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Original

Comparative Study of the Gezira Scheme Canals Efficiency

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ABSTRACT

The agricultural sector plays a key role in Sudan economy. It is well known that the Gezira Agricultural Scheme is the largest irrigated area in Sudan, and largest area under one administration in the world. The Gezira Scheme problem is that it suffered for several decades from political urgent decisions which led to low production. This was associated with apparent destruction, degradation and poor irrigation. These formidable problems revealed the main objective to solve the drawdown preventing development. This extended the objectives which in turn revealed the existing conditions of the Gezira Scheme, checked irrigation drainage infrastructures networks, water supply control, as well as released demands with its impact on crops rotations and production.

The study methodology paved the road to keep the irrigation canals in perfect condition fulfilling the entire objective leading to solution of all the problems. Field and office works can be successful if they function with excellence during periods when there exists low water supply, such that the discharge in the canals continue with optimum or close to the optimum design discharges two cases were considered, Zananda and Haj Abdalla canals. The study indicated that renovation of such conditions is achieved with such conditions. This was supplemented with the positive results of fieldwork practices inherited from the past, associated with the high-level limits of the scientific recommendations. It is seen that Silts, weeds in the canals are the most problems encountered with the scheme. In addition to mismanagement of water discharge and crops rotations.

Keywords: Infrastructure Destruction, Political Decisions, Drainage Rotations and Production Fund raising

Introduction:

The Gezira Irrigation Scheme lies between the Blue and White Nile Rivers south of Khartoum, irrigated by gravity via Sennar Dam from the Blue Nile River. Its area was 300,000 and extended to 2.1 million feddans (about 882,000 hectares) [1]. It has favorable physical clay soil properties and excellent climatic condition. It was irrigated since 1923. The Gezira State population according to 1993 census was over two million inhabitants [2]. Fig. 1 is the map of the Sudan, showing the location of the Gezira Scheme and Gezira State. The scheme has an educational potentials and industries as well as roads. The flow of the Blue Nile River is regulated by the Sennar Dam built in 1925 followed recently by the multi-purpose Rosaries dam built in 1966[3]. The farmers tenant's population of the Gezira Scheme approaching 102,000, according to the latest census process shared areas of 20 feddans per capita. The main problems in the scheme are that the canals and drains are silted and infected by weeds as shown in Fig. 2. The problems of silts and weeds at the canal gates opening are shown in Figs. 3 to 6. [4].

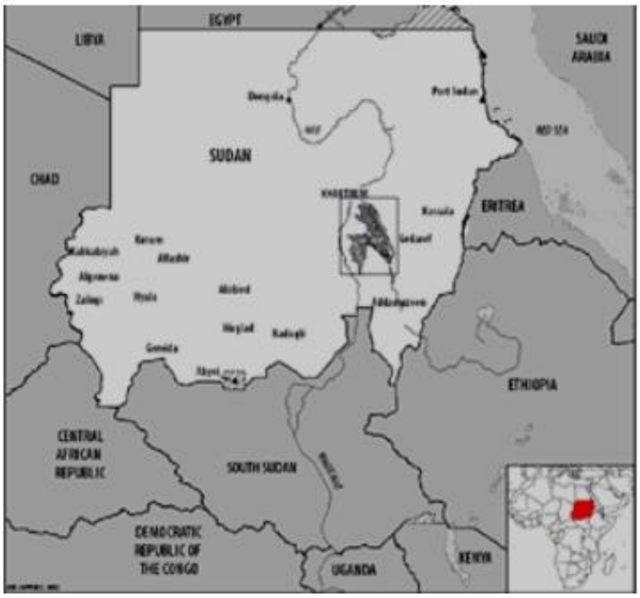

Fig. 1 Sudan Gezira Scheme and State

Fig. 2 Typical irrigation network infected by weeds and blocked by silts

Fig. 3. Upstream site at sluice gate opening

Fig. 4. Downstream site at sluice gate opening

Fig. 5. Weeds and silts at movable weir opening (1.3m)

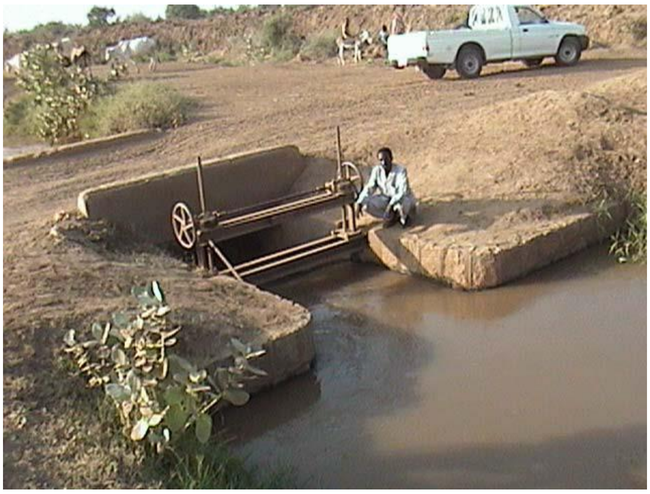

Fig. 6. Weeds and silts at movable weir opening (2.0 m)

The hydraulic structures of artificial irrigation require planning, design and construction as well as operation and maintenance of canals and drains network. When proper design is implemented for an irrigation canal, three types of banks of the design canal are used. Fig. 7 shows three types of canals banks [6]. Drainage is an essential necessary to make successful irrigation. A suitable drainage system is essential to drain off excess water to prevent damage of water structures and diseases [7]. Stable irrigation and drainage require non silting non scouring canals network with permissible optimum velocity. A typical suitable irrigation network with suitably selected parameters to render the network to be free of water weeds infections is shown in Fig. 8[5].

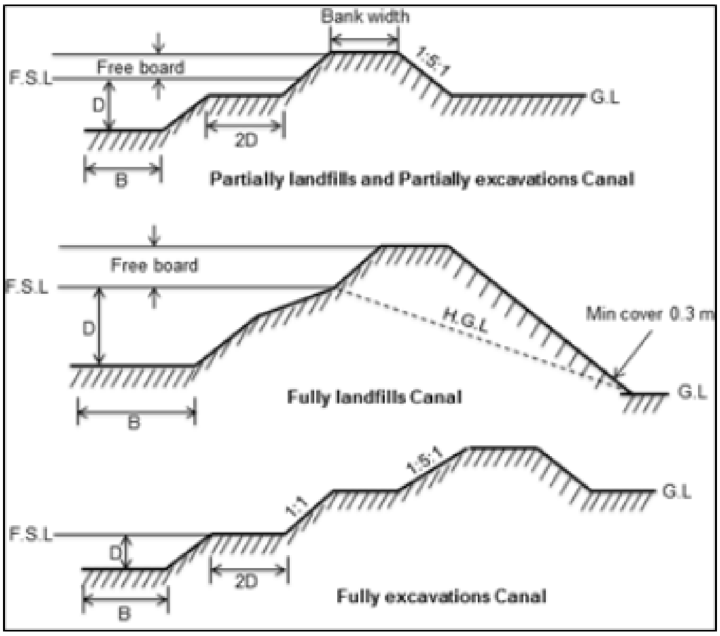

Fig. 7. Three canal type cross sections

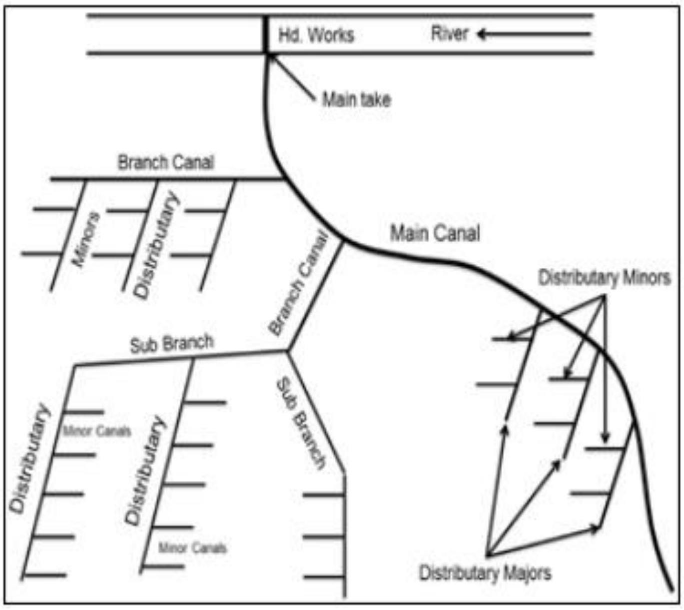

Fig. 8. Typical suitable irrigation network

When a canal is free from silt and safe from erosion, it is said to be stable. To fulfill these requirements, some authors proposed the following relations:

Kennedy proposed [8] the relation.

$$V_0 = C.D^n = 0.55.D^{0.64} ---(1)$$

Where: -

$V_0 =$ Critical non silting non scouring velocity, $C \,\&\, n \equiv$ Coefficients affected by location and type of soil.

Chezy equation [8] has the form: -

$$V = C\sqrt{R\,S} - - - (2)$$

Where: -

$V =$ Velocity in $\frac{L}{T}$ $\left(\frac{m}{sec}, or \frac{ft}{sec}\right)$

$C \equiv$ Coefficient with dimension

$$= \frac{L^{\frac{1}{2}}}{T} \left(\frac{m^{\frac{1}{2}}}{sec}, or \frac{Ft^{\frac{1}{2}}}{sec}\right)$$

$$R = \frac{A}{P} - - - (3)$$

$R \equiv$ Hydraulic radius L (m,or ft), $A \equiv$ Area in (m^2), $P \equiv$ Wetted perimeter in (m), $S \equiv$ Longitudinal slope of the canal, dimensionless

$$\frac{dh}{dl} = \frac{h}{l(m)}$$

Manning formula [8]. being more popular is now the most recent in the design of canals. It has the form:

$$V = \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}} - - - (4)$$

Where: -

n and C have the relation:

$$n = \frac{R^{\frac{1}{6}}}{C} - - - (5)$$

$$A = (b + zy)\,y - - - (6)$$

$$F.B. = \sqrt{cd} - - - (7)$$

$$B.T.W. = d + \left(\frac{b}{d}\right)^{\frac{1}{2}} - - - (8)$$

$$Q = C\sqrt{A} - - - (9)$$

$Q \equiv$ The discharge to be drained, $C \equiv$ Coefficient function of soil type, $A \equiv$ Area to be drained.

$$S=\frac{f^{\frac{5}{3}}}{3340Q^{\frac{1}{6}}}=\frac{0.0003f^{\frac{5}{3}}}{Q^{\frac{1}{6}}}---(10)$$

Where:

$f \equiv$ Silt factor function of soil type, $Q \equiv$ Discharge to be drained.

To prevent weeds growth the slope s, should be in the range (1:1500 – 1:3000) .

The soil is the base of the plant roots, which supplies it with water and metals. The required properties of the suitable type of soil is given in Table (1) showing soil texture groups.

Table No. (1): Soil Texture Groups

No.	Main group	Sub-group	Average particle dia. (mm)
1	Sand	Fine gravel	1 - 2
		Coarse sand	0.5-1.0
		Medium sand	0.25-.5
		Fine sand	0.1-0.25
		fine sand	0.05 – 0.1
2	silt		0.05-0.005
3	gray	Fire clay (Colonial)	0.002-0.005

Objective

Difficulties in control and distribution of water in the Gezira scheme are essential problems. These problems were resulting in deterioration of irrigation and agriculture infrastructures of the scheme, and distorts rotation of cultivation. The study revealed the existing situation of the Gezira scheme infrastructures, checked the existing irrigation and drainage canalization networks compared with the original design. Also, water supply control is associated with demand and its impact on crops production.

Methodology

The plan includes collection of data from offices and fields. It includes conducted details about the

Gezira consideration of the existing designs of the irrigation canals networks and their associated drains including escape drains. The field visit will consider inspection of conveyance and distribution system, canals regulators, including moveable weirs. Field outlet valves were also inspected. In addition, escapes drains, minor canals, and field irrigation systems as well as field drainage system were visited.

The study analysis considered the relations among different crops productions and water supply data in different years using SPSS techniques.

Analysis and results

The irrigation system comprises twin main canals running from the head works at Sennar to a common pool at the cross-regulator at km 57. The Managil main canal of 186 m3/s design capacity was constructed to serve the Managil extension parallel to the old Gezira main canal of 168 m3/s capacity. The water distribution (in the late 1990's) system included, the two main canals of total length of 261 km with total conveyance capacity of 354 m^3/s (186 + 168 =354) m^3/s at head works to 10 m3/s at the tail end. Fig. 9 shows the layout and channels distribution. The original design of the Gezira irrigation scheme recognized that the nature of the soil is of low water table, therefore there is no need for providing subsurface drainage of the fields [9]. The only need for drainage was for dealing with surface runoff from rainfall or excess irrigation.

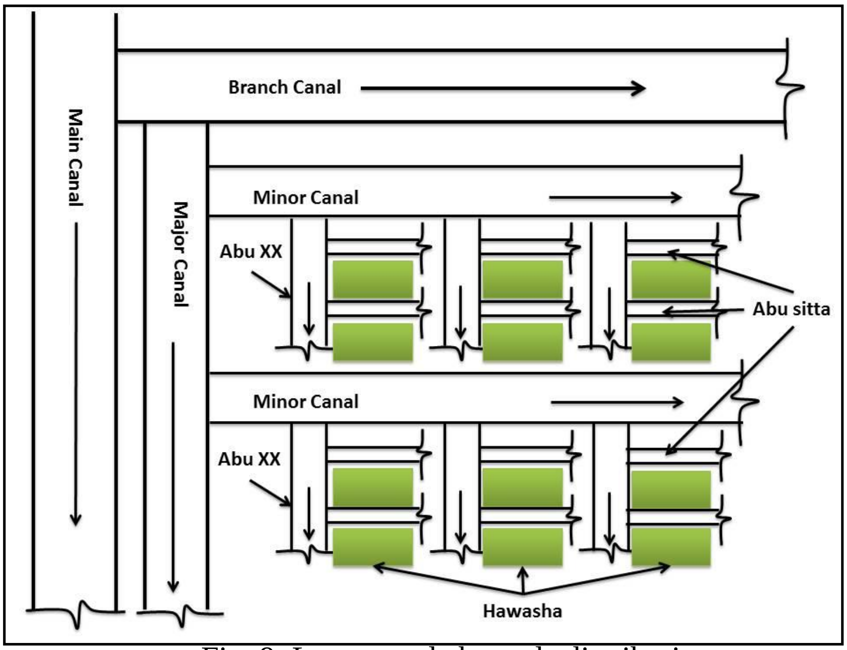

Fig. 9. Layout and channels distribution

Case study:

To study the Gezira Scheme Irrigation System typical canals in the heart of the Gezira Scheme area was selected, namely Zananda and Haj Abdalla canals [10].

Case1 Zananda canal1:

The cross sections for reach1 are shown in Fig. 10. The information for Reach1 is bed slope 1- 0.0001, bed width 6 m and the discharge Q = 5.5 m3 /sec. and for Reach2 are bed slope 1- 0.0005, bed width 5 m depth 2 m and the discharge Q = 5.5 m3 /sec.

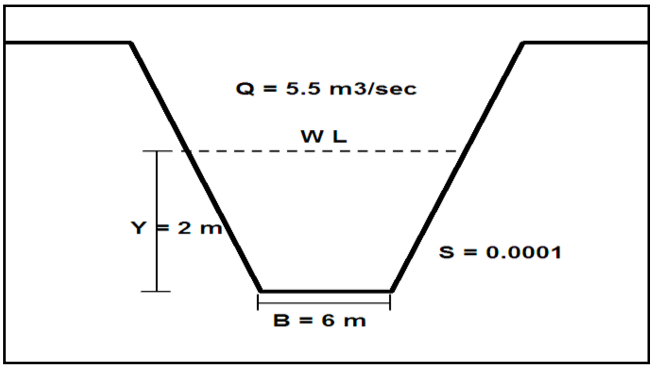

Fig. 10. Reach1 cross section of Zananda canal [10]

To calculate the area with depth D=2 m

A = BD + D2/2

$$A= 6* 2+22/2 = 12+2=14m2$$

Q = A.V

5.5=14.V

V=0.4 m/ses

V_0= 0.55D0.64

V_0 (critical velocity " non-silting and non-scouring channels in steady regime".

$$V_0 = 0.55 (2) 0.64 = 0.85 \text{ m/s}$$

$$P = B + D \sqrt{5}$$

$$= 6+2\ \sqrt{5}\ = 10.5 \text{ m}$$

$$R = \frac{A}{P} = \frac{14}{10.4} = 1.3 \text{ m}$$

Useing Kutter equation [8] to calculate the velocity:

$$V = \frac{23 + \frac{1}{N} + \frac{0.00155}{s}}{1 + (23 + \frac{0.000155}{s})\frac{N}{\sqrt{R}}} * \sqrt{R * s}$$

That's mean the V calculated must be near to V actual to determine stable section.

So, the V calculated value is V= 0.469m/sec. and

V actual = 0.4 m/s.

Using the same procedure for Reach 2 resulted:

V_{actual}=0.458 m/sec.

$V_{calculated}$=0.504 m/sec.

Therefore, the calculated water velocity is near the actual velocity for Reach1 and Reach 2, which means the Zananda canal is stable.

Case2 Haj Abdalla canal:

Here 5 reaches were considered (Reach1 to 5). Table 2 showing the collected data. Following the same procedure of calculations as done for Zananda canal the results for the actual and the calculated velocities for each reach was obtained and presented in Table 3.

Table 2 Haj Abdalla canal data

Reach #	Q (M^3/s	Velo. (m/s)	Water depth (m)	Bed	
				Width (m)	slope
1	5.1	0.46	1.64	3.5	0.0001
2	5.1	0.35	1.94	3.5	0.0005
3	4.66	0.35	1.86	3.5	0.0005
4	1.94	0.28	1.34	2.5	0.0005
5	1.94	0.28	1.34	2.5	0.0005

Table 3 $V_{calculated}$ Versus V_{actual} for Haj Abdalla canal

Reach #	Critical Velocity V_0 (m/s)	V_{actual} (m/s)	$V_{calculated}$ (m/s)
1	0.75	0.46	0.59
2	0.84	0.35	1.4
3	0.82	0.35	1.44
4	0.66	0.28	1.43
5	0.66	0.28	1.43

The calculations focused that Zananda section was considered stable while Haj Abdalla canal was not stable noticed variations in the calculated and actual water velocities with different discharge amount. The irrigation water supplied to the Gezira carry silt, which is deposited in the irrigation canals. Other sources of siltation are wind-blown material and canal banks eroded by wind and rains. The minor canals are most seriously affected by siltation due to the low velocity of the water in this night storage canals system. Factors that have a contribution to increase volume of silt accumulation in the Gezira scheme are:

(a) Crop intensification.

(b) Increased cultivated area to its present stage of 2.1 million feddans resulting in a twofold increase of water release to the irrigation canals that resulting in a corresponding sedimentation increase into the network system.

(c) The silt accumulation of the dead storage of Sennar dam volume and scouring of fine deposits by flood flows passing through Sennar reservoir maintained at spillway level during flood season.

(d) Increased erosion in Ethiopian upper catchment associated with alternative drought periods of several successive years.

Due to lack of modern survey equipment's and trained personnel, proper sediment investigations and calculations of volumes excavated are not correctly and systematically conducted. This resulted in a wide range span from 4 to 10 million m3 variations in estimating annual sediment depositions. [11]. However, temporarily continuous systematic measurement of silt entering into the system by the Hydraulic Research Station (HRS) in collaboration with Hydraulic Research Ltd. U.K. was conducted in mid-1988. Their important observations revealed that of the nearly 6 million tons of sediment that entered the Gezira and Managil main canals between July and November 1988 and more than 95 percent consist of clay and silt particles. Very little scouring of deposited sediment occurs in major and minor canals. The HRS research report concluded that "slope limitations make it impossible to design regime minor canals in the Gezira scheme. The sediment control options are limited to excluding sediment at the intake or trapping sediment in silting basins. By far the greatest volume of maintenance on the drainage system is also that of silt clearance. Virtually all the minor drains are totally silted up so that they now take the form of a slightly depressed wide strip of uncultivated land between the lowest part of a number and the bank of the next minor. The average rate of silt clearance from the canals has increased progressively from an average of 4.2 million m^3 per year during the period 1973- 1977 to about 6.2 million m^3 in 1983 and after 1999-2005 the project and irrigation network is still suffering, silt clearance kept between 20-30 million cubic meters with an average of 25 million cubic meters per year (at least). Despite that this was logically and reasonably unacceptable.

Furthermore, the study analysis considered the relations among different crops productions and water supply data in different years using SPSS techniques involving discharge in $m^3/\sec$. The area is in feddans and production in tons. The results indicated that: the production of Sorghum has the form of equation (11), production of groundnut has the form of equation (12), production of cotton has the form of equation (13), production of wheat has the form of equation (14), and production of vegetables has the form of equation (15).

$$Y = 1716.8X^2 - 16884X + 431743 --- (11)$$

$$Y = 22214 Ln\,X + 124913 --- (12)$$

$$Y = 12594\,X + 321912 --- (13)$$

$$Y = 7537.5 Ln\,X + 163547 --- (14)$$

$$Y = 2e + 0.8e^{0.1688} --- (15)$$

The study was extended and the relation among both the yearly used water and the actual cultivated area as well as yearly used water and total silt removed was indicated in Figs. 7 and 8. This was obtained using simple correlation. The relation between the quantity of required water and released water is as shown in Fig. 9. Also Fig. 10 shows used water versus released water.

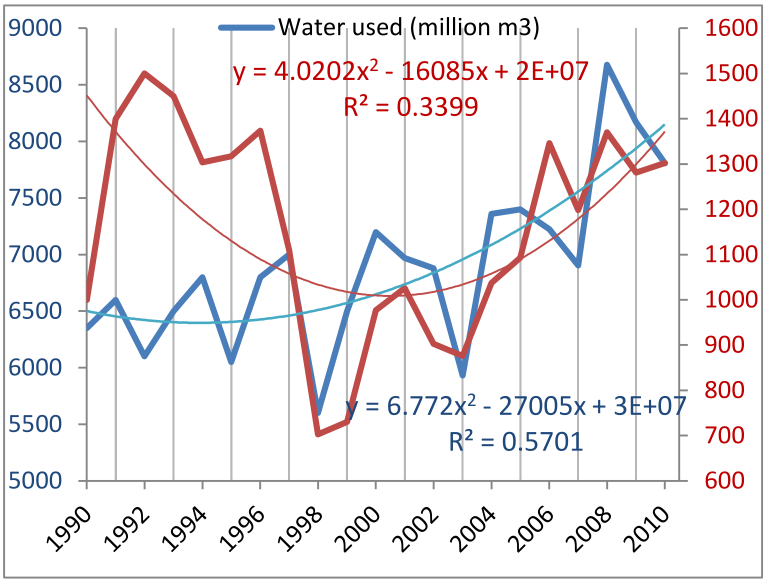

Fig. 7 Water used vs. cultivated area (1990 – 2010).

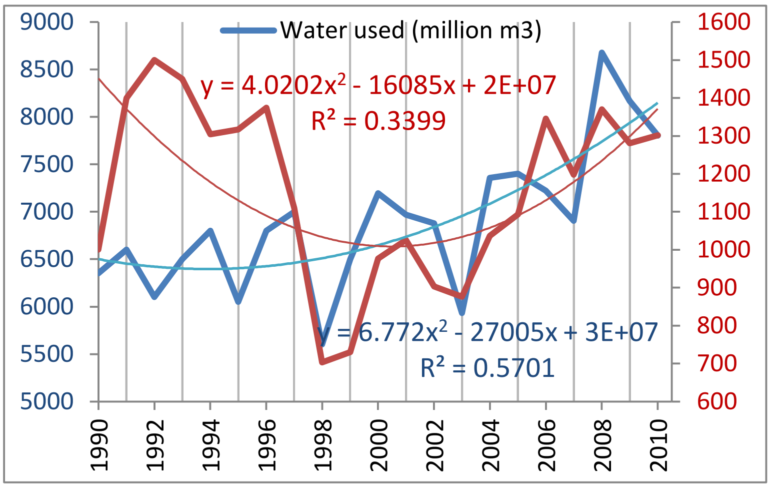

Fig. 8 Silt removal versus used water

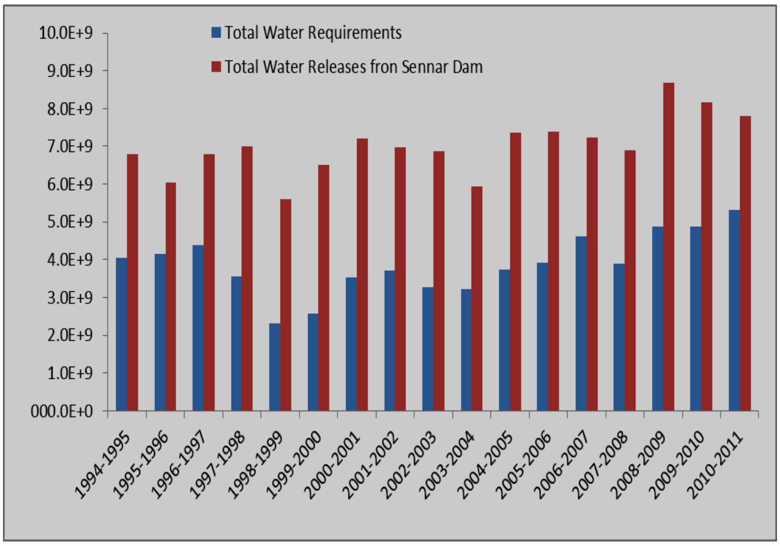

Fig. 9 Quantity of required water and the total released water

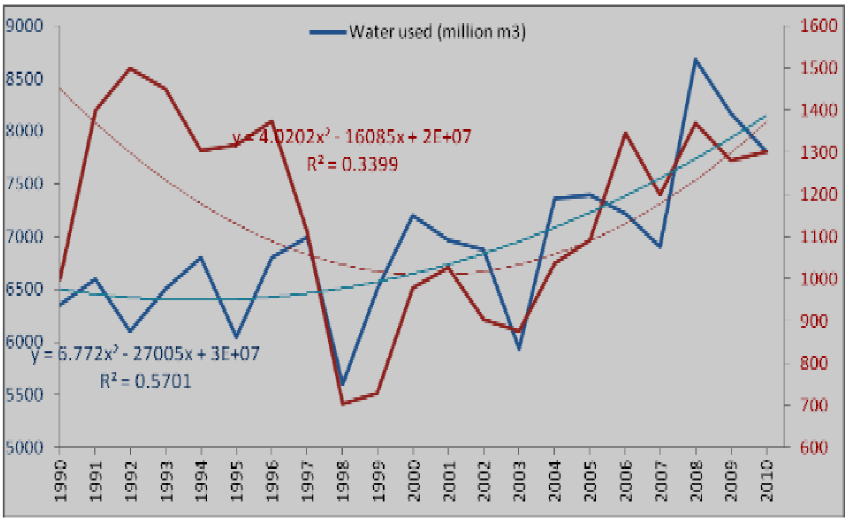

Fig. 10 Used water versus released water

Conclusions and recommendations

The Gezira agriculture scheme is one of the famous schemes through the word. Many crops were used in an area of about 2.1 million feddans. Since the scheme has started at 1925 and the water channels and the drainage systems were built more than fifty years old, so many problems may arise such as sedimentation of silts and growing of weeds along the major, minor canals and drainage system. This study concentrates on the efficiency of the canals considering the water discharge and the velocity in two cases conditions, Zananda and Haj Abdalla canals. Also, some interest goes to the crop's cultivation and the irrigated area relations considering the amount of released water from Sennar dam. The following points can be registered:

- ❖ It was apparent that the Gezira scheme production has seriously declined especially after the year 2005.
- ❖ Silt accumulation obstructed the water flow, so the existing night storage irrigation system is not practiced.
- ❖ The Scheme infrastructures are completely destroyed. Most of the canals and drains longitudinal sections and cross sections designs are not stable case of Haj Abdalla canal.
- ❖ Some canals are still stable e.g. Zananda canal.
- ❖ The quantity of water used is too low relative to the required water.
- ❖ It is noted that weeds and silts sedimentation make some troubles and obstructions at the openings e.g. sluice gates and movable weirs.

- Low water velocity will result in more siltation.
- It is noted that the drainage system is not working well.

Recommendations

- The Scheme fundamentally requires rehabilitation to all its infrastructures.
- Raising efficiency of production requires developing an agricultural rotation through proper planning, and financing.
- Irrigation and maintenance must be carefully and correctly conducted under good engineering supervisions to grantee rehabilitation and future sustainability.
- The water management and the supervision of canals operation must be under good judgement and experienced personnel's.
- Rehabilitation and renovation canal to the original stable design section reversing to actual none silting and non-scouring velocity.

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