by night-storage regulators. The main design criterion of the minor canals is a command of 20 cm above the highest parts of the field (as Full Supply Level (FSL)).

WATER DISTRIBUTION FARM LEVEL

The uniform slope of the land in the Gezira Scheme has permitted a very regular layout of fields. The field irrigation system (Abu xx) is designed to serve the Number (1,350 m × 280 m) at intervals of 292 m along the Minor Canal, Field Outlet Pipes take-off at right angles (12 meters long and 0.35 m diameter). This unit is divided into eighteen 5-feddan plots (called Hawashas) watered by secondary watercourses called Abu Sitta (Abu vi) taking-off from watercourses. In 1995 the Hawasha size was reduced to 4-feddan plots, which increased the Hawashas to 22 per Number. The Abu xx has a command of about 0.20 m and its theoretical capacity is 116 l/s (5,000 m^3/12 hours).

DRAINAGE SYSTEM

The drainage system in GS is for dealing with surface runoff from rainfall or excess irrigation. The present surface runoff drainage system consists of Minor Surface Drains of total length of about 6,000 km and Major Drains totaling about 1,500 km in length. Minor Drains run parallel to Minor Canals. These discharge into the Major or Collector Drains, which generally follow the lines of natural drainage and lead the runoff water to outfalls and back to the Blue and/or White Niles. However, in most of the GS this does not happen, since several drains terminate in large local depressions and so runoff water either has to be pumped into nearby canals, or is allowed to pond up and then evaporates, usually on land which is unsuitable for agriculture. The lands so flooded are left uncultivated deliberately but often are used unofficially by labour settlements.

IRRIGATION MANAGEMENT IN GS

The current water management in GS is substantially away from the original design. The volume of water released to the system at Sennar dam increased by more than three-fold from 2.0 billion m^3 in 1957/1958 to 7.0 billion m^3 in 1997/1998.This increase in the water demand is attributed to addition of the Managil Extension (420,000 ha) and the introduction of the agricultural intensification in 1960s. The additional amount of water carries more silt, besides that irrigation begins a month earlier than before. The latter forces the peak crop water requirement to coincide with the peak of the silt concentration in the Blue Nile. The irrigation management of the GS has always been divided between the Ministry of Irrigation and Water Resources (MOIWR) and Sudan Gezira Board (SGB). The MOIWR is responsible for water supply and maintenance of all the canalization system, and the SGB is distributing the water to the farm fields. However, in 1999 the responsibility of the Minor Canals (maintenance and the distribution of irrigation water) was transferred to SGB, leaving the Main and Major canals to the MOIWR. In 2006, following the new GS Law, all the irrigation management was handed over again tc MOIWR, after six years of GSB managing the system. In this period the system experienced the most serious deterioration throughout its long history as it will be explained later in this paper.

SEDIMENTATION IN GS

The problem of sediment deposition in irrigation facilities represents a challenge to those responsible for Operation and Maintenance (O&M). The problem is not only seriously affecting the performance of these facilities, but also jeopardizing their sustainability. Figure 2 shows the sediment loads entering the GS. It is clear the variation from one year to another, however the peak of sediment concentration is about 1% by weight in the third period of July, then reduces to a few hundred parts per million in October, Figure 3. High sediment concentrations are usually maintained for only a few weeks, on the rising limb of the flood hydrograph of the Blue Nile. (HR Wallingford, 1990) concluded that there was no clear relationship between sediment concentration and Blue Nile discharge. This indicates that sediment loads are supply controlled, a feature known the wash load sediment transport. It is clear that, the behaviour of the sediment distribution in GS is highly linked to the sediment distribution in the Blue Nile, Figures 2, 3.

The MOIWR records show that between 1933/1938 the mean sediment concentration entering the GS Main Canals in August was only 700 ppm, while the average sediment concentration in August 1988/1989 was increased to 3800 ppm, an increase of more than five times. However, during the Nineties the sediment concentration values jumped to about 8000 ppm, more than 11 folds, which indicate the serious land degradation and soil erosion in the catchment of the Blue Nile in Ethiopia Highland in addition to the contribution of the local seasonal streams U/S Roseires Reservoir inside Sudan, which is usually carrying high sediment concentration.

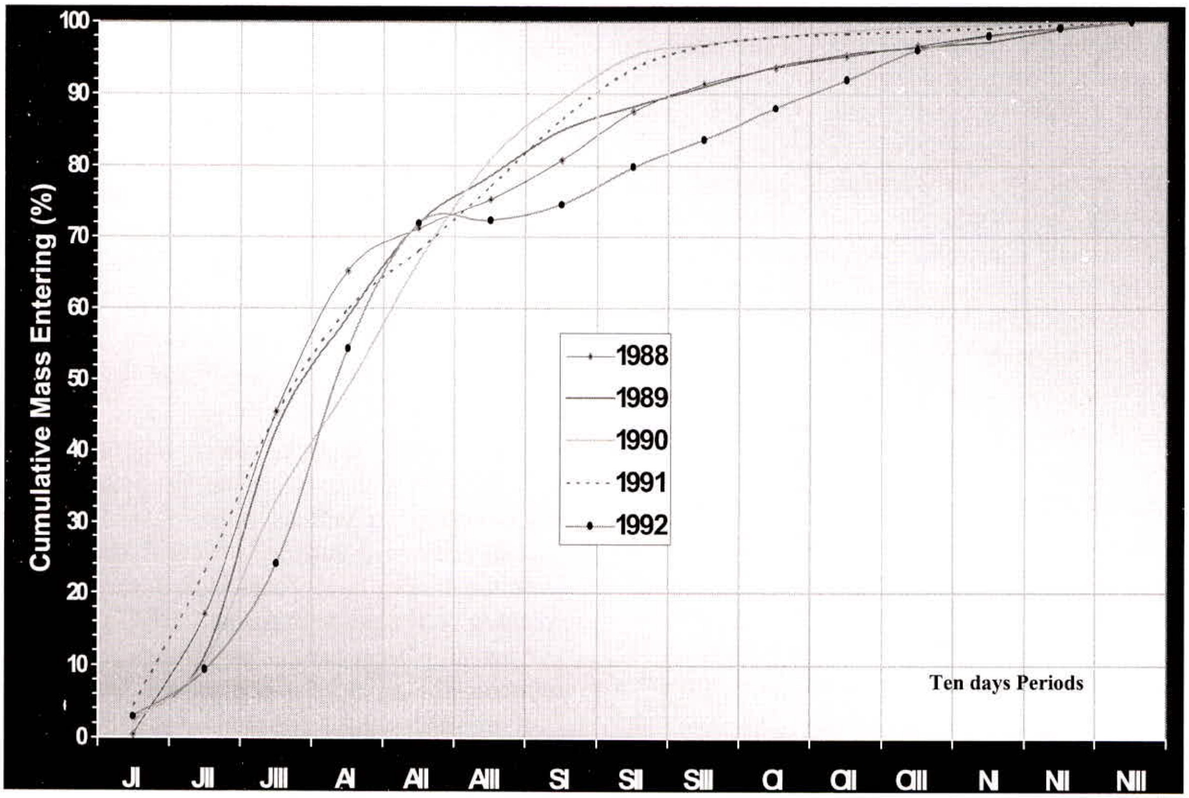

Fig. 2: Cumulative Sediment Load in GS (1988–1992)

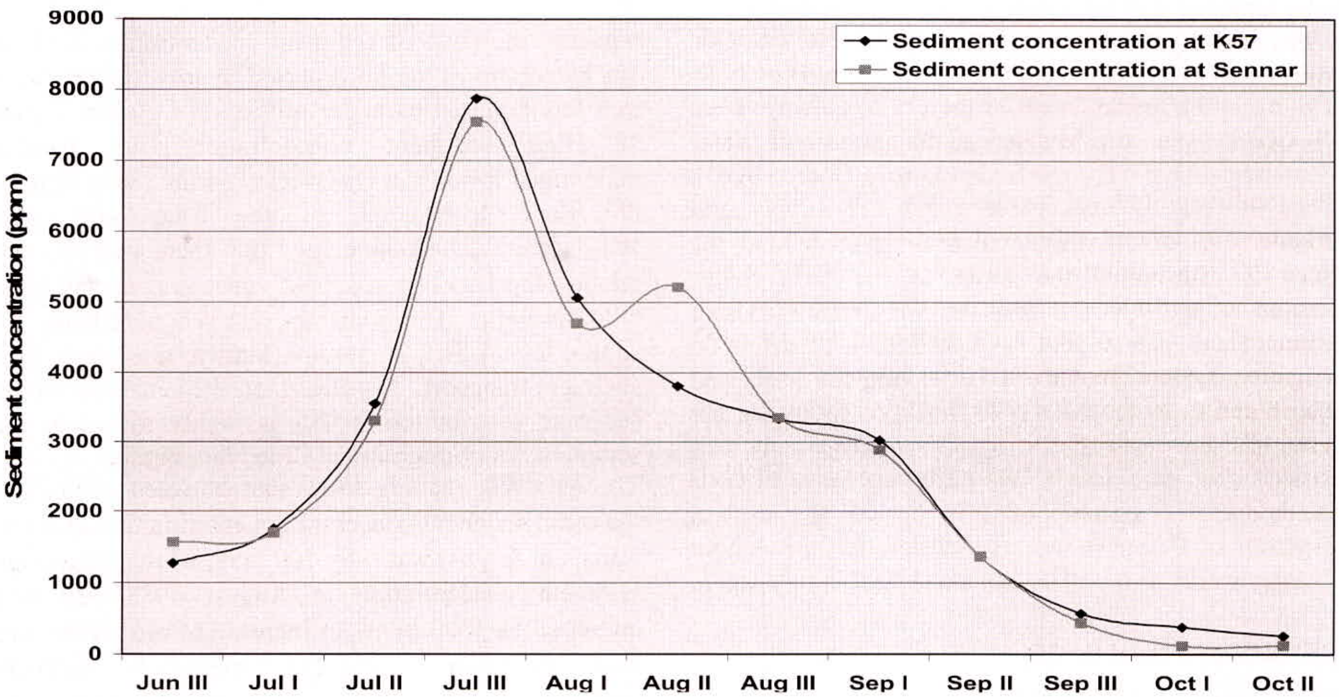

Fig. 3: Sediment Concentrations in Blue Nile and GS Main Canals 2002

Joint efforts were carried out by HR Wallingford in collaboration with MOIWR (1988) concluded the following important points, which is solid base for sediment studies in GS.

- 97% of the sediment entering GS during the flood season consists of silt and clays.
- About 70% of the sediment settles in the irrigation system over a short period from mid-July to the end of August (~three weeks). Figure 3 gives similar results.
- The proportion of the sediments entering canal reaches that settles increases as canal capacities reduce.
- The approximate distribution of sediment deposition is: 5% for the Main canals; 23% for Branch and Major Canals; 33% for Minor canals and 39% passed to Farm Fields.

However, later researches carried out by the Hydraulics Research Station of MOIWR gave 5% for the Mains, 22% for Branches and Majors, 33% for Minors and 40% for Farm Fields. The upper irrigation system (Main, Branch and Major canals) had been designed as non-scouring non-silting, experienced sedimentation problems in the last twenty years. This is quite different attitude from the early stages of GS (before the fifties). The general sediment distribution trend indicates clearly the increases of sediment deposition as the water moves downstream the system, confirming the fact that the type of the sediment is a wash load.

IMPACT OF AQUATIC WEEDS ON SEDIMENTATION

The aquatic weeds growth is a serious problem in GS, especially during the winter time, where the irrigated water is clean without sediment. Growth of aquatic weeds aggravates the sedimentation rate while the sediment depositions furnish good environment for weeds to grow. (Ahmed and Ahmed, 1993) reported that there are three types of aquatic weeds in GS, namely: submerged, emerged and floating. Echinochloa Stagina (emerged) is the common species and is responsible of most of the irrigation difficulties. Therefore, these two problems create many irrigation difficulties leading to reductions in crop yields and increasing the cost of O&M. However, many approaches have been implemented to mitigate the problem with a little success and many failures.

Traditionally, manual labour was used for removal of weeds, but this practice has been abandoned due to health hazards (such as bilharzias). Excavators with specialized weed-cutting are used to remove weeds from the canals, but it faces lack of funds to keep them working. (Ahmed and Ahmed, 1993) concluded that narrow and deep canals may have positive effect in reducing the aquatic weeds growth by preventing the sunlight reaching the submerged vegetation. Moreover, high velocities are creating in the canals in order to make water turbidity, which also prevents the sunlight to reach the vegetation. Therefore, the weeds volume to be removed will be reduced. Moreover, less aquatic weeds growth means less sediment deposition and less cost of O&M.

SEDIMENTATION IMPACT ON FARMS LEVELS

The total magnitude of the sediment load entered the irrigation system is estimated to exceed 1000 mm^3 since 1925 (the commissioned year of the scheme).The amount of sediment passed to the farm fields is estimated as 40% of the total sediment entering the irrigation system annually. If this amount is evenly distributed throughout the scheme, the surface ground level of GS is supposed to rise on average by 4.5 cm (0.6 mm per year). If this is compared to the rather gentle and flat slope of GS (~5 to15 cm/km) irrigation difficulties are definitely expected in many parts of the scheme. The situation will be even worse if we considered the sediment rate of 3.5 mm (increased in the farm field level annually), reported by (Mahmoud, 1999). The bad land preparation carried out by improper machines, which in most cases make the farm looks like a dish, will added more complication to an already problematic situation. This is the main reason, why the scheme recently has run into financial difficulties.

PRESENT MANAGEMENT SITUATION IN GS

To improve any irrigation scheme performance three main components are required:

1. Capital investment and inputs.
2. Building capacity of organization responsible for O&M, and
3. Enabling individual farmer skills.

If the above main components are applied to measure the GS performance, a gloomy situation may dominate all the aspects of the scheme. The recent Law of GS passed by the Parliament in 2006 is aiming to improve the deteriorating conditions of the scheme, is on the contrary turned it into a kayos and the GS now is loosing its compass totally. The Law was based on the (WB Report, 2000) recommendations, which attempted to give the farmers more freehand in selection of crop pattern and rotation. Moreover, it created what is called Water Use Associations (WUAs), without consideration to the nature of the scheme. When this scheme was constructed in the first quarter of the last century, two important rules governing both the irrigation water distribution and agriculture side were established. The first one is the Canal Regulation Rule and the second is the Rule and Regulation (R&R). Since the seventies many changes took place. However, most of them unfortunately failed to achieve their goals and have negative impacts on the scheme, especially on the irrigation system management. The Author of this paper believes that the GS, setup and design, is not flexible; therefore any modifications and/or changes without careful and intensive studies will lead to irrecoverable damages. To restore the discipline in the scheme again, it is high time to follow carefully the pervious regulations and rules coupled with strict management and financial systems. On the other hand, the heightening of Roseires dam on the Blue Nile will help a lot in providing continuous irrigation water to GS throughout the year. In this case better crops rotation and crop intensity can be introduced in the scheme and hence good returns.

MITIGATION OF IRRIGATION SYSTEM

Desilting has always been needed to restore the canalization system, since the starting of the GS in 1925. Plate 1 shows the sediment removal from the GS canals while Plate 2 tells the accumulation of sediment on the canal banks.

Plate 1: Canals Sediment Clearance

Plate 2: Accumulation of Sediment on Canals Banks

The amount of annual sediment removal and its cost of removal are shown in Figure 4. In earlier years when the irrigation canals were in good conditions removal of 5 to 7 million m^3 of sediment was considered to be quite satisfactory, (WB, 2000).

The process itself was carried out in a scientific method with high professional practice; hence the canals L-sections were restored. However, recently (Gismalla and Fadul, 2006) claimed that restoring the L-section of the canals in GS is not a suitable solution but it will accelerate the sediment deposition. (Ahmed, 2003) on the other hand argued that the stage of canal regime condition is not always applicable since the actual GS slope is 5 to 10 cm/km while the regime canal design requires about 57 cm/km of land slope, which is not available.

In recent years the canals conditions were deteriorated to an extent they failed to satisfy the crop water requirements. In 1999, a substantial canal desilting program was carried out. According to the MOIWR records and as shown in Figure 4, 41.0 million m^3 of sediment had been removed from the GS canalization system. The Author of this paper believes that, what happened in 1999 was not realistic and is not scientific, i.e. the 41.0 million m^3 was fictitious, reflects the mismanagement and realization on unskilled personnel. If that figure was true, it means that the canals were over excavated and their cross-sections were widened. This is really a waste of the GS financial resources and has led to a great damage to the whole canalization system, which is still, suffering from it up to now. The following season (2000) more than 17.5 million m^3 of sediment was removed i.e. in only two years 7.0 m^3 per meter length of the whole GS canalization system were removed, which is impossible and not practical.

These irresponsible practices of sediment removal enlarge the debt burden, which is facing GS now, following many years of unprofitable performance. The total debt of the scheme reached US$ 34 million by the end of 1999 compared to the estimated annual revenue from Gezira agricultural activities (excluded livestock) equivalent to about US$ 46 million, (WB, 2000), while the total debt of GS in 2005 exceeded 150 million US$. Figure 4 indicates a very strange phenomenon, while the water used in GS in 12 years (1987–1998) is almost averaging annually to 6.0 billion m^3; the sediment amount had never exceeded 14 million m^3 annually. However, a turning point was the year 1999 when the GS Authority declared its responsibility to perform the sediment removal from the GS canalization system. The result was drastic and damaging to GS. The average of the sediment removal for the period (1999–2005) was 25 million m^3/year. No body from the authorized personnel has ever explained in scientific terms, why this is happening? The latter amount is compared to the total average of sediment entering the GS every year according to many studies, between 6.0 to 10 million m^3, (Gismalla, 2003). It is also noticed that the amount of water used and the cropped area in the last 6 years, Figure 5, are drastically less than the average, which indicates the continuation of declining trend of GS. Such situation,

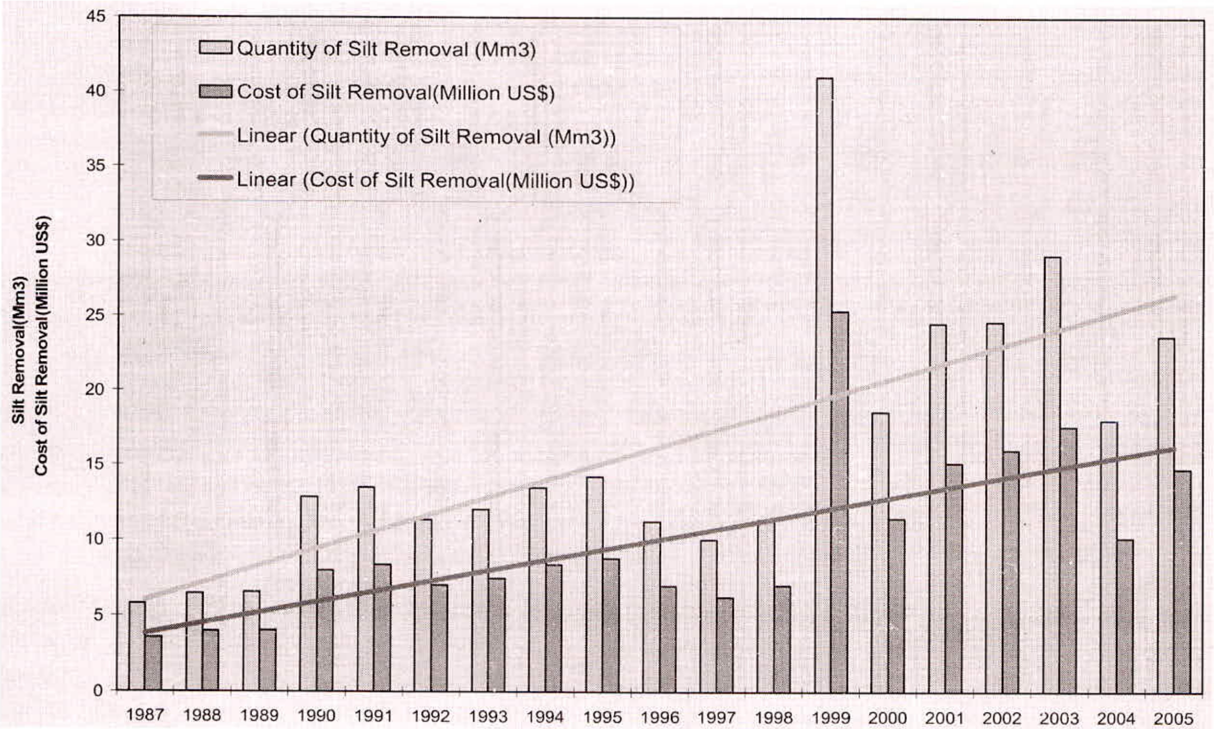

Fig. 4: Quantity and Cost of Sediment Removal in GS (1987–2005)

Figures 4, 5, gives an alarming signal that the invention of non-professional personnel in highly technical matters is serious and has its irrecoverable damage to the irrigation system. Moreover, the latter damage has been dragging on since then, and the whole irrigation system is suffering and it will continue to do so for years to come.

EFFECTIVE SOLUTION FOR SEDIMENTATION

Sediment control through improved watershed management is viewed as more sustainable and effective mitigation measure. Regarding the fact that almost the entire catchment of the Blue Nile lies outside the boundary of the country in the Ethiopian plateau, it is high time to incorporate sediment control activities with the integrated river basin development adopted by the Nile Basin Initiative (NBI) and the Upstream and Downstream project led by IWMI. Watershed erosion is the other face of the problem for Ethiopia, that pose a great challenges causing significant socio-economic and environmental impacts, hindering rural development with an eventual result of food insecurity. Therefore, it is the interest of both countries to cooperate to alleviate the negative impacts of erosion and/or sediment deposition.

SOCIO-ECONOMIC AND ENVIRONMENT

The deposition of sediment in irrigation canals and its subsequent built-up of aquatic weeds results in great magnitude losses in agricultural production. The sediment clearance from the irrigation canalization system costs more than 60% of the total cost of the O&M in GS. This may be attributed to the drought period which took place during the eighties from the last century and the policy of the food security adopted in Sudan by increasing the irrigated area without taking any mitigation measures regarding the negative consequences on the reservoirs and the irrigation canal networks. (Siyam, 2006) carried out an intensive study regarding the economic impact of the Roseires sedimentation on the agricultural production and the hydropower generation. The economical loss is calculated based on the present value criteria (PV) and considered as a percentage of the total project cost. Water volume equivalent to the silted volume of Roseires reservoir has assumed available for irrigation in each year. Figure 6 shows the economical revenues forgone in agricultural and energy sectors as a percentage of the original dam cost verses discount rate. The irrigation management is getting more difficult if the cost of sediment and aquatic weeds removal is coupled with serious reservoirs (Sennar and Roseires dams) sedimentation.

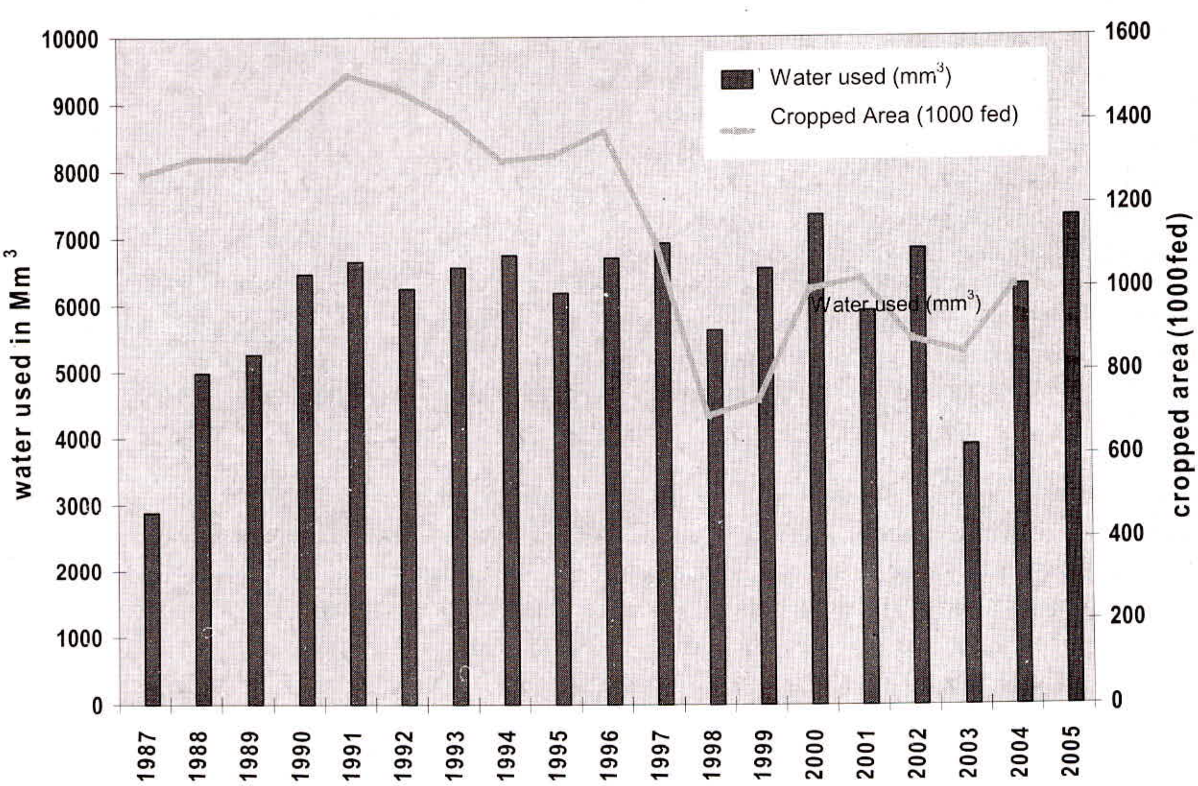

Fig. 5: Water used and Cropped Area in GS (1987–2005)

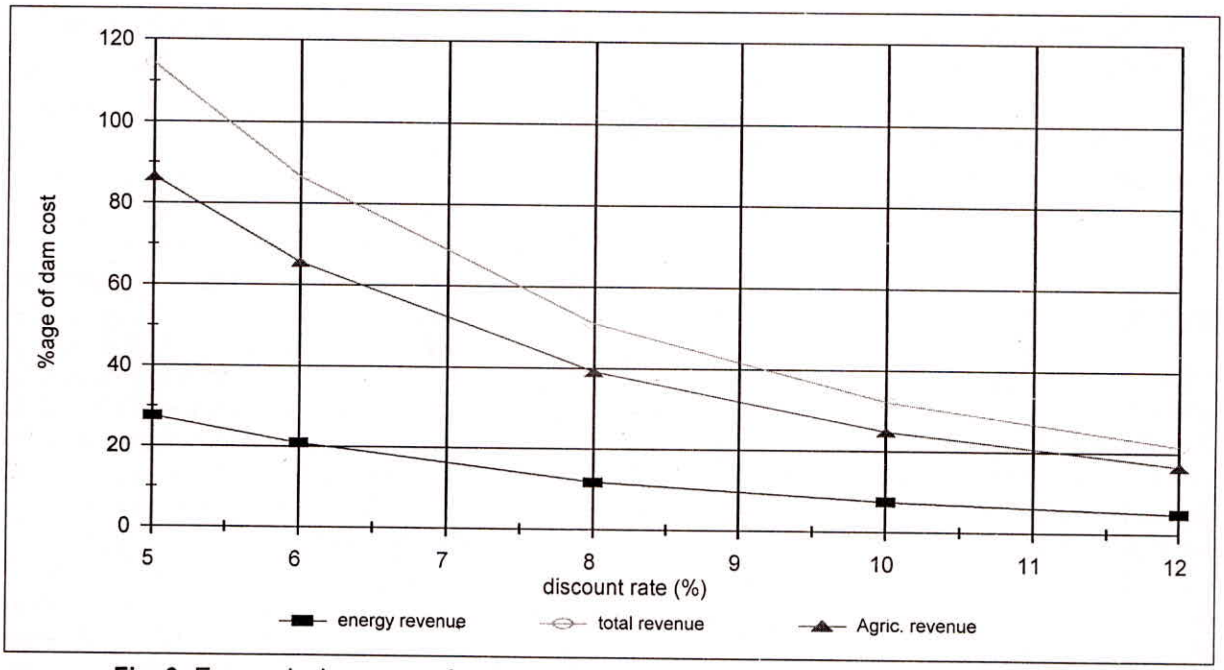

Fig. 6: Economical revenues forgone in Agricultural and energy sectors as a percentage of original dam cost versus discount rate

CONCLUSIONS

The GS after 80 years of operation encountered may management difficulties in different aspects, especially in the infrastructure of the irrigation system. It has been proven that the sedimentation problem is complicated by the mismanagement, improper handling of the irrigation management and lack of timely maintenance.

Sedimentation and aquatic weeds represent a great challenge for GS management. Part of the sediment problem can be solved through joint efforts between Sudan and Ethiopia.

It is recommended to study the possibility of constructing a sediment control structure in the main water distribution point (k57), e.g. sediment excluder involving settling basin or proper mechanical means of excavation. However, integrated sediment management coupled with proper watershed management is the way ahead.

The current sediment removal practices should be changed and more scientific methods should be adopted.

There is no doubt that the GS irrigation system is not flexible, where adaptation of any changes and/or modifications requires clever handling.

The recent GS Law (2006), by no means, is going to make the life more difficult in the scheme; therefore, gloomy future is expected unless the nature of the scheme is taken into consideration.

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