CHAPTER 3

On-Farm Water Management Practices and Crop Production Indicators in Selected Areas of the Gezira Scheme

K. Azharul Haq, Gamar D. Khatib, Ahmed A. Salih[14]

3.1 INTRODUCTION

In the Gezira Scheme cotton and wheat are the major crops. In recent years, however, wheat has become the principal crop replacing cotton. The area planted to wheat has been increasing significantly over recent years and it is expected that by the mid-decade it will reach 300,000 ha if the present trend of sacrificing the cotton area in favour of cereals continues and adequate water can be diverted at the Sennar dam. On the other hand, the cotton area has registered significant decreases over the last few years and the trend is continuing. Data related to acreage and yield of wheat and cotton are given in Figures 1 and 2.

Figure 1. Trend in Wheat and Cotton acreage in the Gezira Scheme.

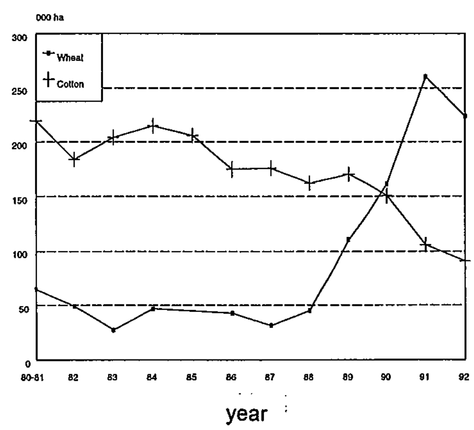
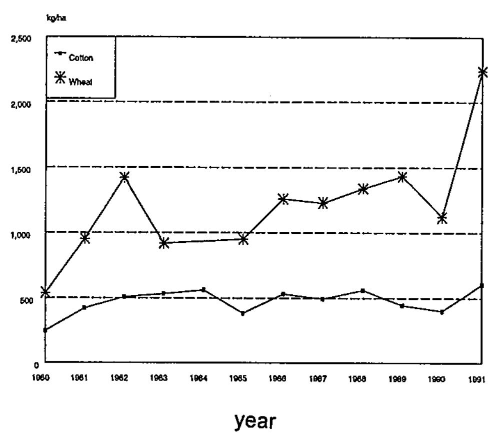


Figure 2. Yield trends for Cotton and Wheat.



[14]Irrigation Specialist, International Irrigation Management Institute, Colombo, Sri Lanka, Manager, Water Management Unit, Sudan Gezira Board, Medani, Sudan and Soil Phycist, Agricultural Research Corporation, Medani, Sudan respectively.

In the 1991-92 crop season 228,288 ha was planted to wheat as compared to 260,000 ha in the 1990-91 crop season. This 12% decrease in area was a direct consequence of the loss of nearly 17,000 ha (approx. 7% of the area planted) due to a shortage of irrigation water during the previous year. Though there has been a significant increase in wheat area (45% increase in 1991-92 over 1980-81), the yield has been quite unstable. Taking 1980 -81 as the benchmark year, the yield of wheat increased from 0.50 t/ha to 1.60 t/ha in 1989-90, an increase of nearly 350 percent. The wheat yield in recent years has, however, have shown erratic trend. As compared to the previous season, wheat yields increased by about 110 percent (in 1991-92 over 1990-1991), whereas in 1990-91 the average yield declined by about 21% over 1989-90.

During the same season 92,000 ha were planted to cotton as compared to 105,000 ha in the 1990-91 crop season, a 13% decrease. Though cotton area showed a general decline over the whole period, the most significant reduction, 40%, took place between 19989-90 and 1991-92. This decrease can be attributed to a government policy to move cotton to rainfed areas and increase cereal acreage in the irrigated schemes. Another important reason is that, for this export crop, farmers were paid at the official conversion rate, which was only 10% of the "street" price. Like wheat, cotton also went through the cycles of high and low yields with the 1991-92 harvest producing an all time high of 2.28 t/ha, an increase of 52% over the previous season and 144% over the benchmark year.

Both wheat and cotton cultivation in the Gezira Scheme is nearly fully mechanized except for cotton picking which is done manually. Until recently, like cotton, wheat was also the "State Crop". The Government, through the Gezira Board, provided all the inputs and services and after the harvest the cost of production was reclaimed from the tenant. It was also mandatory for the tenant to deliver all of his production to the government at a price previously determined by the authority, except that the tenant was allowed to keep 95 kg/ha for domestic consumption. From 1991-92 crop season, the government has decided to deregulate wheat production. But cotton continues to be the state crop.

During the 1991-92 season, studies were conducted in 8 and 7 "Numbers" (Number is generally a 38 ha block of contiguous farm land) for wheat and cotton, respectively, belonging to three "Minors" at: 1 the Pilot Farm located in Tayba Block of Messelmia Group; and 27 and 17 "Numbers" for wheat and cotton, respectively, in the Mikhashfi Group (Figure 5), to quantify and evaluate the effect of agronomic and water management parameters on their production. For wheat, 3 additional Numbers were also included from the Wad Habouba Group.

Both primary and secondary data were collected for the study. Primary data were collected on soil moisture(wetting and depletion characteristics), plant density (for wheat), volume of dead storage, irrigation frequency and duration, and yields. All other data were collected from relevant SGB offices.

3.2 WEATHER

The weather data have been collected from the Wad Medani weather station (200 km south east of Khartoum), which is presented in Figures 3 and 4. The data indicate that both the seasons experienced extreme weather conditions. The 1990-91 crop year received less than average rainfall, experienced higher temperatures, and high wind-runs. The wheat season (November-April) was also characterized by high temperatures. Both the average maximum and average minimum temperatures were higher by 2-3 degrees from the 10-year average, as well as from those of the previous year (1989-90). This adversely affected seedling establishment, as well as vegetative growth, including tillering. The temperature, however, cooled off from early January and was quite favourable during the rest of the growing season. Worst affected were the fields that were planted at the recommended optimum time. Due to colder temperatures during the months of January, February and March, the late planted areas produced better yields than the scheme average.

By contrast, the 1991-92 crop year was extremely favourable in terms of both water and weather. A well distributed rainfall pattern in the project area, as well as in the catchment, coupled with reductions in cotton, groundnuts and wheat acreages, ensured a relatively adequate water supply during the entire crop year, especially during the wheat season. The growing environment during the wheat season was near perfect. Water adequacy, combined with better crop husbandry and improved management, resulted in significant increases in both cotton and wheat yields in 1991-92 compared with the previous season.

3.3 CROP PRODUCTION PRACTICES

3.3.1 Agronomic Practices

Agronomic data were collected from the SGB Block offices through questionnaires. In the whole of the study area, only two varieties, Debiera for wheat and shambat for cotton, were planted. Seed was machine drilled at the rate of 142 and 26 kg/ha for wheat and cotton, respectively.

For wheat, nitrogen (N) at the rate of 190 kg/ha in the form of urea (87.6 kg N), and phosphorus(P) at the rate of 95 kg/ha as TSP, were applied as basal during land preparation. P was applied with the first plowing whereas N was applied during the final land preparation. For cotton, only urea was applied at the rate of 190 kg/ha.

Wheat was harvested by combine harvesters and the yield estimates were made from the harvesters grain tank. Cotton yields were estimated from farmers "cotton yards".

3.3.2 Irrigation and Water Management

The layout of the water application system of a typical "Number" is shown in Figure 6. From the "Minor", water is supplied to a "Abu Ashireen" which has an average carrying capacity of 116 l/sec and serves one "Number". The "Number" is sub-divided into 18 "Hawashas" of 2.10 ha and each "Hawasha" is served by an "Abu Sitta"(50 l/sec capacity). Each "Hawasha" is further sub-divided into seven "Angaya" having an area of 0.3 ha each. Irrigation water to each "Angaya" is delivered through a small field channel called

"Gadwal" (7 1/sec capacity). A small field divider called "Tagnet" divides the "Angaya" into two equal halves, whereas each "Angaya" is supplied by two "Gadwals". Furrow and basin methods of irrigation are practiced for wheat and cotton cultivation, respectively. For better water management, the present recommendation is to divide each Hawasha into 42 plots of equal size.

The "Abu Sitta" runs perpendicular to the "Abu Ashireen" and both the "Gadwal" and "Tagnet" run parallel to the "Abu Ashireen". The existing practice is to irrigate half of the "Number" at one time. Originally, the on-farm water management practices called for applying irrigation water first to the tail end. But due mainly to unreliability, this is not practiced.

Water is supplied by the Ministry of Irrigation (MOI) based on the "indent" submitted by the Assistant Block Inspectors of the Sudan Gezira Board(SGB). The SGB is responsible for the operation of the "Minors" and "Abu Ashireenn". This responsibility has since been transferred to the MOI. On-farm water management is the responsibility of the tenants. Water is usually supplied to each "Number" in rotation on a fixed volume(5000 cu.m per day) over a fixed time interval (14 days).

3.4 RESULTS AND DISCUSSION

3.4.1 Agronomic Practices

Earlier, it has been mentioned that the crop production system is standardized and the cultural operations are carried out by the SGB. The variations appear to occur in the dates of planting and harvesting. The discussion will, therefore, be limited to these two parameters.

Over the last decade, planting dates for wheat have considerably changed. The recommended optimum dates at present is from the last week of October to the end of November. Planting upto mid-December, however, has become acceptable. During the year-long study on 35 wheat "Numbers", the monitored data indicated that the entire area was planted during the recommended period. Planting dates ranged from October 31 to November 30 (Table 3.1).

Planting dates monitored by other researchers (Hydraulic Research Ltd, 1991) in 1988-89 and 1989-90 reported that planting was delayed in both seasons by about three weeks. The date of planting did not have any significant impact on the trend of yields, though there was a wide range of variation from 0.48 t/ha to 3.33 t/ha. Yield variation was probably due to factors other than irrigation.

During the 1991-92 season, cotton was also planted within or near the optimum range in the majority of the Numbers monitored (Table 3.2). The planting date was spread from 05-07-91 to 28-07-91. In 1988-89, planting occurred upto two weeks before the official dates for minors at the head of the scheme, whereas at the tail end areas of the scheme planting was extended upto two weeks beyond the end of the recommended period (July 15 through August 15). In 1989-90, the spread was much reduced. Like wheat planting, the date also did not show any significant trend on cotton yields, though there was a wide variation in yields from 1.14 t/ha to 2.45 t/ha.

Table 3.1. Agronomic practices and their impact on wheat yield.

Serial No.	Location	Number	Date of sowing	Date of harvesting	Field duration (Days)	Yield T/ha
1	Tayba Shimal (Tayba)	2	11.06.91	04.08.92	154	3.09
2	Tayba Shimal (Tayba)	6	11.04.91	04.01.92	147	3.33
3	Ibrahim (Tayba)	2	11.21.91	04.16.92	147	1.95
4	Ibrahim (Tayba)	12	11.19.91	04.21.92	154	2.09
5	Ibrahim (Tayba)	17	11.07.91	04.10.92	155	2.36
6	Sunni (Tayba)	3	11.28.91	04.15.92	139	2.14
7	Sunni (Tayba)	11	11.04.91	04.08.92	156	2.62
8	Sunni (Tayba)	14	11.06.91	04.10.92	156	2.48
9	Saadiya (Huda)	1	11.02.91	04.10.92	159	1.93
10	Saadiya (Huda)	7	11.20.91	04.10.92	141	0.98
11	Saadiya (Huda)	10	11.26.91	04.10.92	135	1.38
12	Kareima (Huda)	1	11.12.91	04.12.92	151	1.48
13	Om Husan (Huda)	1	11.03.91	04.16.92	163	1.36
14	Om Husan (Huda)	7	11.08.91	04.16.92	159	1.09
15	Om Husan (Huda)	12	11.05.91	04.16.92	162	1.09
16	Garash (A.Gani)	1	11.24.91	04.29.92	156	2.33
17	Garash (A.Gani)	7	11.25.91	04.29.92	155	1.93
18	Garash (A.Gani)	10	11.26.91	04.28.92	153	1.81
19	Hamdnall (A.Gani)	1	10.31.91	04.04.92	157	2.55
20	Hamdnall (A.Gani)	7	11.06.91	04.05.92	150	2.71
21	Hamdnall (A.Gani)	9	11.07.91	04.05.92	149	2.52
22	Abdalla Yousif (A.Gani)	7	11.02.91	04.10.92	159	2.59
23	Abdalla Yousif (A.Gani)	21	11.30.91	04.16.92	137	2.57
24	Abdalla Yousif (A.Gani)	31	11.30.91	04.16.92	137	3.19
25	Garab (Abrag)	39	11.15.91	04.17.92	153	2.19
26	Garab (Abrag)	36	11.13.91	04.17.92	155	2.31
27	Garab (Abrag)	33	11.10.91	04.15.92	156	1.81
28	Garab (Abrag)	7	11.04.91	04.05.92	152	2.64
29	Garab (Abrag)	10	11.05.91	04.05.92	151	2.64
30	Garab (Abrag)	63	11.20.91	04.20.92	151	1.55
31	Garab (Abrag)	1	11.01.91	04.05.92	155	2.5
32	Garab (Abrag)	54	11.20.91	04.20.92	151	2.4
33	Um Sayala (Istrahna)	3	11.20.91	03.20.92	121	0.98
34	Elwalie(Istrahna)	23	11.01.91	03.01.92	121	0.92
35	Hieloat(Istrahna)	10	11.15.91	03.15.92	121	0.83

Table 3.2. Agronomic practices and their impact on cotton yield.

Serial No.	Location	Number	Date of sowing	Date of harvesting	Field duration (Days)	Yield T/ha
1	Tyba Shimal	3	05.07.91	23.12.92	170	2.46
2	Tyba Shimal	9	08.07.91	12.12.92	156	2.00
3	Sunni	4	15.07.91	08.12.92	145	1.83
4	Sunni	8	14.07.91	27.12.92	165	2.17
5	Sunni	12	20.07.91	30.12.92	162	2.26
6	Ibrahim	8	28.07.91	19.01.92	174	1.57
7	Ibrahim	14	15.07.91	28.12.92	165	2.31
8	Gorash (A/Gani)|	2	08.07.91	21.12.91	165	1.91
9	Gorash (A/Gani)	5	10.07.91	22.12.91	164	1.83
10	Gorash (A/Gani)	11	15.07.91	22.12.91	159	1.30
11	Adb alla yousif (A/G)	2	16.07.91	24.12.91	160	1.63
12	Adb alla yousif (A/G)	11	18.07.91	24.12.91	158	1.57
13	Hamadnalla (A/G)	2	16.07.91	24.12.91	160	1.97
14	Hamadnalla (A/G)	11	13.07.91	20.12.91	161	1.57
15	Adb alla yousif (A/G)	25	21.07.91	27.12.91	158	1.57
16	Hamadnalla (A/G)	5	16.07.91	23.12.91	159	1.63
17	Om Husan (Huda)	13	27.07.91	25.12.91	150	1.37
18	Om Husan (Huda)	5	22.07.91	22.12.91	152	1.57
19	Om Husan (Huda)	2	20.07.91	22.12.91	154	1.97
20	Kariema	12	18.7.91	22.12.91	156	1.14
21	Kariema (Huda)	5	15.7.91	22.12.91	159	1.71
22	Saadiya (Huda)	10	15.7.91	20.12.91	157	1.43
23	Saadiya (Huda)	2	10.7.91	21.12.91	163	2.17
24	Kariema (Huda)	2	17.7.91	22.12.91	157	1.37

Note: Harvest date indicated is the date of 1st picking. Cotton is generally picked 3 times and after each picking Irrigation is applied. Two to three weeks gap between picking is a usual practice.

Yields are in seed cotton.

3.4.2 Irrigation Water Management

3.4.2.1 Water Supply

Earlier, it was mentioned that water is supplied by the MOI against an indent submitted by the SGB Block Inspectors. The procedure for indent is very simple. Every Inspector demands 5000 m3/day (12 hrs) per "Number" for the duration of irrigation, which is usually 14 days. This demand remains constant during the whole year, irrespective of type of crop grown, stage of crop growth, or the season at which crops are being grown. An analysis of this magic number indicated that 5000 m3/day/Number seems to be the peak requirement for groundnuts, which are grown during June-October period. The peak crop water requirement of groundnuts has been estimated at 1207 m3/fd in June, which translates to about 4000 m3/Number/day (source GRP: Staff Appraisal Report). This higher and blanket type of indenting is probably done to play safe and should now be replaced by indents for specific crops and specific seasons. Estimates of monthly water requirements for different crops of the Gezira scheme are available, which should be utilized (Table 3.3). It can be seen that, depending on the growth stages, water requirements vary widely between crops during the same months. For example, the crop water requirements for ELS(extra long staple) and MS (medium staple) cotton is 475 m3/ha during the month of July as against 1666 m3/ha and 1420 m3/ha for groundnuts and sorghum, respectively. Similarly, during October, the water requirement for ELS cotton and MS cotton nearly peaks to 2100 m3/ha and 2420 m3/ha, respectively, as compared with 960 m3/ha and 435 m3/ha for groundnuts and sorghum. The above discussion amply demonstrates the need to realistically prepare indents to meet actual crop water requirements.

Except for groundnuts and sorghum, the water requirements for other crops are comparatively lower during the first three months, which incidentally brings nearly 60% of the silt load into the system. A better matching of deliveries to demand will prevent the diversion of unnecessarily large supplies, and hence, will reduce the silt problem (6 to 7 million tons of silt are carried into the system every year).

3.4.2.2 Frequency and Duration of Irrigation

Table 3.4 indicates that, for wheat the frequency of irrigation has followed more or less the recommended 14 day interval, in most of the cases. Yet, in some cases, the frequency was stretched to 28 days (Saadiya/Huda; Number 1) between the first and second irrigation. The lowest irrigation interval of 7 days was experienced by Number 1 of Kariema/Huda between the 2nd and 3rd irrigations. The total number of days of irrigation application also varied significantly between the "Numbers" (Table 3.5). "Number" 17 of Ibrahim/Tayba received water for the highest number of days, which was 88. The total number of days of water application varied from 44 to 88 days.

Table 3.3. Monthly crop-water requirements in the Gezira scheme (m^3/ha).

MONTH	COTTON ELS	COTTON MS	WHEAT	GROUND-NUT	SORGHUM
January	724	150	799	0	0
February	150	0	23	0	0
March	105	0	0	0	0
April	0	0	0	0	0
May	0	0	0	0	0
June	0	0	0	1.207	806
July	200	200	0	700	598
August	565	576	0	868	910
September	548	753	0	924	936
October	884	1.016	257	404	435
November	889	915	657	0	0
December	822	569	737	0	0
Total	4,887	4,179	2,473	4,103	3,685
M3/ha	12,678	10,447	6,388	9,722	8,759
Mm	(1270)	(1045)	(640)	(972)	876)

Source: Gezira Rehabilitation Project, Staff Appraisal Report.

Note: Crop requirements are at field outlet pipe taking into account the staggered planting dates and requirements for initial irrigation.

Crop requirements are calculated using the crop factor based on GRS field measurements (GRS 1979) and the Penman EO at Wad Medani.

FAO recommendation for wheat:450-650 mm.

Table 3.4. Date of first and last irrigation, irrigation frequency and interval - a case of wheat crop during 1991-92.

SERIAL NO.	LOCATION	NUMBER	DATE OF FIRST IRRIGATION	IRRIGATION INTERVAL (DAYS) 2ND	3RD	4TH	5TH	6TH	7TH	8TH
1	Tayba Shimal (Tayba)	2	11.15.91	14	16	16	15	14	16	-
2	Tayba Shimal (Tayba)	6	11.18.91	18	14	16	15	14	12	-
3	Ibrahim (Tayba)	2	11.28.91	13	12	14	14	15	-	-
4	Ibrahim (Tayba)	12	11.23.91	13	14	14	15	16	12	-
5	Ibrahim (Tayba)	17	11.17.91	18	14	15	13	16	14	-
6	Sunni (Tayba)	3	12.02.91	16	15	12	14	14	-	-
7	Sunni (Tayba)	11	11.14.91	13	13	11	13	14	14	-
8	Sunni (Tayba)	14	11.17.91	12	12	14	16	11	14	-
9	Saadiya (Huda)	1	11.08.91	28	15	15	15	15	13	-
10	Saadiya (Huda)	7	11.22.91	14	17	16	17	18	19	-
11	Saadiya (Huda)	10	12.01.91	18	15	16	16	16	17	-
12	Kareima (Huda)	1	11.20.91	18	7	15	14	14	18	-
13	Om Husan (Huda)	1	11.21.91	18	14	14	17	15	14	-
14	Om Husan (Huda)	7	11.14.91	17	17	15	16	13	16	-
15	Om Husan (Huda)	12	11.16.91	17	15	17	15	16	15	-
16	Garash (A.Gani)	1	11.29.91	18	15	14	13	14	14	-
17	Garash (A.Gani)	7	12.01.91	18	14	14	15	14	14	-
18	Garash (A.Gani)	10	12.03.91	18	14	14	13	14	15	-
19	Hamdnall (A.Gani)	1	11.17.91	18	15	14	14	16	-	-
20	Hamdnall (A.Gani)	7	11.10.91	18	16	14	17	17	16	-
21	Hamdnall (A.Gani)	9	11.20.91	18	15	15	14	14	16	-
22	Abdalla Yousif (A.Gani)	7	11.14.91	19	14	16	14	16	14	-
23	Abdalla Yousif(A.Gani)	21	11.03.91	21	13	15	14	14	17	-
24	Abdalla Yousif(A.Gani)	31	12.05.91	18	14	14	14	13	14	-
25	Garab (Abrag)	54	11.22.91	18	17	16	15	17	14	-
26	Garab (Abrag)	39	11.20.91	20	14	15	14	15	16	-
27	Garab (Abrag)	36	11.17.91	19	16	16	15	15	15	-
28	Garab (Abrag)	33	11.15.91	18	14	17	15	17	16	-
29	Garab (Abrag)	7	11.12.91	18	14	16	16	14	16	-
30	Garab (Abrag)	10	11.15.91	19	14	16	15	16	15	-
31	Garab (Abrag)	58	11.25.91	16	16	14	15	16	16	-
32	Garab (Abrag)	63	11.29.91	11	15	16	14	15	16	-
33	Um Sayala (Istrahna)	3	11.20.91	15	15	10	16	15	16	-
34	Elwalie (Istrahna)	23	11.01.91	14	15	12	14	15	10	16
35	Hieloat (Istrahna)	10	11.15.91	14	17	14	16	15	-	-

Table 3.5. Date of first and last irrigation, irrigation frequency and interval - a case of cotton crop during 1991-92.

	Location	Number	1st Irrig Date	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	Last Irrig Date
1	TS	3	08/7/91	14	14	24	15	15	14	15	15	15	13	23	01/01/92
2	TS	9	10/7/91	15	15	14	14	16	14	15	15	14	15	14	18/12/91
3	Sunni	4	18/7/91	15	14	16	15	14	13	16	17	16	13		14/12/91
4	Sunni	8	17/7/91	18	16	15	15	17	14	15	14	17			05/01/92
5	Sunni	12	23/7/91	17	14	17	13	14	15	16	15	13	13	15	31/12/91
6	Ibrahim	8	02/8/91	18	18	18	16	12	22	18	18	16	20		25/01/92
7	Ibrahim	14	17/7/91	16	15	17	16	13	15	16	14	14	15	22	05/01/92
8	Gorash (A/Gani)	2	05/7/91	Rain	Rain	Rain	14	14	15	14	14	15	14	16	26/12/91
9	Gorash (A/Gani)	5	08/7/91	Rain	Rain	Rain	14	16	14	15	14	14	13	16	28/12/91
10	Gorash (A/Gani)	11	12/7/91	Rain	Rain	Rain	14	16	15	14	14	15	16	15	02/01/91
11	Adb alla yousif	2	14/7/91	Rain	Rain	Rain	14	13	14	15	14	16	15	15	31/12/91
12	Adb alla yousif	11	15/7/91	Rain	Rain	Rain	14	14	14	15	15	15	14	15	30/12/91
13	Hamadnalla	2	14/7/91	Rain	Rain	Rain	15	14	14	14	15	14	14	12	24/12/91
14	Hamadnalla	11	12/7/91	Rain	Rain	Rain	14	14	14	14	14	14	14	14	22/12/91
15	Adb alla yousif	25	18/7/91	Rain	Rain	Rain	14	14	16	14	15	14	15	16	06/01/92
16	Hamadnalla	5	15/7/91	Rain	Rain	Rain	14	14	14	15	14	14	14	15	30/12/91
17	Om Husan (Huda)	13	27/7/91	Rain	Rain	Rain	14	13	14	16	14	14	17	16	10/01/92
18	Om Husan (Huda)	5	20/7/91	Rain	Rain	Rain	14	15	14	14	14	14	14	15	03/01/92
19	Om Husan (Huda)	2	18/7/91	Rain	Rain	Rain	14	14	14	14	14	14	15	17	04/01/92
20	Kariema (Huda)	12	14/7/91	Rain	Rain	Rain	14	14	14	15	14	14	14	15	31/12/91
21	Kariema (Huda)	5	15/7/91	Rain	Rain	Rain	24	12	14	14	15	15	15	15	04/01/92
22	Saadiya (Huda)	10	15/7/91	Rain	Rain	Rain	15	14	14	14	14	14	13	14	25/12/91
23	Saadiya (Huda)	2	08/7/91	Rain	Rain	Rain	16	14	15	14	16	16	16	15	01/01/92
24	Kariema (Huda)	2	15/7/91	Rain	Rain	Rain	15	13	14	15	14	14	15	15	29/12/91

For cotton, all of the Numbers (No. 1-7) of the Pilot farm received 12 irrigations. The Numbers in the Mikashfi groups received 9 irrigations; three irrigations were skipped because of rainfall. The irrigation interval ranged from 12 to 25, and 12 to 24 days, respectively, in the Pilot farm and Mikashfi Groups. The total number of irrigation days ranged from 55 to 78 and 74 to 83 in the pilot farm and Mikashfi Groups, respectively.

A common practice among the researchers is to correlate the crop yield with the number of irrigations applied. From the above discussion, it is quite evident that this approach, in many cases, may lead to erroneous conclusions because there could be a wide difference in the volume of water applied between fields, even if the number of irrigations is identical. Table 3.6 indicates that, even with a lower number of irrigations, an area can receive significantly larger amounts of water.

Primarily, this is possible due to two reasons: 1) uncontrolled flow; and 2) increased hours of operation. The number of irrigations can be correlated to yield only if the flow rate and irrigation time per unit area can be kept constant, which is extremely difficult to achieve in a vast irrigation system like Gezira. The total depth of actual water application was significantly higher than the estimates available for the area. Table 3.3 presents estimates of the evapotranspiration requirement of wheat for the Gezira scheme.

3.4.2.3 Crop Water Requirements and Actual Application

Estimated crop water requirements for major crops in the Gezira scheme are presented in Table 3.3. These fall within the range recommended by the FAO (cotton is 700-1300 mm; Dura is 450-650; and wheat is 450-650 mm; Irrigation and Drainage Paper No. 33). In 1990-91, the average depth of application for wheat ranged from 667mm to 993mm (Haq, K. A., 1991). In 1991-92, the data computed from 35 Numbers indicates that the range was from 661mm to 1380 mm (Table 3.6) with an average value of 848 mm. All values are significantly higher than the recommended value of 640 mm. The actual depth of irrigation application for cotton was computed for the 1991-92 season only. Water application for cotton ranged from 932 to 1908 mm with an average of 1200 mm (Table 3.7) as compared with the recommended 1045 mm.

All the application depths have been computed without accounting for the rainfall. With rainfall, the average application for cotton will increase by 99 and 163 mm for the Pilot Farm and Mikashfi Groups, respectively, thus decreasing both the application depth and the WUE further.

Table 3.6. Irrigation frequencies, irrigation days, depth of application and - a case of wheat crop.

Serial No.	Location	Number	Area ha	Irrig. nos.	Irrig. days	Depth applied (mm)	WUE kg/m3
1	Tayba Shimal (Tayba)	2	29	8	44	759	0.41
2	Tayba Shimal (Tayba)	6	29	8	66	1138	0.30
3	Ibrahim (Tayba)	2	32	7	73	1141	0.17
4	Ibrahim (Tayba)	12	38	8	80	1053	0.20
5	Ibrahim (Tayba)	17	34	8	88	1294	0.18
6	Sunni (Tayba)	3	38	7	80	1053	0.20
7	Sunni (Tayba)	11	38	8	78	1026	0.25
8	Sunni (Tayba)	14	38	8	77	1013	0.24
9	Saadiya (Huda)	1	37	7	65	868	0.22
10	Saadiya (Huda)	7	28	7	56	987	0.10
11	Saadiya (Huda)	10	19	7	53	1204	0.26
12	Saadiya (Huda)	1	36	7	56	771	0.19
13	Om Husan (Huda)	1	38	7	57	754	0.18
14	Om Husan (Huda)	7	38	7	58	767	0.14
15	Om Husan (Huda)	12	38	7	57	754	0.15
16	Gorash (Abdel Gani)	1	37	7	52	703	0.33
17	Gorash (Abdel Gani)	7	38	7	50	661	0.29
18	Gorash (Abdel Gani)	10	38	7	50	661	0.27
19	Hamdnall (Abdel)	1	28	6	46	811	0.31
20	Hamdnall (Abdel)	7	38	7	57	754	0.36
21	Hamdnall (Abdel Gani)	9	13	7	55	784	0.32
22	Abdalla Yousif	7	38	7	55	727	0.36
23	Abdalla Yousif	21	38	7	53	794	0.37
24	Abdalla Yousif	31	38	7	53	701	0.46
25	Gorab (Abrag)	54	35	7	56	808	0.30
26	Gorab (Abrag)	39	38	7	55	714	0.30
27	Gorab (Abrag)	36	38	7	58	754	0.30
28	Gorab (Abrag)	33	38	7	56	741	0.24
29	Gorab (Abrag)	7	38	7	55	714	0.36
30	Gorab (Abrag)	10	38	7	55	727	0.36
31	Gorab (Abrag)	58	38	7	55	727	0.36
32	Gorab (Abrag)	63	21	7	50	1380	0.13
33	Um Sayala	3	38	7	65	855	0.11
34	Elwalie	23	38	8	73	965	0.10
35	Hieloat	10	38	6	64	842	0.10

Table 3.7. Irrigation frequencies, irrigation days, depth of application, crop yield and WUE - a case of cotton crop.

Serial No.	Location	Number	Area ha	Irrig. nos.	Irrig. days	Depth applied (mm)	Yield t/ha	WUE kg/m3
1	Tyba Shimal	3	29	12	87	1500	2.46	0.17
2	Tyba Shimal	9	29	12	71	1224	2.00	0.16
3	Sunni	4	34	11	115	1690	1.83	0.11
	Sunni	8	38	10	118	1552	2.17	0.12
5	Sunni	12	38	12	142	1868	2.26	0.12
6	Ibrahim	8	38	11	123	1618	1.57	0.10
7	Ibrahim	14	38	12	145	1908	2.31	0.12
8	Gorash (A/Gani)	2	38	10	79	1040	1.91	0.18
9	Gorash (A/Gani)	5	38	10	78	1026	1.83	0.18
10	Gorash (A/Gani)	11	38	10	71	934	1.30	0.14
11	Adb alla yousif	2	38	10	76	1000	1.63	0.16
12	Adb alla yousif	11	38	10	76	1000	1.57	0.15
13	Hamadnalla (A/G)	2	28	10	55	982	1.97	0.20
14	Hamadnalla (A/G)	11	13	10	31	1192	1.57	0.13
15	Adb alla yousif	25	30	10	60	992	1.57	0.16
16	Hamadnalla (A/G)	5	36	10	76	1055	1.63	0.15
17	Om Husan (Huda)	13	38	10	81	1065	1.37	0.13
18	Om Husan (Huda)	5	38	10	80	1058	1.57	0.15
19	Om Husan (Huda)	2	38	10	78	1032	1.97	0.19
20	Kariema (Huda)	12	19	10	41	1080	1.14	0.10
21	Kariema (Huda)	5	19	10	42	798	1.71	0.16
22	Saadiya (Huda)	10	19	10	41	1078	1.43	0.13
23	Saadiya (Huda)	2	37	10	83	1123	2.17	0.19
24	Kariema (Huda)	2	37	10	74	998	1.37	0.14

3.4.2.4 Soil Moisture Profiles

Soil moisture profiles for both cotton and wheat during the 1991-92 crop season were determined by using the neutron probe from four successive depths of the root zone (15, 30, 45 and 60 cm). For wheat, 27 sets of data were collected from the study area on moisture depletion characteristics, which are presented in Figure 7. Soil moisture data were collected from one Hawasha each from three Numbers of the Pilot farm area. These represented the head, middle and tail Hawashas of Tayba Shimal, Sunni and Ibrahim minor canals. Samples were collected from 9 points in each "Number". For cotton, profiles were constructed from eight locations of two Numbers (i.e., Number 12 of Sunni minor and Number 7 of Ibrahim minor). Data were collected from the soil profile after the standing water disappeared from the soil surface. The data indicate that, throughout the growing season the soil moisture content, in most of the areas monitored, was maintained well within the appropriate range. For Gezira soils, the field capacity (FC) and wilting percentages (WP) are 42% and 18%, respectively. The average moisture depletion in the study area ranged from 10% to 15% in a two-week period. This means that if the soil moisture in the root zone was brought to the field capacity, the moisture content will be lowered to around 27% in two weeks which is well above the WP of 18%. The findings indicate that the possibility exists to increase the irrigation interval from the now practiced 14 days.

3.4.2.5 Crop Yield and Water Use Efficiency

The wheat crop in the Gezira Scheme is harvested mechanically by combine harvesters. Yields were estimated from the grain hopper of the combine. During the wheat harvest, it was observed that the harvesters were leaving behind a sizeable quantity of unharvested wheat, which was being collected by a large number of women and children trailing the harvesters. Though this grain ends up in the family grain basket, yet it is not reflected in the yield estimate. The unharvested yield was estimated to be around 10% of the harvested amount. The average yield of wheat in the study area was 2.0 t/ha. This is nearly double the average yield of 1.12 t/ha obtained in 1991. The reason for this higher yield can be attributed to a very good weather year coupled with a reduction in planted area (which provided adequate water) and the season experienced near optimum growing conditions. The yield, however, was still significantly lower than the potential of the variety (5.0 t/ha) as well as those obtained in the research farm. The reasons can be many, including low fertilizer uptake by the plants, weed infestation, 2-3% area of Numbers remain unplanted due to machine sowing, another 2% of high lands receiving less than adequate moisture, less than optimum plant population, loss due to shattering, other machine losses, etc.

Yield, water use efficiency (WUE) and related data have been presented in Tables 3.6 and 3.7. The WUE for wheat ranged from a low of 0.10 to 0.46 with an average of 0.26. Even the highest value obtained is significantly lower than the recommended WUE of 1, which should be achieved for sustainable and profitable wheat production. The highest yield, as well as WUE, were obtained by applying 701 mm of water in 7 irrigations with 53 days of application. The lowest WUEs were obtained in three Numbers with 842, 965 and 1380 mm depths of application (the last figure is one of the highest depths applied) in 7 irrigations, with 50 days of water delivery. The preceding analysis clearly demonstrates that both wheat and cotton have increased over the years, yet they are well below the recommended standard of 4.5 t/ha for wheat and cotton, respectively. Therefore, it is essential to review the crop production processes in the Gezira Scheme, not only to improve the WUE, but also to reduce the gap between the higher and lower performing areas.

For cotton, WUE values ranged from 0.10 to 0.20 with an average of 0.15 as compared to the recommended range of 0.40 to 0.60. The ratio between actual and potential value is 0.37 as compared to 0.32 for wheat. This indicates that cotton utilized irrigation water more effectively than wheat. The average yields and WUE for both the crops, however, continue to remain extremely low. To further improve this situation, not only the irrigation application should be matched more precisely with crop requirements, but management of the entire crop production system should be improved.

3.5 CONCLUSIONS AND RECOMMENDATIONS

1. Flow control and regulation should be strengthened by recalibrating structures, especially those at majors and below. Studies conducted by other researchers indicate that though the total volume of water entering the system is adequate to meet the crop water requirements, yet serious distributive inequity exists between different areas of the scheme, as well as in different "Numbers" of the same area, with the tail ends being universally deprived of their fair share. Determined efforts should also be made to construct flow measuring devices at the Abu Ashreen levels.

2. Due to siltation, weed growth and malfunctioning hydraulic structures, the conveyance characteristics of the canals have changed from those of the original design. Till these are restored, the system should be operated not by the strict design specifications, but by the existing conveyance conditions. That means personnel responsible should supervise the water distribution system more closely and intensively, while regulating the flow as per existing conditions, which may demand operation of the structures in ways significantly different than those prescribed in the manual. Water flowing well over/under the regulator and overtopping of the canal banks are increasingly becoming common in the scheme. At the present time, the only way to avoid this is to keep an eye on the situation and regulate the flow accordingly.

3. Though conveyance losses in the scheme are very low (< 10%), yet significant amounts of water are lost due to dead storage and overtopping of the canals. Dead storage losses quantified in the "Abu Ashreens" and "Abu Sittas" of three "Numbers" in the Pilot farm indicated losses of 1000 to 1200 m^3 per irrigation per Number. Effective ways, including manual pumping of water, should be adopted to use this water. If 75% of the 29000 "Numbers" are cropped, and an average of 8 irrigations are applied, a total volume of 210 million m^3 of water will be lost through dead storage,

which is equivalent to 40% of the average monthly supply during January, when the water requirement for wheat is the maximum and constitutes about 3.4% of the average annual release of 6100 million m^3 for the entire system.

4. Water management within the "Hawasha" is far from desirable. Two types of edge effects have been observed, both contributing to yield reduction. The high lands within the Hawasha estimated to be 5% suffer from water stress and the low lands and furrow ends from waterlogging.

   To irrigate high lands near the edges of the Abu Ashreens, the tenants raise the water level above the 'freeboard' by constructing cross dams on the Abu Ashreens. This practice reduces the gradient between the minor and Abu Ashreen that reduces flow and, depending on the duration of high-land-irrigation, tenants may lose a substantial amount of their share of water. High lands should preferably be irrigated by (a) using the water from the dead storage of Abu Ashreens and Abu Sittas, and (b) constructing deeper furrows for row crops and deeper corrugations for small grains (like wheat). For wheat, after the first irrigation, the 42 standard basins should be re-adjusted or fine-tuned following the wetting pattern of the land or the contour.

   Over/under irrigation results from a lack of knowledge about the cut-off time. Tenants use their judgement to turn off irrigation water. Some guidelines should be provided to the tenants on the duration of irrigation. They should be made aware that over-irrigation is often more harmful than under-irrigation.

5. To save irrigation water, row crops (cotton, dura, onion, etc) may be irrigated by alternate furrows (i.e., every furrow should service two rows). Alternately, if the existing method of furrow irrigation is used alternate furrows should be irrigated every time water is applied. It is estimated that upto 30% of the water can be saved without sacrificing the yield. In the 1990-91 crop season, yield trials on cotton were conducted on the Pilot farm by using the "one-furrow-service-two rows" method. There was no significant difference in yield as compared to the conventional furrow method. The study unfortunately did not consider water as a variable.

6. Limited studies conducted in June, 1992 in collaboration with ARC on moisture distribution from "naked" furrows (uncropped) indicated that moisture distribution is somewhat uniform up to about 1.5 m on both sides of the furrow when water is allowed to infiltrate for nearly 24 hrs. This opens up the possibility of irrigating upto three rows between furrows. Further studies are needed to confirm this. If successful, this would be expected to reduce the volume of water required, as well as reduce weed growth because the wetted area will be reduced.

7. Furrow irrigation practiced in the scheme is really controlled flood irrigation because the field is normally flooded by introducing the water through the furrow. This exposes the plant to prolonged and undesirable ponded water condition. This is especially injurious when the crop is in the early

stages of vegetative growth. Furrow irrigation in its true form should be practiced, except when fertilizer is applied on the ridges.

8. At present, the Abu Sittas takes too much time to convey water along their entire length of 280 m and this contributes to low application efficiency. It is, therefore, recommended that pilot studies be conducted by relocating the Abu Ashreens through the middle of the Number. This will reduce the length of the Abu Sitta by 50% and irrigation can be completed in a shorter time duration. For this, no new Abu Ashreens needs to be constructed. Half the area of the Numbers on either side of the Abu Ashreen will constitute the new Number. This new arrangement is also expected to discourage the construction of "Nacus" (unauthorized Abu Sitta) by the tenants. Some people will argue that the slope of the Gezira may not permit this practice. But, the very existence of a large number of "Nacus" nulls this hypothesis. Also, the slope is so small (5 to 10 cm per kilometer), which can be adjusted without making a major investment.

9. Investigations should also be made to assess the possibility of conveying water from the minor to the Abu Ashreens on both sides. This is being practiced in certain areas of the scheme where the slope is favorable. As has been mentioned earlier, the gentle slope of the scheme may not prove to be a major constraint. During the 1991-92 crop season, tenants of Number 12 of Sunni minor were in fact drawing water both from the Sunni and Ibrahim minors. One-third of the area was being supplied from the unauthorized Ibrahim minor. Where night storage is employed, a few hours in the mornings will be the optimum time to irrigate.

   Normally such arrangements will require resectioning of the minor. But, in the Gezira scheme, the minors also act as night storage reservoirs; hence, the minors expected to accommodate the increased volume without much difficulty. Also, if night irrigation (which is already being practiced by the tenants) is formalized, the minors will be able to carry the required capacity to serve both sides.

10. Night storage systems (NSS), introduced over half a century ago for social reasons rather than technical reasons, seem to have lost their relevance and tenants in many areas of the scheme are irrigating their hawashas at night. This practice should be encouraged and at the same time be institutionalized. This will have the following advantages:

    1. The larger volume will increase the velocity, thereby resulting in decreased sediment deposition in the minors, which at present accepts over 30% of the sediment entering the system. The sediment will be transferred to the Abu Ashreens and will be easier to manage if the responsibility for the maintenance of the Abu Ashreens are transferred to the tenants and each tenant is asked to maintain his portion of the canal. Some researchers have expressed concern that sediment diverted to the Abu Ashreens may

increase the elevation of the farm land. The 10 million m^3 of sediment entering the system every year will increase the field levels by about 1 mm in 1 year.

2. Night storage weirs will no longer be required. This will also reduce sediment deposition in the majors, which also gets 30% of the sediments carried into the system. Repair and maintenance of these structures will also be eliminated as these will no longer exist.

11. During the 1991-92 crop season, data collected from the study areas indicated that though the average plant density was near optimum, the variation was highly significant. This was especially true for wheat. Plant counts from three Numbers of the Pilot farm indicated that the average densities for wheat were 522, 490 and 648 per m^2 in Sunni Minor (Number 11), Ibrahim Minor (Number 18) and Tayba Shimal Minor (Number 2), respectively. For the same Numbers, the maximum and minimum densities were 284 and 828, 252 and 808, and 412 and 928 plants per m^2, respectively. This type of density distribution decreases yield in areas that are overcrowded and also in the sparsely populated areas. Improper adjustment of the seeder, and lack of experience on the part of the operator, are two major contributing factors. Also, observations showed that 3 to 5% of the areas in these Numbers did not have any plants at all. Agronomists from ARC and SGB should investigate and identify the exact causes for the abovementioned situations and recommend remedial measures.

12. Nearly a third of the scheme area is fallowed every year for improving soil fertility in order to increase crop yields, especially those of cotton. But the unstable trend in cotton yields over the years have negated this hypothesis. If water were made available, there is a high likelihood that the cropping intensity could be increased to 100% without further sacrificing yield. This was supported by most of the field staff. Therefore, a strong recommendation that is the potential for conjunctively using surface and ground water be pilot tested for technical feasibility, economic viability and farmers acceptance.

13. Distributive inequity was also observed at the micro-level (i.e., at the Hawasha level) in 1990-91. The soil moisture content in different parts of the same Hawasha varied more than the recommended 20%, which demonstrates the need for better distribution by improving leveling and control of water delivery.

14. Water depletion profiles computed for cotton and wheat in the 1991-92 season indicated that the soil moisture content in the effective root zone was much higher than the allowable depletion limit before the next irrigation was applied. This indicates a possibility for extension of the irrigation interval.

16. The Gezira soil is low in organic matter content (0.35 to 0.40). Higher organic matter content is expected to improve soil structure, water holding capacity, infiltration rates, etc.

In the early days, when chemical fertilizers were non-existent, nitrogen fixation by leguminous crops (dolicos lablab) and fallows in the rotation were the only ways to high soil fertility levels and ensured availability of essential nutrient for cotton (Burhan and Mansi, 1967). At the present time, despite heavy fertilization of the crops in the intensified rotation--3N as urea for cotton, 2N for Dura and 2N for wheat-- the yield of all the crops either continued to decline or showed no definite trend of increase. Therefore, to restart the use of organic manure is becoming increasingly important.

There are several cheap and abundant sources of organic matter, such as agricultural residue, animal manure (it is estimated that there are over 1.2 million animals in the scheme area and another 2 million graze through the scheme every year). The third source would be the growing of green manure crops during the lean season.

Based on the recommendation made in 1991-92, experiments have already been initiated for composting cotton residue. It will take several years before scientists can make recommendations on the amount needed per unit area (tons/ha), optimal size of the pit that can be easily constructed and maintained by the tenants, number of crops one application of organic matter will sustain, and the extent of possible reductions in the application of chemical fertilizers.

Raising a green manure crop during the fallow rotation offers a good potential for organic manuring. The best time for planting the crop would be just after the first significant rainfall of the season (> 15 mm) and biomass should be incorporated after 40-45 days. In the rice growing areas of south Asia, the rice crop preceded by a green manure crop increased yield by about 1 ton/ha and at the same time reduced the application of chemical fertilizer (N) by 50%. In the process, a total of 15 t/ ha of green biomass was incorporated into the soil. Studies should, therefore, be initiated to select suitable green manure crop(s) and the amount of biomass to be incorporated (t/ha) for increased, sustainable and economically attractive yields. In selecting the green manure crops, researchers should ascertain what kind of materials are available off-the-shelf that have relevance to the field conditions. Some new varieties of cowpeas developed at the International Institute for Tropical Agriculture (IITA) can be used for green manuring after the crops have been harvested. These are said to be good as cattle feed as well.

Determined efforts must also be made to effectively use animal manure for improving soil fertility and soil characteristics, including those affecting water movement through the soil. A good starting point would be to encourage farmers to use animal manure who very soon will be growing 50,000 fd (21000 ha) of citrus. Later, the practice could be transferred to field crops.

Though organic manuring is not generally practiced in the Gezira scheme, yet some of the progressive farmers, the ones producing the highest yields, are using all kinds of organic residues, including animal blood.

17. Studies conducted during 1990-91 and 1991-92 found that the water use efficiency (kg of yield per m^3 of water) for the major crops, cotton and wheat, are very low. In 1990-91, the water use efficiency (WUE) in three selected numbers ranged from 0.14 to 0.39 as against the recommended values of 0.80 to 1.00. In the 1991-92 season, even with a significant increase in wheat yield over 1990-91, the WUE efficiency continued to remain low and ranged from 0.10 to 0.46.

18. In 1991-92, some crops, especially wheat, were left unharvested after the crop was ready for harvest and the optimum harvest time was exceeded by a minimum of 31 days and a maximum of 52 days. This was also true in the 1990-91 season, even on the Pilot farm. To reduce shattering losses, it has been recommended that timeliness in the harvest be ensured.

19. Until 1992, the SGB was responsible for operation and maintenance of FOPs and Abu Ashreens. Responsibility has now been transferred to MOI. Like most of the distribution system, these have also departed significantly from their designed specifications. It is strongly recommended that farmers be increasingly involved in the operation and maintenance of the FOPs and Abu Ashreens. FOPs should be calibrated in such a way so that farmers are able to quantify the volume of water entering into their systems. For easy maintenance of the Abu Ashreens by the tenants, brick-lined reference sections should be constructed every 200 meters for two meter lengths throughout the entire length of the Abu Ashreens.

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