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Irrigation Management Practices for Wheat Production in the Gezira Agricultural Scheme, Sudan

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Abstract: Assessment of the impact of the current irrigation practices of the Gezira Agricultural Scheme (GAS) by tenants with reference to wheat (*Triticum aestivum*) during two seasons was undertaken. Tenants were applying irrigation water either in excess or less than the crop water requirement (CWR). This might have been attributed to: (a) variation in water supply caused by weed infestation, silt deposition, and water indenting not based on the actual CWR, and (b) unawareness of the tenants about the adverse-effects of over-irrigation. As such, the tenants who had good access to the water tended to over-irrigate their crops, thus putting the other users under water shortages. Such water management practices have resulted in application of 30 to 40% irrigation water in excess of the actual CWR and reduced crop yields. This excess water could have been easily used for increasing the area under wheat. In this regard some suggestions are proposed.

Key words: Crop water requirement, indenting, water management.

In the last two decades, the Sahel region of Africa was affected by a series of drought spells that resulted in serious water shortages and consequently, serious deficit in food production. This shortage of water, which affected agriculture mostly, has necessitated efficient water use for increasing cropped area and maximizing crop productivity. Excessive application of irrigation water reduces yields as does water stress (Maurya *et al*., 1994; Sharma and Swarup, 1988; Farah *et al*., 1997).

In the GAS, which is the largest in Sudan, efficient water management of the limited water is required. Plusquellec (1990) reported that yields of cotton and wheat in GAS were 2 to 3 times below the potential yields obtained at the research stations. One of the major reasons for these low yields is the poor water management practices which have serious impact on the availability and economics of irrigation water and calls for maximum irrigation production efficiency (Levine and Bailey, 1987).

Little information is available on the effects of water management practices by tenants of the GAS on crop productivity. The present investigation was undertaken to study the influence of irrigation management practices in the GAS on wheat production.

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Study Site

Location and soils

The GAS in Sudan covers an area of about 0.9 million ha located in the triangle land between the Blue and White Niles, south of Khartoum. It is irrigated by gravity from Sennar Dam situated on the Blue Nile some 280 km south west of Khartoum. The climate of the area is arid and continental. The soils of the GAS are characterized by heavy cracking clays (Vertisols) with low water permeability (Salih *et al*., 1992). Although such behavior may have some advantages, for example, reduced deep percolation and seepage losses from the conveyance system or at the field level, inappropriate water management practices, particularly through excessive application of irrigation water, result in waterlogged conditions.

Irrigation supply and indenting

The layout of the irrigation system of the GAS is illustrated in Fig. 1. The irrigation water is delivered from the major to a minor canal and then through a field outlet pipe (FOP) into the "Abu XX". The FOPs are designed to discharge 5000 m^3 per 12 hour. Each "Abu XX" irrigates, on an average, 37.8 ha called a "number". The number is divided into 18 tenancies of 2.1 ha each, which is irrigated by a small ditch called "Abut UI" (Fig. 1).

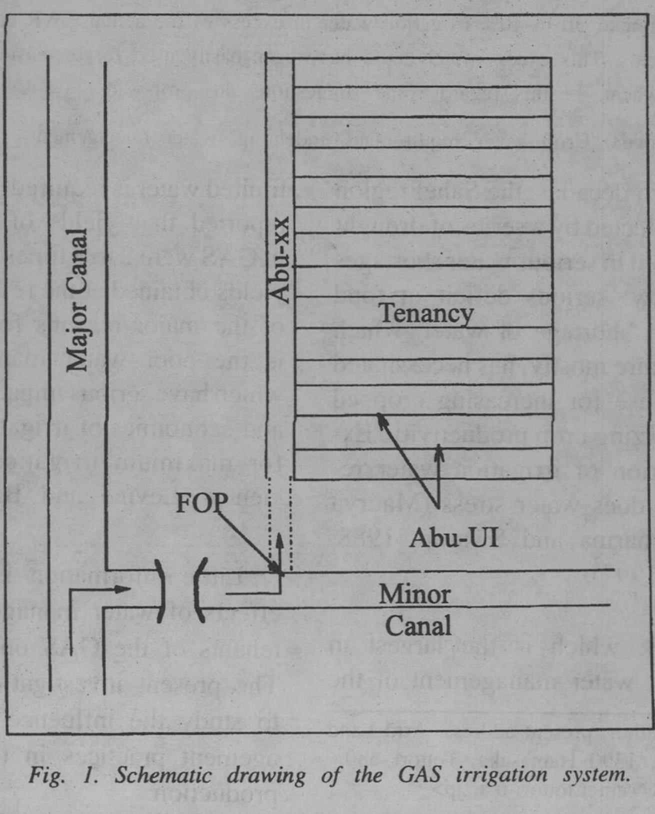

Fig. 1. Schematic drawing of the GAS irrigation system.

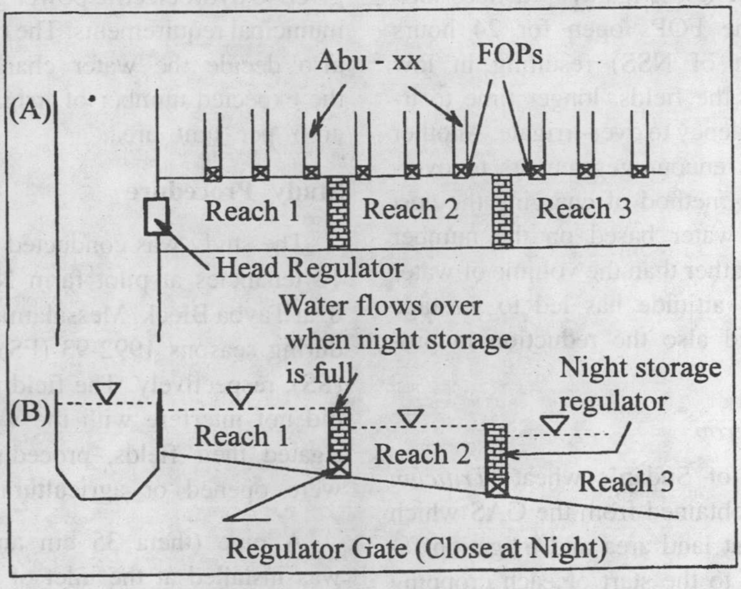

Fig. 2. Schematic drawing of the minor canal showing the night storage system (NSS): a) plane view, and b) side view.

Due to the practical difficulties of irrigation at night, the irrigation system was designed to operate on what is known as the night storage system (NSS). The idea was to store water in the minor canals during the night by dividing the canal into reaches by flow regulators (Fig. 2). Closing the FOPs during the night will raise the water level high enough for adequate irrigation during the day.

At the initial planning and design of irrigation system of the GAS, there was little information concerning the CWR and an empirical method was adopted upon which the layout of the irrigation system was based. Assuming about 950 m^3 ha^{-1}, equivalent to 67 m^3 ha^{-1} day^{-1}, the discharge of each FOP should irrigate a "number" in 7 days. The irrigation interval has been determined as fourteen days. However, in the late 1960s, research was carried out to determine the actual CWR values according to Penman method (Fairbrother, 1984). Neither the actual nor the empirical methods are adhered to by the scheme management or the tenants.

Before the present intensification and diversification, the GAS operated satisfactorily on the basis of the original design and regulation, but several problems emerged around mid 1970s as a consequence of increase in cropping intensity from less than 40% in the early 1960s to 80% at present. This resulted in a 3-fold increase in irrigation water releases and excessive deposition of silt and weed infestation. In order to cope with this situation, the tenants began to adopt new irrigation practices such as leaving the FOPs open for 24 hours (abandonment of NSS) resulting in low discharges to the fields, longer time to irrigate and tendency to over-irrigate. Another reason which encourages tenants to over-irrigate is the method of charging the cost of irrigation water based on the number of irrigation rather than the volume of water applied. This attitude has led to wastage of water and also the reduction in productivity.

The wheat crop

The bulk of Sudan's wheat (*Triticum aestivum*) is obtained from the GAS which has the largest land area and irrigation facilities. Prior to the start of each cropping season, depending on the amount of water stored behind in dam to maximise irrigation efficiency, the GAS and the Ministry of Irrigation (MOI) decide the area to be planted with wheat. Consideration is also given to hydroelectric power generation and municipal requirements. The two authorities also decide the water charges based on the expected number of irrigation for each crop per unit area.

Study Procedure

The study was conducted taking 14 and 12 tenancies at pilot farm No. 6 and No. 8, at Tayba Block, Messalamia Group, GAS during seasons 1992-93 (FS) and 1993-94 (SS), respectively. The field measurements did not interfere with the way tenants irrigated their fields, procedures the gates were opened or agricultural activities.

A pipe (theta 35 cm and 1 m long) was installed at the inlet of each tenancy. To allow measurement of water flow, the pipe had a rectangular groove at the top through which a vane flow meter (Weller, 1986) was lowered into the pipe and allowed to deflect. The momentum is obtained by

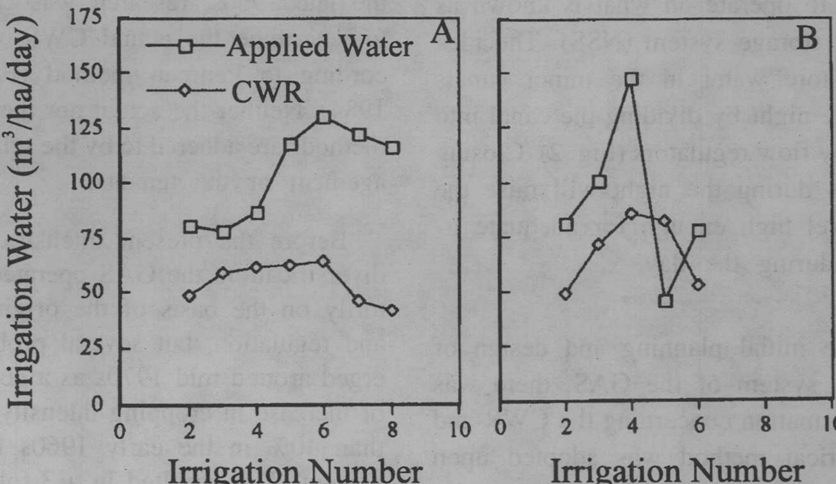

Fig. 3. Applied water and CWR of the wheat crop for different irrigations in seasons 1992-93 (A) and 1993-94 (B).

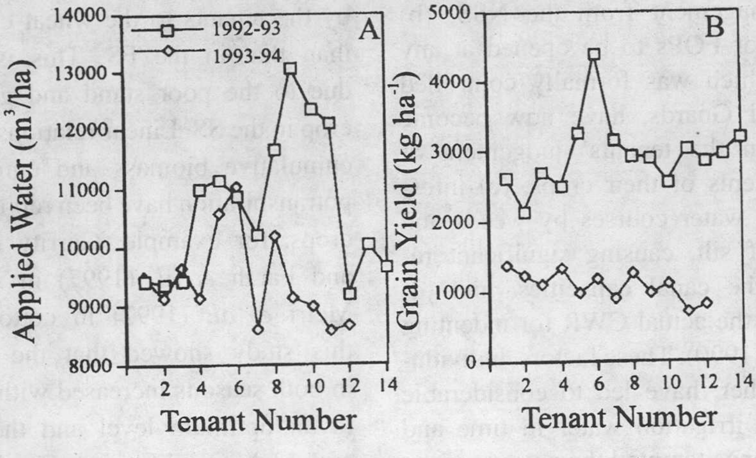

Fig. 4. Effect of tenant location from head to tail on the amount of applied water during the growing seasons (A) and wheat grain yield (B).

applying weights to the flow meter vane until it attained an equilibrium position. The flow rate is then computed using the calibration equation of the vane flow meter. Measurements were taken three times a day between 6 AM and 6 PM and their means were taken as the discharge entering each tenancy.

The actual CWRs were calculated for each irrigation interval using the crop factors developed at the Grezira Research Station (GRS) (Fairbrother, 1977).

All tenancies received 8 irrigations in the FS and 6 irrigations in the SS. The duration and interval of the irrigations were monitored round the clock. At harvest, grain yields of each tenancy were recorded. The weather data in the two seasons were taken from the meteorological station at the GRS, about 10 km away from the study site.

Results and Discussion

The result of this study indicated that tenants had applied more water than required in both the seasons and for all waterings, except for the 5th irrigation in the SS, which was not applied and as such, the interval between the 4th and the 6th irrigation was extended to nearly 30 days (Fig. 3). This practice of over-irrigation is probably attributed to the absence of equity in supply of irrigation water at the minor canal and Abu-XX levels and the variation in the water supply from head to tail (Faki *et al.*, 1989). It was also shown that the tenants located in the center of the Number applied more water than those at the head or the tail, with no comparable increase in their crop yields (Fig. 4). The main reason for application of less water by tenants at the head of Abu-XX, was due to their confidence in obtaining the quantum of irrigation water whenever they wanted. Those at the tail end could not get the sufficient quantity of water to apply, because of excessive water applications by those in the center. The lack of confidence in the system, felt by many of the users, might be due to: (a) deviation of the irrigation management from the NSS, (b) the number of FOPs to be opened at any one time, which was formally controlled by the canal Guards, have now become dependent on the tenants' judgement of the requirements of their crops, (c) infestation of the water courses by weeds and deposition of silt, causing significant reduction of the canal capacities, and (d) not applying the actual CWR for indenting (Plusquellec, 1990). These factors, individually or together, have led to considerable variations of irrigation water in time and space, and hence tempted the users to over-irrigate their crops whenever they got the opportunity to do so.

Regarding the effects of water application on the wheat crop, the study showed that the grain yield in the SS was lower than that of the FS (Fig. 5), most probably as a result of the warmer weather, which prevailed during the SS (Fig. 6). However, in spite of the warmer conditions in the SS, the amount of water, which was given by the tenants to the wheat crop, was less than that in the FS. This is presumably due to the poor stand and growth of the crop in the SS. Linear relationships between cumulative biomass and cumulative evapotranspiration have been reported for many crops, for example, Garrity *et al.* (1982) and Farah *et al.* (1997) in sorghum and Meiri *et al.* (1992) in cotton. However, this study showed that the grain yields in both seasons increased with added water to an optimum level and then decreased with higher applications (Fig. 5). Maximum yields were attained at around 11500 and 9500 m^3 ha^{-1} for the FS and SS, respectively. Deviations from these amounts tended to decrease grain yield. A very similar result was reported by Farah *et al.* (1997) in sorghum, However, Fairbrother (1977) found that the annual CWR for wheat is about 6800 m^3 ha^{-1} under Gezira conditions. Thus, the tenants' applications were about 40 and 30% in excess of CWR in the

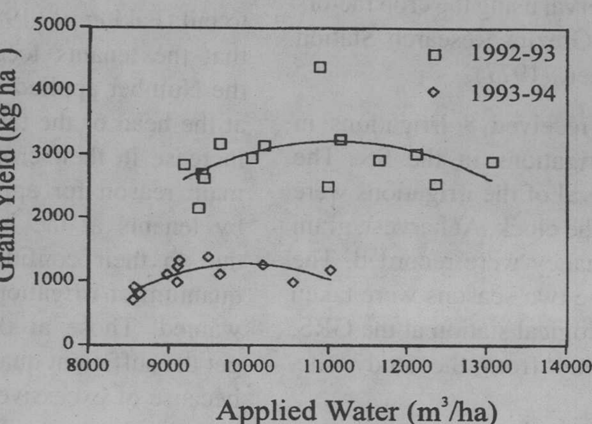

Fig. 5. Wheat grain yield as a function of applied water.

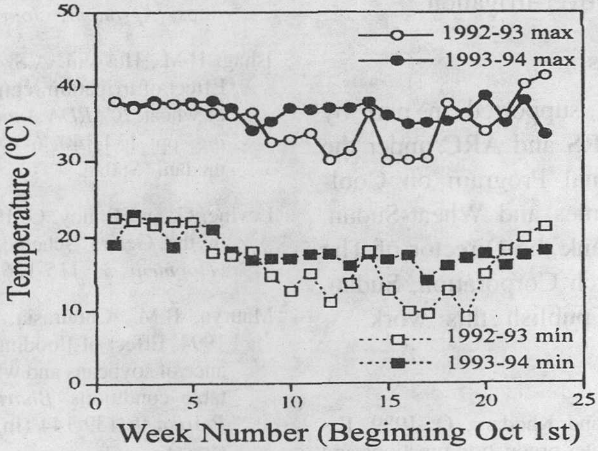

Fig. 6. Maximum and minimum temperatures during the two wheat growing seasons.

FS and SS, respectively. It was also observed that the time to irrigate a number was extended to about two weeks in both seasons instead of the recommended 7 days.

The fewer number of irrigation, coupled with the missing of the 5th irrigation, which extended the irrigation interval to nearly 30 days, might also have contributed to reducing the yield in the SS. The time of the 5th irrigation was contemporary with that of early formation of the reproductive stage, namely grain initiation. Studies on the effects of skipping of irrigations, at heading and anthesis stages of wheat, showed that soil moisture stress had maximum adverse effect on grain yield (Ishag, 1992; Farah *et al*., 1993). On the other hand, the loss in grain yield due to water application in excess of the actual CWR, might have been due to subjecting the crops to water saturation conditions. The effects of waterlogging during the vegetative growth stages, for 2, 4 and 6 days, were found to reduce tillering, plant height, head emergence and resulted in significant grain yield reductions amounting to 18, 29 and 47% as compared with no waterlogging, respectively (Sharma and Swarup, 1988).

This study has shown that much of the irrigation water was wasted and resulted in grain yield decreases. Proper irrigation management could have saved considerable amount of water and improved irrigation production efficiency.

In conclusion, it is proposed that the present water management practices in the GAS can be improved by: (a) adoption of the actual CWR for irrigation application, (b) regulation of irrigation intervals according to the needs of the crop, (c) charging users on the basis of actual volume of water used and not the number of irrigation or area cropped, (d) maintenance of the canals by timely removal of weeds and silt, and (e) making the tenants aware of the ill effects of over-irrigation.

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