Irrigation Management Transfer in the Gezira Scheme, Sudan

A case study on farmers' operation and maintenance strategies in Tuweir minor canal

MSc. Thesis by Ertiban Woldegebriel

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Master thesis Irrigation and Water Engineering submitted in partial fulfillment of the degree of Master of Science in International Land and Water Management at Wageningen University, the Netherlands

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Summary

The Gezira Irrigation Scheme, in Sudan, reclines south of Khartoum between the Blue and White Nile Rivers. For more than 80 years since its establishment the Scheme has been a very important asset for the country's economy.

The scheme was designed for cotton plantations. It was designed to serve water to 50% of its gross command area in two consecutive growing seasons (summer and winter). With the scheme the cultivated area could be irrigated at the same time on the basis of a 14 day rotation. But later, in the 1960s, a crop diversification and intensification policy was implemented in the Scheme. This policy has affected the original design of the irrigation system. The need to operate the system beyond its capacity, together with an increment of the actual sedimentation rate which comes from the Blue Nile's catchment, has allowed increased silt loads to enter the canal system. Because of this increasing sediment loads at each level of the canal network, operation and maintenance (O&M) costs have risen since the 1970s to a point that is beyond the capacity of the government. However, it is not clear, if there are water supply shortages in the area, why and where there are water supply shortages, and it is not clear how farmers have been responding to this water supply and siltation changes.

In view of that, in the Blue Nile programme PhD projects were implemented to analyse the situations (operation and maintenance) in the Blue Nile in depth. One of the PhD project aims is 'Understanding persistence of soil erosion and siltation in the Abbay/Blue Nile Basin'. Under this project, as a case study on a minor canal, this study investigates how 'different actors' management responds to silt load and water distribution changes in the Gezira Irrigation Scheme, Sudan.'

In 2005, the Sudan Government endorsed the Irrigation Management Transfer (IMT) concept in close consultation with the World Bank. One of the aspirations of the 2005 Gezira Scheme Act is, to enable farmers to cover 100% of the O&M costs of their hydraulic unit (minor canal). The principle which would allow this to happen, was to leave farmers themselves to decide to grow more profitable crops. That in turn would empower them to request companies to undertake O&M activities for their minor canal on their own expenses (the virtuous cycle). However, this study demonstrates that the system has entered a vicious cycle of O&M. The reality is that farmers could not even cover the previously set rate of 15% of the water discharges. One of the reasons for this failure to collect money is that due to poor maintenance of the canal system, farmers are suffering from water distribution problems. In the end their unpredictable and chaotic access to water results in low profitability. Moreover, there are no profitable markets for their crops which even further compound the finance issue.

However, farmers are doing their best to cope with water distribution, sedimentation and management changes. If farmers would refrain from practising these coping mechanisms their crops will die. Hence, the farmers' strategies represent their efforts to secure their livelihoods. But, to reclaim the irrigation system in a sustainable manner, rehabilitation of the irrigation infrastructures should be considered one of the first steps.

Acronyms

Abu VI	Abu Sitta
Abu XX	Abu Ishreen
ADE	Assistant Division Engineer
BI	Block Inspector
CPC	Cotton Public Corporation
DE	Division Engineer
FOPs	Field outlet Pipes
GS	Gezira Scheme
HRS	Hydraulic Research Station
MOIHP	Ministry of irrigation and Hydro-Power
IMT	Irrigation Management Transfer
MOIWR	Ministry of Irrigation and water Resource
NSWs	Night Storage Weirs
O&M	Operation and Maintenance
SDE	Sub-Division Engineer
SCC	Sudan cotton company
SGB	Sudan Gezira Board
SG-2010	2010 Reconstituted Gezira Board
WUAs	Water Users Association

Meanings for some Arabic words and terms based on (AbdulGadir and Mary, 1989)

Abu XX	Tertiary canal feeding a number
Abu VI	Quaternary canals feeding a hawasha
Angaya	Area commanded by a jadwal
Feddan	0.42 hectare land (one acre)
Hawasha	Plot belonging to one tenant within a number
Jadwal	Field ditch or furrow taking off from Abu VI
Minor	Secondary canal
Nakoosi	FOPs or Abu VI which are built beyond the design water supply capacity of a canal
Nakoosies	Plural form of Nakoosi
Number	Block comprising usually 90 feddan (37.8 ha)–Tertiary unit
Rubat	Small irrigation basin
Samad	Senior farmer
Tegnant	Dike or Bund

Chapter 1 Introduction

1.1 The Gezira Scheme

The Gezira Irrigation Scheme reclines south of Khartoum between the Blue and White Nile Rivers (Figure 1. 1).The scheme is one of the largest irrigation schemes **(880,000 ha)** on the African continent. The reservoir, Sennar Dam, was completed in 1925. The irrigation system comprises two main canals running from the head-works at Sennar Dam to a common pool at the cross-regulator at km 57. The scheme was established by the British purposely for the cotton production. But in the 1960s with the diversification and intensification policy, other crops like groundnuts, wheat, and vegetables had been introduced in the scheme. Up to recently a pea like crop, locally called 'Kebkebe', has spread widely in the scheme. Generally the Scheme has played a significant role in the country's economic development.

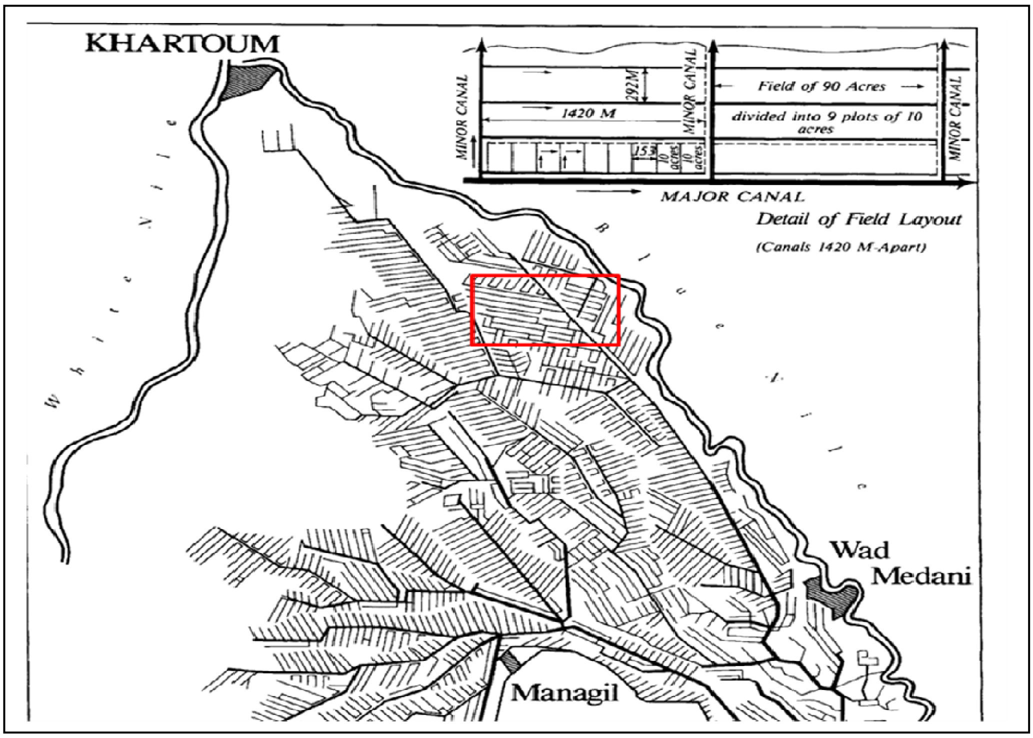


Figure 1.1: The Gezira Scheme (Source: 'Agriculture in Sudan' in Wallach, 1988)**.**
N.B. the Red box is the study site of the Kab El Gidad major

According to the World Bank (2000) report, the scheme has a long history of satisfactory performance, to the extent that it has been used as a model for designing and developing all other major irrigation systems in Sudan, especially up to the 1960s, when the scheme was operated at its designed capacity. However, in contrast to this historical appreciation before the 1960s, recently many studies showed that the scheme has deteriorated due to high siltation problems. The main sources of siltation are the Blue Nile waters, which carry large amounts of sediment from the Ethiopian highlands, as well as wind-blown material, canal banks eroded by rain, and animal crossings inside the Gezira itself (Eldaw, 2004). This resulted in siltation problems in the scheme, and there is a need for high levels of financial capital to overcome this problem. However, the government supplied budget for O&M is insufficient to cover the capital outlay required to cope with the sedimentation problem. For instance canal maintenance costs have increased fourfold to a total of around 15 million US$ annually over the last 20 years (HRS, 2008). Also a decline in the cultivated area of the Gezira scheme has been observed (Eldaw 2004 and World Bank 2000), and there is a lack of 'equity and reliability' of water supply to tenants (World Bank 2000).

1.2 Operation and Maintenance changes in the scheme (O&M)

Sediment load in the Gezira

According to the World Bank report because of siltation, in 1985 the volume of the Sennar reservoir had been reduced by 34 percent and that of Roseires by 25 percent (World-Bank, 2000). Recently these figures significantly increased to 60% and 34% of reservoirs storage capacity reduction for Sennar and Roseires respectively (Younis, 2009). The distribution of the sediment entering into the Gezira irrigation canals (at km 57) in the irrigation network is as follows: about 5 percent settles in the main canals; 23 percent in the majors and branches; 33 percent in the minor canals and the remaining 39 percent pass on to the field (HRS and Wallingford, 1990). Therefore, considerably more extensive and expensive annual silt and weed removal or other related activities (maintaining broken/damaged artefacts) are necessary at each level of the canal network especially from minor canals, to keep the system in a good working condition. In this way one can conclude that the maintenance demands are increasing and the operability of the system is changing.

Water distribution

After flowing 57 km to the north, water is discharged from the Sennar dam to two parallel main canals which are called Gezira and Managil main canals. At this junction (km57), the Managil canal divides into 4 branches, to divert water to the Managil extension, while the Gezira main canal flows an additional 137 km northwards. Then it conveys water to branches and then from branch to major canals as a continuous flow during the irrigation seasons (from July to April). The designed peak capacity of a major in the Gezira is 13.5-15 cubic meter per day per feddan (500 to 1,500 little per second per major canal). From the major water is delivered to minor canals, which had designed capacities of 0.5-1.5 cubic meter per second. The water distribution principle was, at the beginning of the cropping season, the water requirement of the different crops in the minor first had to be calculated and transmitted to the engineer who would determine the amount of water that would be discharged to each reach of the minor canals. Accordingly the required water from the higher levels to the minor had to be conveyed. From the minor canals water flows to Abu-Ishreens (Abu XX)-a small field ditch (tertiary channel)- and from Abu XX to the field through Abu Sittas (Abu VI) - the smallest field channel.

An Abu XX is designed to serve the ‘Number’ or tertiary unit (1,350m x 280m=37.8 hectare land) at fixed intervals of 292 m along the minor canal (Abu Xx’s take off perpendicular of the minor canal). Field Outlet Pipes (FOPs) take-off the water at right angles (12 meters long with a 0.35 m diameter). This unit was divided into nine 10-feddan plots (called Hawashas) watered by secondary watercourses called Abu VI taking-off from water courses. But later it became eighteen 5-feddan plots. In 1995 the Hawasha size was reduced to 4-feddan plots, which increased the Hawashas to 22 per Number. But at present the hawasha is reduced almost to a 2-feddan plot by which the number is divided into 44. The Abu XX has a theoretical capacity of 116 l/s (Ahmed, 2009). These infrastructural modifications all indicate that many changes have taken place in the scheme.

1.2.1 Management problems and Irrigation Management Transfer (IMT) in the Scheme

‘The irrigation network of the Gezira Scheme is extensive and the management of irrigation operations at any level of the network represents a constraint for the other levels’ (Eldaw, 2004, p. 16). The overall management of the Gezira scheme has been changing over time due to the problems encountered.

Before, 1950 the management was performed by the Sudan Plantation Syndicate. In 1950 the Sudan Gezira Board replaced the former managing body Sudan Plantation Syndicate. Then up to recently (2009) the management was between Sudan Gezira Board (SGB) and the Ministry of Irrigation and Water Resources (MOIWR). The MOIWR was responsible for the maintenance of the irrigation network with budgets fixed by the government and the SGB was responsible for water management in the minor canals up to the field level with joint account system budgets. But there was a problem related to collecting water charges from farmers. Furthermore there was a problem to settle the required Budget for MOI that helps it to undertake O&M.

World Bank (2000) concluded that the problem of limited O&M that appeared in the scheme was mainly related to management problems. Therefore a solution was recommended such as irrigation management transfer (IMT) throughout the scheme. Accordingly the Sudan government empowered farmers as the main actors of the IMT, through 2005 Gezira Act. The Gezira Scheme Act of 2005 transferred the responsibility for O&M at minor canal level into the hands of the farmers, whilst at the same time liberalising the crop pattern allowing tenants to grow the crop of their own preference.

Following the 2005 Act, water users association (WUAs) were established in the whole scheme around 2007. The aim is ‘‘achieving optimum utilization of available water through a participatory process that endows farmers with a major role in the management decisions over water in their hydraulic unit’’(Elfiel, no date). Here ‘Hydraulic unit’ refers minor canals level, since WUAs are established for each minor canal. In other words, the government wants to transfer all its responsibilities under the minor levels such as operation and maintenance- works to farmers. Hence, the WUAs are authorised as an intermediary between farmers and the government. Under the new arrangement, farmers would specify their O&M-needs through the WUAs, then WUAs would address these needs by hiring O&M services from companies or transmit the request to the higher responsible bodies (former SGB &MOI).

Despite the frustrating problems facing the Gezira irrigation scheme, the causes and consequences of the problems are not yet known precisely. In particular it is not known, how much and why the sediment concentrations occur, how this has affected the water distribution pattern in the Gezira scheme; how siltation and water distribution patterns observed in various types of canals is related to management responses of the different actors through changes in operation and maintenance of canals; and what are the consequences of increased siltation on changes in the irrigated command area at different parts of the scheme. This calls for a deep longitudinal understanding of the relation between actors’ influence on siltation through their management response (through operation and maintenance) of the scheme and the process and impact of silt deposition in the irrigation canals in a spatially and temporally differentiated manner. Therefore, the Blue Nile research Programme established a project to solve such problems.

The Blue Nile research programme comprises a collaboration between UNESCO-IHE Institute for Water Education (the Netherlands), University of Khartoum, Addis Ababa University, Free University (VU) of Amsterdam and IWMI-Ethiopia. The aim of the programme is to increase our understanding of how people in the Blue Nile River Basin are linked to each other through an in-depth analysis of farming practices, hydrology, sediment flows, land use, the gender dimension of land and water use, the economic and social value of land and water use and an analysis of how the increased knowledge on these topics can be institutionalized. There are different research projects included in this programme. One of the projects is a PhD-project with the objective ‘to investigate whether and how specific configurations of social actors and material artefacts can be related to and explain persistent soil erosion and siltation in the basin’ (PhD proposal of (Hermen, 2009). This PhD-project includes two case studies, on two minor canals of one major canal in the Gezira main canal, studying how land and water users deal with high sediment loads in the Gezira irrigation scheme in Sudan.

This research is one of the case studies on one of the minor canals (Tuweir minor canal). It focuses on farmers strategies to cope with siltation/water distribution changes. The second case study on another minor canal of the same major was studied by another MSc. student (Koen Mathot), who is in the same MSc study programme (MIL) at Wageningen University.

1.3 Problem statement

Without substantially changing the amount of water diverted from Sennar dam, the Gezira Scheme has been facing problems with high siltation levels and water distribution changes. The total irrigated area size and water used in the scheme has reduced below the average in the last six years (Ahmed, 2009). Moreover the irrigation infrastructure and agricultural production has deteriorated (Eldaw, 2004). However, there is no clear understanding, if there are water supply shortages in the area, why and where. And it is not clear, what strategies farmers have been practicing to cope with this change, how farmers interact with each other or with water users associations and canal operators; with what operation and maintenance rules they get water to their fields. This study seeks to create a more profound understanding of those issues. Moreover, the study investigates how farmers respond and how their interaction recursively affects water distribution and siltation patterns.

1.4 Research objectives

For more than 80 years since its establishment, the Gezira irrigation scheme has been very important asset for the country's economy. However, the scheme has faced a pernicious problem of siltation which affects its performance. Consequently Operation and Maintenance (O&M) practices are becoming difficult and costly. Water distribution between upstream and downstream irrigators is also a problem. Faced with such problems farmers are manipulating the scheme on their own trying to save their crops. In view of that, under the PhD project 'Understanding persistence of soil erosion and siltation in the Abbay/Blue Nile Basin', I am interested to investigate how 'farmers respond to silt load and water distribution changes in the Tuweir Minor canal, in the Gezira Scheme , Sudan.' with the following objectives.

Scientific objectives:

1. To analyse what silt load, water distribution and management changes have taken place in the scheme.
2. To understand what various actors' management responses through O&M-works have been used to siltation and water distribution changes in the scheme. And what the impact of their response has been to the system.
3. To identify impacts of water distribution and siltation on agricultural performance (in terms of irrigable area size, yield or crop preference).

Social objective:

The development objective is to assess the possibilities, limitations and implications of actors' responses to siltation and water distribution changes in terms of O&M -practices.

Personal objective:
My personal objective to do this research in the Gezira Irrigation Scheme, in addition to the impressive nature of the problem settings in the scheme, are-

- To assess its links to political/institutional, and financial affairs. In spite of much attention having been given to resolve the problem both by national and international organizations, like the World Bank, little success is observed in the Scheme. This is startling – My question is: *what is behind it*?

- For me, doing a research in a challenging environment but in a well-developed, huge, well-known and aged irrigation Scheme, where famous experienced people are involved, makes me feel privileged. I wish to gain much experience, and knowledge, in facing and understanding a natural resources problem on the ground. Moreover, to be part of a solution, engaging with crucial pieces of information on this huge asset (scheme) is interesting and also very important for my future career.

1.5 The Thesis outline

Chapter 2 provides the scientific perspective related to this research, the theories used and the key concepts employed during the study. It also presents the research questions and methodology of this research.

Chapter 3 introduces the operation of the scheme in the past and present. Based on different reports from the scheme and different sources of information, I outline the present operation situation in the study site- Tuweir minor canal. Also treated in this chapter are the reasons for a difference between the past and present operational management. Recent changes like the introduction of the WUAs on the irrigation system are included in this chapter.

Chapter 4 explains the performance of water distribution in the area. It elaborates information on the theoretical and actual water distribution activities undertaken in the Scheme. It also highlights the water distribution situation differences within the Tuweir minor canal.

Chapter 5, this chapter is about maintenance activities in the scheme. It includes an analysis of the sediment load entering the Scheme, and its cause and effects on the Scheme. I aim to show the maintenance situation of the Tuweir minor canal, especially for the 2010 season.

Chapter 6 is about water availability and crop performance in the area. Here, I present the crop rotation and crop choice strategies in the past and present as well as factors which can influence the crop performance in the area.

In Chapter 7 I analyse the farmers' strategies. It addresses the different coping mechanisms farmers apply to deal with changes in water distribution, sedimentation and management which take place in the area. It also gives an overview of the linkages and effects of the mechanisms on each other and on the irrigation system.

Finally, Chapter 8 presents a conclusion, recommendation and discussion of this research. It provides a conclusion, on the operation and maintenance of the system, the farmers' response to O&M changes, and the effect of siltation on water distribution changes in the area.

Chapter 2 Theoretical Framework and Methodology

This section presents the scientific approach, the theories, concepts, the methodology as well as the limitations of this research.

2.1 Scientific Approach of this Research

This research is based on the social constructivist perspective. Here, the different actors, who have been involved at different levels of the scheme management and use cannot be detached from the consequence, how and why O&M- practices are related to high siltation problem. In other words the actors are both part of the affected and causative agents of the problems. So, the nature of knowledge of the problem is affected or created by these actors. For instance, in Tuweir minor canal, impacts of farmers' strategies on the irrigation system come about when farmers start to cope with water shortage or siltation problems. Hence both the cause and effects of social actors' actions recursively shape each other.

In this research the cause- effect relationship of siltation, water distribution changes and O&M-practice according to different management response (farmers' strategies), or physical levels are within the Gezira irrigation Scheme boundary context. Hence, it is not a universality valid context. However, the mechanisms observed in this study might to some extent also be at work outside the scheme boundary.

The interdisciplinary nature of this research is, comes normally, since '*object and purpose (should) define what approach is suitable* to address a particular problem' (Mollinga, 2008 , p.5). Accordingly understanding and analysing the different actors' influence regarding siltation or water distribution needs to employ both a social and technical methodology simultaneously. Hence there is a need to define so-called hybrid concepts i.e. both social and technical concepts are interlinked. Knowledge has been gained from the different actors' perspectives. How they perceive siltation problem through O&M-works, water distribution and the organizational activities in the Scheme reflects the social dimension of this research. On the other hand the technical observations-at which level or parts of the canal the siltation is more concentrated, how, where, when the O&M-practices are going on, observation of the nature of the cultivated area etc. and measured water level in the canal as well as taken sediment samples are technical views. So these two dimensions (social and technical) can be analysed simultaneously using a hybrid concept.

However, this young approach is challenging to 'conceptualize' and to integrate methodologically due to the ontological and methodological difference of the two sciences (Mollinga, 2008). Moreover, uncertainties like being a foreigner with different culture and language influenced the Gezira Irrigation Scheme's people (farmers, engineers). They seemed reluctant to give us some sensitive data, particularly related to the management changes that took place in the scheme in 2010. However, different attempts were made to fill in the gap. For example, acting as 'insider' or having a good relationship with the society, i.e. respect the social world (culture, religion), of the target groups was part of my approach to tackle interdisciplinary.

2.2 Theories of this research

Socio-technical approach

The socio-technical approach, in which irrigation systems are seen as socio-technical systems (Mollinga, 2003)**,** helps to understand contests over water in Gezira, especially in understanding the relation between siltation/water distribution changes with the various actors in the scheme through their strategies of managing siltation or water distribution or struggling to satisfy their livelihood (improving agricultural performance).

To understand how the land and water users in Gezira manipulate the water and silt distribution, particularly through studying O&M practices, it is important to look at which crops they decide to grow and what are the possibilities and limitations of the water management, infrastructure and maintenance situations to get water to these crops. The limited capacity of the system is important to understand the level of competition over water in the system. All people especially want to get water in September and October in the Gezira. Many water users and experts report that shortages arise because the people do not use the rules for operation as originally designed, because they cannot sit back and wait for their crops to die. Hence, it is important to investigate this situation from a socio-technical angle.

The socio-technical approach also stresses that water is a politically contested resource and that through this water allocation, distribution power relations are constituted, negotiated, mediated, reproduced, transformed or otherwise shaped by the actors (cf, Boelens and Zwarteveen, 2005; Bolding et al., 2000; Bolding, 2004; (Mollinga, 2008)). For instance who are capable to manage operational activities at which level depends on a particular power relation (e.g. level of education or wealth status). This power relation can be negotiated, mediated, reproduced or transformed. For instance in terms of O&M challenges in the Gezira, rich farmers are capable to buy a pump that helps them to irrigate directly from the main system (major canal). On the other hand, pumping directly from the major or minor is not allowed, but some people can get away with it through political relations. Therefore, this power relation is established through financial capital or relation with membership of the managerial board (political or security bodies).

Moreover, from the actor network theory (Law, 1994), the ‘follow the actor’ principle was borrowed. Using this principle, I constructed a water network (Bolding, 2004) in which I described how people manipulate water (in terms of O&M) on its way from off take to field.

2.3 Conceptual framework (Key concepts)

The key to understanding the struggles over water in the case study is to understand the links between the O&M (sediment load and water distribution changes) and, crops grown by different actors with their strategies in the Gezira system within a certain time dimension.

Operation Activities

Uphoff defined that operation is an activity on the *structures* ‘to acquire, distribute and remove (drained) water according to some determined plan of allocation’ (Uphoff, 1986), p 38). But, in this research the concept is a bit wider than Uphoff’s definition of operation; the concept applies to all irrigation infrastructures instead of only on the distribution structures. The infrastructure may include many things but in this report there is only a focus on canal, controlling/regulating structures (Night Storage Weirs (NSWs), weirs at the off-take, Field Outlet Pipe and farmers’ field) in terms of water distribution patterns/strategies that are applicable inside the scheme from the actual field up to the minor canals.

Water distribution

Water distribution is ‘the process of actual water proportioning in practice–‘the concrete distribution of wet water’-it is about water scheduling that is a certain amount of water per a certain area for a certain time duration (Boelens, 2008) and (Uphoff, 1986). The relation between ‘hydraulic laws’, the ‘control infrastructures’ in use and the socio technical linkages between techniques (design, operation, maintenance), ‘users’ and ‘providers’ often lead to typical patterns of distribution (Treffner et al., 2010). Users and Providers refer both technical and social actors (operators, irrigation engineers and management bodies at different levels of the network). The typical patterns of distribution are proportional flow, rotational system, request or supply system, and head-end or tail-end control, along the command of irrigation canal. Likewise, water distribution in the scheme has been influenced by different phenomena. In the early 1960s the Gezira scheme was expanded and crop diversification has taken place. Consequently water distribution patterns were changed following the increased amount of available water supply.

Further to the amounts of water available in an irrigation system, effective irrigation management promotes, equitable, reliable, timely water supply to users. So, it promotes user satisfaction and trust in the system through saving them from spending additional costs to irrigate, i.e. pumping costs or time spent in case of inappropriate water distribution changes. It also encourages them through high crop productivity. But the reverse leads to a steady deterioration of the whole system. Likewise, the real situations in the Gezira scheme such as unequal, un-reliable and non-scheduled water distribution among users (World-Bank, 2000) are due to ineffective irrigation management practices in the system. The World Bank report shows that ‘the Scheme has over time turned into one of the least efficient with irrigation intensity typically less than 50 percent’(World Bank, 2000, p. i)).

Sediment load and Maintenance activities

Sediment load or siltation is muddy water that ultimately reduces: the reservoirs’ water storing capacity; the canals water carrying capacity and water distribution situation to plants in the field (because sedimentation in the field results in difficulties for continued gravity irrigation). Silt load is the frequently mentioned problem in the Gezira scheme. This study considered how this most important problem has been changing over time and how it can be influenced by various actors’ response directly or indirectly. Another important dimension is the time-bound nature of sedimentation. There are annual and seasonal variations of sediment load in the area. At the start of the rainy season in the Ethiopian highlands, the Blue Nile river flow reaches its maximum peak from the end of June to end of August. At this peak, the sediment contents of irrigation water in the scheme are high, containing on average 70% of the annual sediment load entering the scheme (Younis, 2009). At the end of the dry season (end of April), when the flow drops to a minimum (about 2 % of the peak) the silt content is at its lowest rate. Therefore, in this research the main focus was on the highest sediment accumulation periods that has been recorded from July to August to analyse changes over a time range (from 1988-2009).

On the other hand, maintenance is a way of keeping the irrigation infrastructures functional. It includes the assessing of infrastructures performance in a particular time whether the problem is observed or not. It also comprises de-silting of deposited sediments or removing of grown weeds; and amending of broken artefacts in a particular period of time at/in which the problem is observed, in order to have ‘efficient acquisition, distribution and removal of water’ (Uphoff, 1986, p.38).

Operation and Maintenance Rules and hydraulic property relation concept

In this research O&M rules are defined as formal or informal rules that have used to operate the system (water distribution schedules to different levels, irrigation turns between farmers and relation between management structures to perform operation tasks), as well as the rules that have used to perform maintenance activities at different levels in the scheme.

Hydraulic property is conceptualised as: as coward stated irrigation property right specifically for Asian case that collective social action in irrigation system is based on property relation (Coward, 1983 as cited by Coward, 1986). Hence, '....irrigation groups formulated principles of action and acted out irrigation tasks in ways that reflected prior and continuing investment in their hydraulic property' (Coward, 1986, p. 495). Therefore, hydraulic property is a typical hybrid concept to link the social (property relation/ownership) to the technical (maintenance of a technical object-artefact). In particular in Tuweir minor (can be also in the Gezira system) hydraulic property relation concept is very useful to explain why farmers often refrain from undertaking maintenance work, unless it concerns nakoosi infrastructure they have constructed themselves. For instance, in Tuweir minor one nakoosi user has replaced his nakoosi FOPs at his own expense, and the maintenance of this Abu XX is also under his responsibility, but there is no FOPs which replaced by normal users in the Tuweir minor.

Crop performance

Irrigation water supply performance is a concept which is related to increasing water adequacy (is there sufficient water for every farmer to grow his or her crops?); water equity (which relates to head vs. tail water distribution-a lower irrigation performance at the tail end of the system) and reliability (predictability of water and timeliness, i.e. is the irrigation schedule meeting farmers' actual needs?) (Ahmed, 2009). Since the crop performance is influenced by the irrigation performance, the crop performance concept can be adopted from the irrigation performance concept.

Moreover, crop performance concept also considers users crop choice preference or criteria, irrigated area changes in a certain area since a certain period of time. It also assesses yield differences of different crops that grow in the area whether related or not with siltation or water distribution changes in the scheme. For instance, the total irrigable area size in the scheme has reduced in size (Ahmed, 2009 and Eldaw 2004). So, whether this change links to silt load or water distribution changes and the type crop the farmers want to grow preferably had been assessed.

Farmers' Strategies

Farmers' strategies are coping mechanisms developed by individual or groups of farmers to cope with short or long term problems of water shortage, siltation or other management aspect such as maintenance or irrigation related problems. These coping strategies produce negative or positive impacts on one or groups of farmers at different locations in the system. As defined by (Abdalla et al., 1989) these strategies are undesired practices mainly during water shortage periods that are developed by the farmers with a view to save his/her crops. The practices are undesired practices may from an engineers' perspective, since such practices are perceived to interfere with the planned water distribution. However, these strategies can be seen as reflecting a level of flexibility and ingenuity on the part of tenants to keep the system working despite it suffering from such heavy sedimentation, and break-down in effective management.

Irrigation management transfer and management leaders (responsibilities)

In an irrigation system there are various types of structures such as weir, channels and gates which comprise together physical structures of the irrigation system. Similarly 'bureaucratic agencies, and water users associations represents important organizational structures that establish patterns of authority, communication and other interaction among the people involved in irrigation' which constitute 'management structures' of the irrigation system (Uphoff, 1991, p.31).

Various management leaders in the Gezira scheme are believed to be part of who are influenced by sedimentation/water distribution changes in the scheme at the same time they have influenced sedimentation and water distribution changes through their management responses in the study site. Hence, even though there might be many different actors that have a direct or indirect linkage to the Gezira scheme (say consumers), the focus of this research has been only on the following key management actors. such as ministry of irrigation (MOI), Sudan Gezira Board (SGB before 2010) and the Sudan Gezira 2010 (the Sudan Gezira board management body in 2010), different O&M companies (Hadaf, Taiba), water user associations (WUAs) and different groups of farmers (owners, sharecropper, renters or labours). These management leaders have involved at different levels of the irrigation system.

As Uphoff stated that classifying the irrigation system by their number of levels of operation and organization is a good way to use structure (Uphoff, 1991), hence we can see the Gezira scheme into three different levels, and which management leader involved at which level is as follows.

1. *Main level*

In the Gezira scheme context, the main levels are treated from a minor off-take to Sennar Dam. In this level various management agencies have involved to carryout operation and maintenance activities, such as MOI, SGB and different O&M companies. For instance, up to 2009, the scheme management MOI and SGB was responsible for undertaking the maintenance of primary, secondary and tertiary canals. But during 2010 change the overall management in this level was transferred to Sudan Gezira 2010, as well as the maintenance activities were transferred to different companies (Hadaf, Taiba).

2. *Minor Level*

In this concept minor level includes down to minor off-take structures (i.e. minor canals and FOPs, Abu XX). In the pre IMT era of 2005, this level was under the responsibility of SGB and MOI. MOI was responsible for maintenance of minor canal and FOPs while SGB was responsible in operation of FOPs and Abu XX maintenance. By 2005 Gezira Act, the management responsibility at minor level has been transferred to WUAs. So, WUAs became responsible in O&M activities of minor canal, FOPs and Abu XX though the practical situation is different (it will be presented in chapter 3). IMT refers to the irrigation management transfer which took place in the scheme in 2005.

3. Hawasha level.

This level indicates farmers farming plots and the Abu VI channels which directly deliver water to the plots. Therefore, the users themselves had to perform O&M at their hawasha level (Abu VI-smallest field channels and furrows inside the farm). While because of the management failure to some extent before 2005 Gezira Act, as well as significant failures after the IMT transfer (2005Gezira Act), operation of FOPs, maintenance of Abu XX are undertaken by users (Tenants, sharecroppers and renters). Even in some areas it was observed that farmers also involved in operating of their minor off-take.

Though some mixing up of management responsibility can be observed at the minor and Hawasha levels, more or less the three levels are important management structures of the Gezira scheme. There is a communication among and between these management structures.

Generally, the following figure frames the above concepts together.

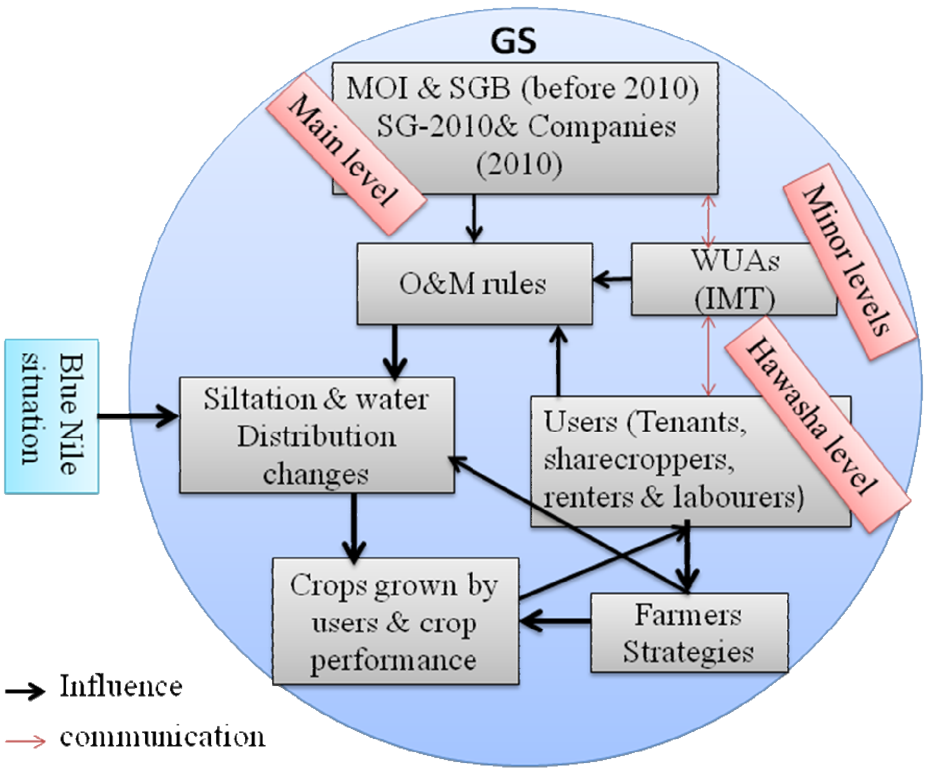


Figure 2.1: The conceptual framework

The figure stands for: siltation and water distribution changes in the Scheme are influenced by O&M rules (which are followed by different management structures at different levels), and by the upper catchment area (Blue Nile River). Siltation and water distribution changes can affect crops grown by different actors and their performance. Then, because of the crop's performance change, farmers practice different strategies to cope with the negative effects of siltation and water distribution changes. However, their strategies might also influence siltation and water distribution changes in the scheme. .

In the figure Black arrows indicate influence while Red arrows represent communication between different management structures

2.4 Research Questions

Main Research Questions

What Operation and Maintenance (O&M) strategies do different land and water users along Tuweir minor of the Gezira scheme apply to irrigate their crops and how are these strategies related to, and shaped by, the increased sedimentation rates and management changes in the Gezira scheme?

Sub-research Questions

1. How is the irrigation system in the Tuweir minor operated in theory and practice and how has this changed over time under consecutive management regimes?

2. How was the maintenance of the Tuweir minor canal performed in the past and present?

3. How is the water distribution performed between and within the 22 numbers along the minor in theory and in practice?

4. What is the cropping pattern and performance in Tuweir minor?

5. What are different land users' coping strategies to get water to and from their fields and in what way can these be differentiated according to location, individual or collective nature, and socio-economic status?

6. How does the application of the above mentioned coping strategies interact with increased siltation and water distribution changes and how do these in turn affect the supply of water to farmers in the same number as well as along the same minor?

7. How does the resulting water distribution pattern and sedimentation affect crop choice and crop yields of different water users of the minor?

2.5 Research Methodology

This section discusses how and which kinds of data are collected; which kind of methodological tools are used for the data collection and; how the collected data is managed, analyzed and reported.

Research Design

This study is a case study type in the Gezira main canal which concentrates on one minor called Tuweir minor in the Kab El Gidad major canal with the aim to contribute to an overall view of the Gezira scheme. The Gezira scheme is huge; so, variations between the different levels even within a single level are obvious. Therefore, to select the major canal, a couple of field visits at different parts of the scheme (middle to tail end) were made.

Finally, the major canal at the tail of the GS, near Khartoum, 194 kilometre (K194) from Sennar dam to the North, which is called 'Kab El Gidad' was chosen. What is interesting in this major as a tail end major is to assess in detail whether the issues of up-downstream distribution of siltation and water have resulted in a different outcome or not. Then, two minor canals at the head and tail end of this major canal were selected. Thus, since two case studies were carried out by two MSc. students, I studied one of the minor canals which is called Tuweir in the upstream part of the major, while the other MSc student studied another minor which is called Biyut Khalifa at the downstream end of the same major. Finally the differences or similarities of up/downstream cases of the major will be incorporated together by a PhD student (Hermen Smit) who is from UNESCO-IHE.

In the Tuweir minor canal, two 'numbers' (90 feddan -about 37.8 hectare land size each) were chosen: one at the head (first reach) of the minor and another at the tail end (last reach). 'Reach' refers to length of the canal between two regulating structures and night storage weirs. That is first reach is from the off take of main, major or minor up to the next respective controlling/regulating structure of each. Similarly from the last structure to the tail end is called last reach. Why the first or last reach is chosen is because first, to assess the head-tail end issues of water distribution in the area; second the Hydraulic research station (HRS) sediment monitoring programme assessed that in the first reach of any canal most of sediment depositions take place (more than 80%) (Younis, 2009). Hence, according to this report, sediment deposition that comes from the same major canal may not be significant at the last reach of a minor. On the other hand water shortage problem at the last reaches (tail end) is a day to day farmers' complaint in most cases of canal irrigation systems. Moreover to overcome the siltation or water distribution changes farmers might have their own coping mechanisms, but it can be different with the geographical differentiations along the minor (up-downstream case). Therefore, to understand all these cases, encountering the real situations of head and tail end issues in the area is required.

We stayed in the Gezira scheme, Sudan for three months. In the first month we stayed in Wad Medani where HRS, the project designing, the Gezira University and nearby SGB head office found. So the place was ideal to collect secondary and primary data from different officials. Therefore, in the first month, mainly adjusting the proposal with the actual situation of the area; communicate with different officials mainly in the mentioned offices; visiting different place in the scheme including Sennar Dam and interviewing farmers and officials to make some key decisions on how to structure our case studies were done. During this month Hermen Smit was supervising us and he stayed with us in the village for a week, for me it was a great opportunity and I gained much field experience. We spent one and half month in the village in collecting the primary data through interviews of farmers, WUAs, canal excavator and measurement personnel's; measurements (sediment sampling, FOPs' discharge estimation) and observations on the particular minor canals situation were also made. In addition, during this time visiting the sub Division Engineer office, in Turabi to collect secondary and primary data were performed. In the last two weeks we turned to Wad Medani back, then in the first ten days, we collected some remaining secondary data and we had interviews with some official. We also presented our main findings and to different officials (HRS, Gezira University, SGB 2010, agriculture offices and project design officials) at HRS. Finally, for the last five days we visited some place in Sudan.

Research Approach

How this research was performed and how the research questions are answered, is explained for each sub question below.

1. **How is the irrigation system in the Tuweir minor operated in theory and practice and how has this changed over time under consecutive management regimes?**

The following steps were made to answer this question

Step one: I reviewed various literature sources to reconstruct how the system had been designed to operate in the past. And it was verified through interviews with farmers, canal operators and the former 'Ghaffir' how the system had been operated in the past in their experience.

Step two: I made observations on both the physical state and actual operation of the off-take of the Tuweir minor canal, the FOPs and Abu VI channels.

Step three: then I compared the difference and the reason why a difference is occurred.

2. **How was the maintenance of the Tuweir minor canal performed in the past and present?**

Step one: I analysed sedimentation/water distribution changes from 1988 to 2009 at each level of the irrigation canal network. To do so I undertook three separate activities: First, I collected sedimentation data at HRS (hydraulic research station). Second I assessed sedimentation/weeds in the minor and Abu XX of the two numbers in the field. This involved a rough assessment of levels of siltation/ weeds accumulation in the minor canals / Abu XX and why. Third, at the major off-take, minor off-take and at the downstream night storage weir I took sediment samples for about 30 days in September. These were analysed at Hydraulic Research Station laboratory (HRS).This helped to verify and corroborate the scheme sedimentation changes which were collected from secondary sources ranging from 1988 to 2009;

Step two: I interviewed users about their experiences of the sediment problem and how they related to it and why. I interviewed many farmers within the minor to know how sedimentation changed over time. And I also interviewed the technical staff from HRS, Turabi officers, a canal excavator and officially appointed measurement men.

3. **How is the water distribution between and within the 22 numbers along the minor in theory and in practice?**

I tried to find out whether the water distribution that is stated theoretically at the beginning of the system is assured in practice or not within different numbers of tenant plots, i.e. to what extent has this plan been practiced in the field (in actual condition); do crops perform well? (entailing qualitative descriptions); So, I assessed the cropping map in the area, as well as the crop performance indicators like water availability; the farmers cost recovery capacity; commercial crops coverage in the area; and the performance of the infrastructure in the area are discussed; who is working on that specific plot- the farmer, sharecropper or labourers? Is the system operated as designed? Or is the system manipulated, and if so how?

To provide for a quantitative description, during the field work period, I have regularly observed the field outlet pipes (FOPs) in each number. I also assessed the water flow into the smallest water courses (Abu VI) in the two numbers (head-tail end of the minor). I took simple measurements at the FOP level to see if the water is distributed as fairly as intended in theory. Say theoretically a 14 days irrigation interval is required to satisfy crop water requirements. But if one FOP gets water more than once within 14 days, it indicates something is different in practice. By means of field observations on FOP operations I tried to find out the reason behind unscheduled irrigation. Generally the procedures which I followed to compose an actual crop map in the area, assess the performance of those crops, assess who grew those crops and what each farmer tried to get water to their fields were as follows:

A. In Theory:

Description of the designed water distribution system: Here I investigated the design capacities and operation rules/management of the minor canal, Abu XX and Abu VI. And I reviewed literature to find out the designed capacity of the canals (the minor, Abu XX and Abu VI); and for how long they can/should be operated per day/week or 14 days interval (plan of water distribution schedule between minors/Abu XX and Abu VIs) to address water demands of the fields according to the designed capacity. Moreover, farmers' verification about the management of the irrigation system, water supply, the irrigation structure and the crop performance in the past through interviews was made.

B. Distribution in practice

I observed the actual water distribution in the minor, during the critical irrigation month (September) through the following steps:

Step one: Water measurements in the minor and two blocks (numbers): Based on my experience of the system at that moment I monitored and measured about eight times the flow of water **delivered to each Abu XX** during the critical month of September around the minor. I also made observations on each Abu VI of the selected two numbers in upstream and downstream cases. I also measured the water level in the minor off-take two times per day for about a month.

Step two: Verification of actual applied water through observation and interviews: during the research stay I have observed, the off-take of the minor, each FOP in the minor and each Abu-VI in the two numbers on various days. The observation was verified through interviews with operators, WUA members and farmers.

Step three: Mapping irrigation intervals: Based on the knowledge obtained from these observations, users' views and measurements I composed the water distribution pattern in the minor system and in the block for different times during this critical period, establishing the actual irrigation turns on a map like is shown in the Annex.

Step four: Assessing the condition of the physical state of the canal and structures: I described the actual physical state of the structures in the minor on the basis of observation and interviews with users. Hence, to check the functionality of the structures, FOPs, night storage weirs (NSWs) in the minor and off-take weirs of the minor, the canal cross-sections and the Abu XX and Abu VI channels situations, the canal banks and the road were assessed in a qualitative manner. These structures play a vital role in guiding the water flow into the target field, otherwise the water might flow somewhere else without reaching the field.

C. Comparison of water distribution in theory and in practice:

Here the actual water distribution in the minor during September was compared with the actual crop requirements and actual water distribution for the grown crops in terms of interval and duration.

I described the differences in watering of the fields in practice-which are during the field work with water distribution in theory in the minor and in the numbers. The comparison is mainly described through farmers' interviews about their crops watering delay.

4. What is the cropping pattern and performance in Tuweir minor?

Step one: **Crop map**: I observed each tenant's plots (all the numbers) in the minor and identified which crops are growing, and I made a crop map showing which crops are grown in each number within the minor in the summer season (from June to October 2010). The following Table shows which information was collected.

Table 2.1: Growing Crops Field data collection Format within the minor

Number	Crop type	Sowing date	Farm size	Remark
1				
2				
>>				
17				

Step two: Qualitative crop performance assessment: I observed the crop performance in the field to check whether the supplied water was likely to be sufficient or not. Because in the field one can see significant difference of growing crops, one looks wilted, others look deep green. Next I have tried to identify where the difference came from by assessing the amount of water each hawasha had received.

5. What are different land users' coping strategies to get water to and from their fields and in what way can these be differentiated according to location, individual or collective nature, and socio-economic status?

This is to find out who manipulates water levels at Abu VI, Abu XX, FOP, and at controlling /regulating structures and what different types of water users do to make sure water reaches their field. To do this during the field work in the critical period of September, I have tried to find out what, how and why people cooperate or not to get water at their field through observations and interviews- *'following the actor'*. Using the principle 'follow the actor', I reconstructed a water network Bolding, (2004) in which I described how people manipulate water, natural elements (like mud) and other actors on the way from off take to field. I identified operators and water users along the route and I established what do they think, why have they done that, are they important persons, who have influenced the flow on the water ways, at the off take. In addition detailed interviews with farmers in the two selected numbers were held. The following steps clarify this in detail:

Step one: observation of the actors:
During the critical water shortage period of September, I have observed critically whether the existing infrastructure, are as designed or replaced or added with new features by users and why. I had watched what the actors have been doing and asked them what their motives were at each level of the minor, at different times of the day.
Step two: **literature review on past practices and responsibilities:** literature has been reviewed to retrieve the past farmers practice and their responsibility/power related to water management. Operators and users was asked what structures/water courses were constructed in the minor to control, regulate and distribute water to the field and how these structures should be operated, for how long, etc.

Step three: **Interviews with key actors:** users, operators and WUA members were interviewed on their strategies to get water to their Hawasha, and if they have any operational guidelines to do so? And what are the rules of cooperation. This was done as follows:
- First I selected 10 farmers in two numbers (upstream and downstream part of Tuweir minor), and I asked them what do they do to get irrigation water; how they get water to their farm and how they depend, cooperate and deal with operators and other users. Also I asked what written or traditional rules exist regarding water distribution within their plots/ Abu XX or minor canal. I asked them which challenges they faced due to the other users' actions or due to cooperative rules if any, to get water near their farm, Abu XX or minor.
- I asked minor canal level operators about their experience of users' strategies to get water to their farms, and how the operators have cooperated or dealt with users, as well as what rules apply regarding these strategies. I held the same type of interview with three members of the WUA.

Step four: Triangulation of different sources: I listed and described what strategies were applied and why users practice these strategies based on observations, interviews and literature review.

6. How does the application of the above mentioned coping strategies interact with increased siltation and water distribution changes and how do these in turn affect the supply of water to farmers in the same number as well as along the same minor?

This question seeks to understand to analyse how the different users' strategies to get water at their plot or at minor canal level interacts with siltation and water distribution changes of the scheme as well as how one user strategy affects another user's water supply at which level within numbers or minors. For example, during a field visit I found out that, every user is responsible to remove silt/weeds or to maintain the Abu XX length corresponding to the width of his or her plots in each number in which their plots found. Therefore, say if one user at the head of the Abu XX has not removed silts/weeds or maintained his/her share of the Abu XX, the other users' plot downstream of this user will be affected by difficulties in getting water. Or, on the other hand to cope with the effect of the head end farmer, those downstream users might try to use water from other Abu XX or minors illegally. They will also try to break/divert or pump water to their field directly from the major canals or main systems. Hence, when users have created their own means to irrigate instead of resolving the existing problems the problem of unpredictable water supply becomes more severe in time. The problems have the same effect at the main system or the Scheme level. The following steps were used, to identify and understand the users' strategies, and the influence of the strategies on the system mainly at the minor levels.

Step one: as mentioned above, I collected data about water and siltation changes and farmers different strategies.

Step two: analyse the influences of users' strategies on the supply of water with in numbers/minor or major, this was done through:

- I Interviewed farmers how they have been affected by their neighbour user strategies, and verified through observation during the field work.
- Different pictures were taken of the water supply situation and the effects of the changes effected by various water users was described and analysed on the basis of the two selected numbers in the Tuweir minor. Moreover, I described users' influence on each other, and how one user depends on other users in the two blocks and in the minor.

7. How does the resulting water distribution pattern and sedimentation affect crop choice and crop yields of different water users in the minor?

During the water shortage period (September-October), I observed the fields particularly in the two numbers to identify who faces water shortages and why? I held interviews with the affected farmers about the effects of the shortage or problem on yields and irrigated area, and how it influences and how they deal with it-in terms of crop choice. That is if their crop choices in the past and present have changed and why? Moreover the different crop water requirements were assessed in a rough manner (looking at irrigation intervals). Therefore, on the basis of this information from the two blocks and the crop map constructed earlier, I could describe how water shortages in September affected different areas in the minor.

Research Techniques

The required study data are of a quantitative and qualitative nature. These data were collected from secondary data sources, literature review; interviews, and observations.

-*Literature Reviews*

Different types of literature were reviewed. These have been used to understand the overall situation of the Gezira irrigation scheme as background information. Literature, such as office reports and research papers about Gezira Scheme in particular with regard to siltation, water distribution; and O&M was reviewed to relate the past and present situation of the scheme. Moreover, other important literature to develop concepts and theories for this research kept recurring as important methodological tools throughout this research.

-*Measurements and sediment sampling*

As mentioned in the research approach section above, water level measurements were taken at the head and middle reaches of the Tuweir minor canal. Simple discharge measurements were also taken at the FOPs of the Tuweir minor. Point sediment samples were taken to assess the siltation concentration changes in September at three locations (off take of Kab El Gidad major, off-take of Tuweir minor and at the downstream of Tuweir minor). These samples were analysed in HRS laboratory to know the suspended sediment in parts per million (ppm).

Quantitative data- Secondary data sources: The quantitative data such as silt load measurements at main canals, the amount of removed sediment and costs, and water distribution measurement records (discharges), the different strategies that have been employed to overcome siltation over a time range was collected from secondary sources- in particular from HRS (sediment monitoring

programme), SGB and MOI, and from Engineers at the major division boxes (i.e. in Turabi office which is where division box of Kab El Gidada major located).
-*Observations*

The making of observations in real-time was an important tool in this research. How observations were made has already been described in the previous section on research approach under each sub question. But as a research method it could also be described here. It is one method of collecting qualitative data. It helped me to gather data that could not be obtained from the interviewees. And it was used for triangulation of data from the farmers and as a first step to get ideas for interviewing. I had divided the observation into two parts, observing actors (tenants, WUAs and operators including silt remover machine and the hydraulic level itself- the selected minor canal and its downstream smaller water courses (Abu XX and Abu VI). That means observing both how the actors perform their day to day activities, and why? (The first) and what the structures look like physically to deliver the required water amount at the required place, why? (Second). But the observations can also be done at the same time.

Observation of Actors
Tenants- at two numbers farm fields; one at the first reach of the minor (head) the other at the last reach (tail) was selected. In four feddans tenancy system number represents 22-23 tenants. But the tenancy size for each tenant varies, could be less than or greater than four, hence; number of tenants from number to number might be different. However 5 tenants in each number of the two blocks are chosen. To know the difference within a number, two tenants at the head of the number, one at the middle and two at the tail were selected for each number.

Then, what are tenants doing at their farm for both head and tail end cases regarding sediment or water distribution impacts, i.e. What are their day to day activities (regarding operation or maintenance, or their relation with the nearby farmer or WUAs) to get enough water to their farm crops, their crop performances (keep in mind other factors rather than water/sediment) were assessed attentively to know the effect between plots.

WUAs-I Interviewed three members how they deal with or do O&M activities- with tenants or at field was observed and interviewed.

*Higher level operators and Engineer-i*n the GS, there are operators at each reach of the major canal and engineer at the head of the major. So the operator at the off take of the specific minor and engineer/operator at the off take of the major were assessed, to see how they are carrying out their activities at their level, if it relates to the above issues (water distribution and sedimentation).

-*Observations of the system itself*

Observation was carried out following the route of the specified irrigation networks from fields (on the selected blocks) up to the minor canal (following the flowing water actor). The structures in the minor including the off taking structure from the major, the field out pipes and the night storage weirs performance was assessed. The sediment situation, the water flow condition also was watched at the morning, and in the afternoon.

-*open and semi structured Interviews*

Semi-structured interviews-techniques were designed to collect the designed data. The actors, mentioned above were interviewed. Basically the following actors have been interviewed, but unforeseen problems like: time, transport access and limited information to the study area and actors' willingness to response, might be a constraint. But attempts will be made to contact all of them. Chatting with actors will be done formally or informally.

Tenants: As mentioned above, in each sub question, different tenants were interviewed. But also one reality in the area is tenants might not be work at their farm, instead they may have given already their land to sharecropper or labourer. Here, the new one may not be known exactly the past situation that went in the field. So attempts were made to get the tenant him/herself to know about the past, otherwise interviewing the sharecropper or labourer was the second option.

In the WUAs, three of them were interviewed (the head, the finance and one from the tenant representative). Here what should be noticed that, since the WUAs seem less functional, all these members are not involved? WUAs were also used as entry point to get tenants list, and their specific place. Operators (at the minor off take), engineer or operator at the major off take and one driver of the hydraulic excavator who removed silts at the minor have interviewed to have their views in this system related the above issues. Information from higher officials of MOI, SGB and HRS was also gathered with kinds of informal chatting and interviewing.

Data management and analysis,

It was tried to manage the collected data (pictures, records, observations and interviews) on a daily basis. This was done by attribute key words to text written in a word document. Later on it was translated into Atlas.ti programme to have got easier access of the interviews data.

Partially data analysis was carried out in the field; this allowed me to collect additional data, which I found missing after analysis. Complete data analysis was done after the field work in the Netherlands. Depending on the collected data, important data analysis methods for qualitative data analysis was used, as mentioned it was Atlas. ti.

Quantitative data analysis: excel spread sheets or other software like SAS to see the trend of silt loads, water distribution and irrigable land size changes over the year were used. Again the correlation of silt load with water distribution pattern and irrigable land size changes will be analysed.

2.5 Limitations of the study

This study suffered from a number of limitations. The main ones are presented below.

-*Language*
Since the national language in the study area is Arabic, and I cannot speak Arabic at all, communication with actors was in English through a translator. But sometimes it was difficult to understand the reality because farmers do not want to reveal it. Speaking the same language helps to understand such a situation from their voice. However, the translator usually translated word by word without analysis whether it is true or not. This is by itself one limitation of this research. Actually, it was tried to minimise the limitation through regular discussions with the translator afterwards. Since, I stayed in the study area with farmers it helped me to assess the reality on the next days.

-*Lack of Secondary data*
Lack of updated data was another limitation I faced. For example, it was tried to find a copy of the 2010 management change declaration from the Scheme directorate, but we did not succeeded. It is even more difficult to retrieve any data that pertain to the minor canal level.

-Locals Perspectives

Though the Sudanese people are sociable and nice to work with, I faced several people, who seemed more sensitive in politics. As a result it was sometimes difficult to ask and incorporate such politically sensitive information. For instance many attempts were made to find the responsible engineer in the Kab El Gidad major to ask his current responsibility and his relation with O&M companies. But he refused to give us information. The reason as he said was 'with security reason we should find him through the 2010 Sudan Gezira'. We tried by approaching the responsible channels, but it proved impossible.

Chapter 3 Operation of the Minor

This chapter will describe operation of the system in theory and practice. The latter is mainly how the users, operators and other bodies have interacted with each other to operate the system corresponding to the past and present time line. First I will discuss the theory of system operation (design) on the basis of how the system had been intended to be operated in the past (3.1). Next I will summarise how it has been transformed, especially according to changes endorsed in the Gezira Scheme Act of 2005 (section 3.2 and 33). Finally the current situation of operation will be presented, mainly based on practical observations during the three months stay in the area with verification through users' interviews (3.4).

3.1 Theoretical Operation of the System in the past

The scheme was designed to serve 50% of its gross command area in the two growing seasons. Then 50% of the cultivated area can be irrigated at the same time on the basis of 14 days rotation. In other words 25% of the gross area is irrigated in 7 days and the remaining 25% for the next 7 days in day and night irrigation schedule (Interviews with HRS Engineer on August 16 2010).

But latter in 1937 night storage weirs (NSWs) were designed in the scheme with main idea since farmers had refused to irrigate at night, so that the NSWs can be used as a night water storage reservoirs by which the minor length is divided into different reaches based on the slope of the minor (Elmohrougi, 2008). Hence when these structures were constructed, rotation among Field out let Pipes (FOPs) was in consideration. That means from the cultivated area almost half of the FOPs were operating for 7 days in 12 hrs of day time irrigation, so that the whole 90 feddans number would be irrigated within the 7 days. In the scheduled Abu XX, 'sud mud' should be built after four hawashas of the past 10 feddan size, so that these upstream farmers irrigated at the same time for three days. Then, the sud- mud should be removed to allow the downstream five hawashas to be irrigated together for the rest four days. In the next 7 days the other half FOPs would be opened in turn in similar ways. The same procedures would be repeated in 14 days (Osman et al., 1989 and World-Bank, 1990), and all this is the responsibility of the Ghaffir, including inspection along the canal length and the Abu XXes to check whether it is working properly or not.

Field operation method: in 40 feddan tenancy a hawasha is a 10 feddan land. Each hawasha is divided in to 16 Angayas' by 8 channels which is called jadwal and ditches called 'tegnants'. These help to irrigate safely for the plants, without any water wastages (Morgan, 1951).

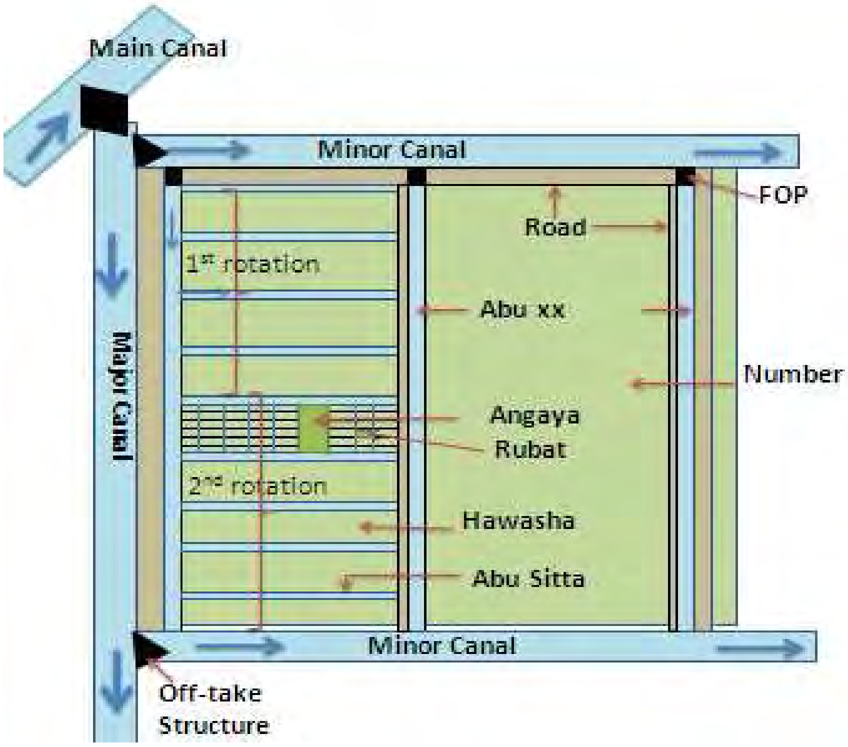


Figure 3.1: The Gezira canalization systematic layout

The above Figure includes the following structures:

Field Outlet Pipes (FOPs): is one of the most important hydraulic structures in the scheme (about 2900 FOPs in total) (Abdalla et al, 1989). In Tuweir minor there are 15 FOPs, but most of them are not functional any more. The FOPs have a designed discharge capacity of 10, 000m^3/24hours (116l/s), with this discharge capacity the 90 feddan lands (number) will take 7 days irrigation in12 hours operation of the FOPs.

Abu XX: is a water channel delivering water from FOPs of a minor to Abu VI. It carries water for the 90 feddan land on day time irrigation during night storage system

Hydraulic structures: are major intakes, minor off-takes and regulators at different reaches of the main, major or minor canals. Their main functions are distributing, controlling and measuring the irrigation water throughout the scheme (Abdaalla et al, 1989).

Abu VI: is the smallest water course which carries water from the Abu XX to the irrigable field. These courses have original discharge capacity of 50 l/s.

3.1.1 The management of the Gezira scheme

Before 1950 the management was divided between Sudan Gezira and the Sudan Syndicate. It consists of 2 irrigational departments each consists of three sub divisions and five agricultural groups. The subdivision engineers were responsible to manage the water that is to deliver the required amount to the syndicate blocks. The syndicate Block inspector was responsible to the agricultural works and the general work of the syndicate (Morgan, 1951). Then from 1950 to 2010 the management had been handled by the Ministry of Irrigation and Water Resource (MOIWR) and the Sudan Gezira Board (SGB) (World Bank 1990). Farmers have had little say on the irrigation system; their full participation on their minor was issued on 2005 Gezira Scheme Act though its practicability has been questionable.

The water management from the dam to the minor off-take is controlled by the MOIWR. SGB staffs operate from the off take to the Abu XX. Release of water from the Abu XX to Abu VI and its control within the field is the responsibility of farmers (Eldaw, 2004). The MOIWR has 7 divisions. These divisions are located in different parts of the scheme, and headed by Division

Engineer. These seven divisions are further sub divided into 23 sub-divisions. The head of the subdivision is called Assistant Division Engineer (ADE). On average each ADE deals with 4 or 5 Block Inspectors (BIs), except in some cases, when different minors within a block belong to different majors or minors from different blocks belong to the same major (World Bank 1990).

On the other hand SGB operates 18 groups, with further divisions into 114 (BI). There is a parallel structure of management: MOIWR alongside SGB. And ADE in MOIWR and BI in SGB are the main actors responsible for water management in the scheme (Wold Bank, 1090).

BI at each minor level calculates the crop water requirements of the following season's crops. They send the results to the respective office division engineers. These engineers summarise the amount of water requirements for various reaches of the canals up to the dam. Then, the amounts of water are delivered to each minor by different water control engineers and operators (Sections) of MOIWR based on the crops demand, as will be explained below.

The 'Ghaffirs', from the SGB were responsible for releasing water from the minor to Field Outlet Pipes (FOPs). He had also operated the NSWs.
The following figure visualizes the interactions between these different bodies to operate the system.

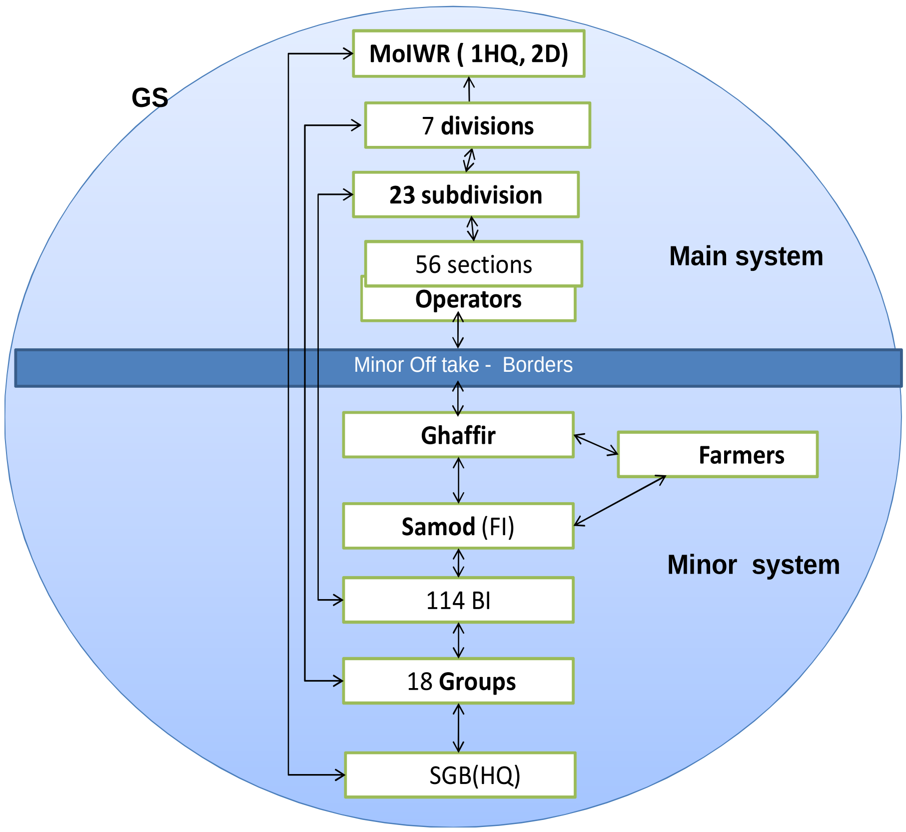


Figure 3.2: The operation system and management interaction in the pre IMT era

In the above figure, farmers communicate with the Ghaffirs and the field inspectors (Samod). Farmers communicate with the Ghaffir, since he is the FOPs and NSWs operator; they follow him to irrigate their fields according to their turn. Field inspectors supervise farmers in the field for agricultural activities including good irrigation management and equal water distribution among them. Similarly, the higher levels MOIWR and SGB personnel communicate accordingly to manage their respective levels efficiently.

Therefore, the SGB and the MOI should reach consensus on the overall planning of the next season crops before the beginning of the season to ensure that maximum efficiency in use of the water, land and irrigation facilities. The MOI requires ensuring that the amount of discharge that is released from Sennar to the respective canals, up to the level of minor off takes, satisfies the crops water requirements based on the BI demand request, with a consideration of the canals water carrying capacity. Hence, with effective control, the water reaches the farmers' fields with the right schedule (time and amount) to satisfy the crops' need.

3.2 Operation during the post-Independence era: collapse

Researches show that the above mentioned effective operation of the system has become ideal. The original design was used satisfactorily for 35-40 years (World Bank 1990). Since then it has been changed from time to time. The intensification and diversification of crops from the 1960s to 1970s (Eldaw, 2004, p. 15) that lead to operating the system over its designed capacity. The water flow from the dam increased from about 2 billion cubic meters in 1960 to 7.1 billion cubic meters onwards. As a result significant amounts of silt are carried into the system. The technical and management inefficiency of water management actors in operational and maintenance activities have also had effect in the steady deterioration of the scheme. In addition the slump in world market prices for cotton made it harder for the Sudan Government to cover the financial requirements of those activities in the scheme. However, the framework of the above figure has been maintained more or less in place up to the recent 2009/10 reforms, though the real management kept deteriorating especially at the minor levels. From the 1970s till 1987 the communication system was in problems (Abdalla et al., 1989) allowing gaps of coordination between the BI and ADE to emerge and shifting away from the old close communication system.

World Bank (1990) cited that inefficient management in both SGB&MOI also became a phenomenon -by the SGB through unbalanced requests that were much higher than the crops needed-44% more, and by the MOI who released much less water than requested-only 78%, with a variation among majors. Moreover little relation existed between MOI gate opening records and the practical value gate openings (HRS report as cited by World Bank, 1990). This also indicates that operation had become theoretical, bearing no relationship to actual water flows in the system.

At the minor level, though the Ghaffirs were supposed to operate FOPs and NSWs, farmers also became actively involved in the operation of FOPs or NSWs, especially during instances of water shortage. In a study done at farm level of the water use in Abdullahi and Nur, the farmers' response was that "We often have to steal it, bribe the Ghaffir to get it or tamper with its level to irrigate our crops on time" (Abdullahi and Osman, 1989). This implies that the actual operation of the system did not go as designed. The functional storages at night and day time operation, with formal rotation between FOPs with good follow-ups of Ghaffir and farmers were changed to an irregular pattern- and 24 hour continuous irrigation without any attendances at night by farmers (World Bank, 1990).The World Bank (2000, p.ii) also reported that 'irrigation infrastructure is in serious disrepair and the distribution of water is inefficient and wasteful'. The presently destroyed and non-functional NSWs and disappeared FOPs in Tuweir minor canal also represent examples of the past management regime in the Scheme (see figures 3.3 & 3.4). These non-functional pipes have impacts on water distribution among numbers. They are exposed for each individual farmer action to get water. Though the NSWs are not functional, still these are operated by some farmers. Usually in Tuweir canal farmers try to create head using sudd–mud at the NSWs which has effect for downstream users.

Figure 3.3: Damaged and non-functional NSWs in Tuweir minor

Figure 3.4: Disappeared FOPs in Tuweir minor

At the time of the Abdullahi and Nur study, farmers were also 'glorifying' the past management system. This is because as the writers confessed in the past communication was good, maintaining the system was fast and the Ghaffirs had been carrying out their responsibilities in good ways (1989). At present almost all of the farmers whom we talked with confirmed this picture of the past situation, especially they appreciated the past 'good' follow up and 'fast' response in operation and maintenance works. I believe, this is because farmers have upset with the present change of management even though the changes were made to address the weak performance of the Scheme. In the past, the government accomplish most of O &M- works by itself, as well as, cotton was grown by the government. Now O&M work responsibilities are transferred to farmers through the water users association. Farmers shall be responsible to their minors situations and be take decision on crops what they want grow for maximum profit. But farmers could not adopt all of them smoothly as the government's thought.

3.3 Addressing the weak performance of Gezira through management reforms (1992-2009)

Since the 1970s many changes have taken place in the scheme but the objectives and goals could not be met. Especially the changes brought negative impacts on water managements (Eldaw 2004).

3.3.1 Introduction of water fee payments-(failed), in the early 1980s

In 1980s, related to the irrigated sub-sector: the introduced policy was rehabilitation of existing projects and changes of production relations and marketing systems. This policy had a aim to promote capacity utilization and productivity improvement in order to maximize production of export crops like cotton and groundnuts. It was also to expand import substitution products like wheat. In this time water charge and individual account system was introduced (Eldaw, 2004 and World Bank, 2000).

3.3.2 Crop liberalisation in the early 1990s

The **'**Policies adopted in the 1990s through 2002, were geared to reallocation of resources in favour of the agricultural sector and removal of bottlenecks so as to improve and enhance the productive capacity of the sector' (Eldaw, 2004, p.3). The major objectives of these policies were liberalization of the economy in order to stimulate agricultural exports to generate more foreign exchanges; attain self-sufficiency and food security; and achieve financial and social stability. And the major instruments of the liberalization policy were removal of subsidies on agricultural inputs; lifting of price controls and government regulations on agricultural products, reduction of subsidies, abolition of monopolies of marketing parastatals and withdrawal of government financing of agricultural parastatals.

Privatisation of public cotton corporation and SGB (1993)-within the context of liberalization policy mentioned above, the cotton public corporation (CPC) was transformed into a private company Sudan cotton company (SCC) in 1993 (Eldaw, 2004). Before the transformation the full control over all the cotton trade was by the government.

3.3.3 The radical changes introduced in the Gezira Scheme Act of 2005

privatisation of land: based on the recommendation that was made by Wold Bank (2000), on the 2005 Act farmers who owned a land before the establishment of the scheme, got land as a 'free ownership' and to whom did not have land in the scheme territory before, the land was given as a 'use ownership for 99 years' (Gezira Scheme Act2005- Article 16).

Hand-over of O&M to WUAs at minor level: the government wants to transfer all its responsibilities such as operation and maintenance works below the minor levels to farmers. Under the new dispensation, farmers can address their O&M-needs through WUAs. Then, the WUAs are authorised as an intermediary responsible bodies between the farmers and the government. The WUAs will either address the O&M works or transmit it to the higher responsible bodies. Unfortunately it has not succeeded in resolving the issue of O&M in the Scheme.

3.3.4 Introduction of Water User Association WUAs (WUAs)

Before the introduction of the WUAs massively in the scheme, a pilot project was tested in Abdelhakam Block in 2000. The pilot project was promising (Eltigani, 2009) because 'it was within a small area, having trained farmers and with good expert follow-ups' (personal communication with Dr. Eltijani in October). Then after in 2007-2008, WUAs were established throughout the scheme. The aim was ''achieving optimum utilization of available water through a participatory process that endows farmers with a major role in the management decisions over water in their hydraulic unit'' (Elfiel, no date). Here 'Hydraulic unit' refers to minor canal level, since WUAs have been established for each minor canal. The communication related water management was expected as follows:

Farmers ⟷ WUAs ⟷ Government (to SGB and MOI)

The WUAs responsibilities and duties

i. To take decisions in planning and execution of field channel operation and maintenance
ii. To make contacts with the ministry of irrigation for water supply and technical advice

iii. Field channel operation, maintenance and the mobilisation of the necessary financial resources for these tasks
iv. To make it possible for each WUA member to have the right amount of irrigation water at the gate of his Abu VI
v. Responsible to execute the technical works and general responsibility delegated to it by the board.
vi. To maintain and update a list of farmers, whether this changes due to buying, selling or otherwise.
vii. To keep the internal roads in the field open throughout the year.
viii. To cooperate with other WUAs, and other responsible bodies, for the benefit of its aims.
ix. To pay the administration and water service fees determined by the board.
x. To determine its financial needs to enable it to take over responsibilities all through the season and collect it from members.

However, the above responsibilities only exist on paper: presently the WUAs are mainly working on collecting water and maintenance charges. Even to collect the charge as the 'financial responsible' person of the WUAs in Tuweir minor explained, they couldn't collect efficiently (September 04-2010). Generally the WUA is not effective in managing the water in the system regardless of its establishment.

To know one of the root causes of the present operation or maintenance-activities changes taking place in the area, I think understand the WUAs condition in the area is one critical point. Because on the one hand the higher officials are thinking as the lower levels are managed by the WUAs (Elfiel, no date), whilst the reality is WUAs are not effective enough. The net result is that operation and maintenance at lower levels in the system is suffering. In interviews with WUA members, farmers and officials several reasons that constraint the effectiveness of the association at the minor level were mentioned. These include:

Lack of experience/knowledge of managing the hydraulic unit:
As farmers said the WUA members have no knowledge to manage the water: 'they are just farmers like us'. As mentioned above, the pilot project was successful. But later regardless the implementation of the pilot project with full commitment in a specific areas, without considering the size of the scheme and without train and supervision of farmers, it has been implemented at a large scale (interview with, Dr E. October 2010). Moreover the establishment has not followed a bottom-up approach (*ibid*), meaning that the actual irrigators had no say in its establishment.

-*Lack of motivation/low (no) payment/ (WUAs):*
As the two members of the WUAs and farmers explained, they have no or very low payment, 'we are doing this voluntarily, how can we sacrifice much time and make a good decision?', they have also their farm or other income generating works to do.

-*Close relation (relatives, neighbours...)/ friends with farmers (WUAs)*
Both farmers and WUA members explained that it is difficult to make a restricting decision to manage the water, because they are living together, they are all tied closely by blood or marriage or neighbourhoods, so it is difficult to take action when some farmers do something wrong, or to carry out their responsibilities. Farmers also consider the members as their colleagues so they don't give respect to the WUAs rules and regulations. They have no a trust that the water can be managed by these members.

-*No collaboration between WUAs:*
'Each WUA member is isolated from each other- no way to collaborate to make good management between them' (interviews with HRS Engineer on August17, 2010). There are 1,580 WUAs as

many as the number of minors in GS (Vice WUAS interview on October 1, 2010). But each stands in isolation.

Election

As the participated farmers explained, the criterion of the four core members' election was 'owning land', and being 'active in farming' and 'stable in the village'. Unfortunately, the head and vice head member of the Tuweir minor are employed in Khartoum (jobs). The first is only in the village on Fridays and Saturdays (weekends) and the other is a driver, who gave his land to a sharecropper. This absence causes complications: how can farmers access these members? Indeed both of them admitted that they are not working for farmers at all. In the head minor the WUA head is also the village head, very well vested with power issues.

3.4 Operation in Practice-the case of Tuweir Minor in 2010

At present, the water management regime seems radically transformed as compared to past management regimes since independence. Some people attributed this to the implementation of the new Gezira Scheme Act 2005, but it is difficult to say whether all changes can be attributed to those envisaged in the Act since additional changes are also observed. For instance the World Bank's statement was 'MOIWR would continue to be responsible for delivering irrigation water to the Gezira Scheme where the SGB would be responsible for irrigation water distribution, operation and Management of canals, and cost recovery (Wold Bank, 2000, P. 56). And the Act states 'the MOIWR is responsible for the maintenance and management of irrigation canals and drainage pumps, and make sufficient water available to water users associations at the intake of the minor canals,' (Gezira Scheme Act2005, -18) reflecting that the responsibility of MOIWR is kept the same as in the past by this Act. Then what is new in 2010? ''The prime deputy to the president signed on 1 January of 2010 a declaration which transferred control over the water to the scheme, and 'the ministry of Irrigation lost its responsibilities for direct O&M of schemes and dams.'' (Interview of higher positioned official of MOI). We couldn't get the document which states this declaration of 2010, but the transfer is confirmed through observations and many other interviews in the field.
So that, contrary to the previous different layers of collaborative operation of the system between the SGB and MOIWR, now the latter seems to be out of play of the Scheme's direct management system (O&M- activities) (Figure 3.5). This was confirmed both by observations during the field work stay at the minor level; and by interviews with previously higher level positioned officials of MOI. They explained that they 'do not have any responsibility to do for the scheme at the movement rather than watching TV and reading newsletters in their offices.' Because their 'responsibility has been given to others who belongs/ shall be under SG-2010-, and private companies.' Now they sit at the office 'awaiting the final decision about their fate in December, 2010'. Some of them are actively looking for another employer. By this time (In December 2010) this radical reform trial period may be over and it might be revised based on the outcomes of the trial. To acquire more information on the change, many attempts were made to meet the 'new' Civil Engineer under the SGB, who is responsible in the study area. In the end we failed to get hold of him, presumably also due to his many reasons not to give us information. He has been working under the MOI since April 2010. Moreover, BIs and FIs have been fired; the scheme's total personnel number has decreased from around 4,000 in the past to 75 presently (Interviews with the present SG-2010 Official).

One may say what is wrong with change? Yet the previous management personnel of MOI enjoy no smooth communication, if not at all, with the new engineers under SG-2010. Hence the transfer of the previous data, reports and management procedures from the old to the new management has not yet been done. In addition, the 'old' Engineers raised the question 'how could the system be managed with '15' engineers at present out of '100' engineers in the past, the worst is without having the past management documents'. However, I hope that the engineers, who transferred from the MOI to the new SGB, might have those documents. About the personnel numbers, the above mentioned new engineer in the scheme was too busy to cover his area. Though I believe the quality of work takes prevalence over the number of staff involved to execute it, the radical changes instituted in January 2010 have resulted in a serious drop in the quality of the work. In addition the newly employed personnel of the SG-2010 have not got a full employment certificate, making it difficult to say whether they can work in full devotion with the necessary qualifications for the job.

Figure 3.5 below shows the present communication lines and the key actors involved in O&M, based on physical observations in Tuweir minor canal. In fact this figure shows communication is possible through different paths, but the observed practice is that both the message and the response arrive too late.

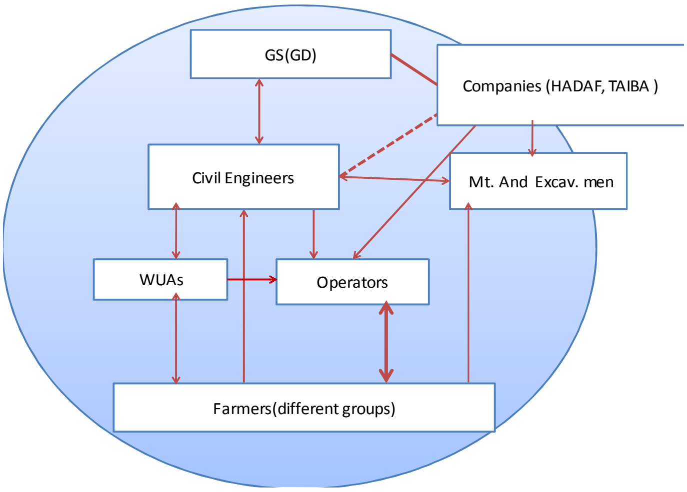


Figure 3.5: Communication routs for O&M at minor level, observation Tuweir minor case

As the above figure shows farmers communicate mostly with the operators. Any farmer goes to the off take operator and former Ghaffir, who now become employer of Hadaf company, to ask them to open fully or close the off take when he/she faces water distribution problems. Farmers also communicate their problems (operation and maintenance) to the engineer directly. In Tuweir Minor on 20 September 2010 one of the farmers, who is after the middle of the canal tried to propose to the responsible Engineer that he himself would cover the fuel costs of the excavator machine, if the engineer in return would assign the excavator to them soon. For more than a week those farmers had not had water to irrigate (for details, see chapter 4). The farmers communicate with the WUA to pay their water fees, but most of the farmers said they do not communicate with the WUA about their problems, because they know it is incapable of solving their problems.

Farmers can also contact the excavator driver in the cases of Abu XX maintenances. In Tuweir minor, farmers have collected money to give to the excavator driver not the company for the same purpose. Actually in this particular case the excavator refused to do so. However, in interviewing the excavator, he confirmed that farmers come to him to ask their Abu XX to be maintained/ cleaned and in some cases he has done. This could be in exchange for money. When possible, he might be motivated on this kind of works because of the money incentive he will be received from farmers. So, I do not think the Tuweir minor farmers have collected the money to him for the first time trial, but this could be from their past experience. The off take operator confirmed that ‘sometimes farmers give some money for the excavator driver to motivate’ (on 22 August 2010), here farmers may want to motivate him, to access him when they need a help (excavation) - a kind of bribing. Also, I do not think the excavator man will devolve the money to the company.

The engineers and the companies work for the reconstituted Gezira Board (SG-2010), and their salaries are paid by the SG-2010. The engineer supervises the companies, for instance in Tuweir minor the operators are supervised by the engineer. Whereas the minor operators, measurement and excavator men are employees of the different companies (Hadaf and Taiba), which pay their salaries. Whereas, before this change, one of the operator (formerly called Ghaffir) was employer of the SGB; the off take operator and the measurement man are new employers of Hadaf company, but if it were in the past they would be under the MOI. To assess the present operation situation in detail, I shall separate the different levels of the minor section, at the off take, FOPs and Abu VI levels.

3.4.1 Operating the off take

There are two Operators who are employers of a 'private' ('security') company which is called Hadaf. One of the operators is working at the off take of the minor, responsible for opening and closing the off take moveable weir gate (Figure 3.6). The other is responsible to follow-up along the minor length from the off take to the tail, including the opening and closing of FOPs, as well as assisting the WUAs members in collecting water charges and contacting with respective bodies. But execution of his job is questionable, since all farmers are complaining this operator is unreliable because he does not report back to them?

As explained in section 3.1 on the past situation, the operator had delivered water based on the engineers predetermined discharge to that specific minor. The engineer would determine the amounts of water to be delivered to his minors and transmit instructions to the operator, so that the latter delivers water to each specific minor accordingly. However, now the practice is operator will operate the gate based on farmers' request (usually when they complain). He said he can manage it by his experience, yet he is a new employee hired just four months ago. As he also said, 'sometimes when the engineer inspects the canal the engineer may order me to open or close it'. Otherwise he will only report to the engineer when he faces a serious problem to operate the system like if there is 'over flow.' As a result, most of the time the canal looks as empty as playing fields (Figure 3.8). Whilst sometimes the minor section suffers from breaking out flows (Figure 3.7).

Figure 3.6: Operation of the Tuweir off-take

Figure 3.7: Breakout of minor section at the third NSW (on 29-Aug-10)

Figure 3.8: Dried canal at downstream of the third NSW (on 1-Sep-10)

But these claims by the operator do not imply that farmers are not involved in the operation of the minor section. As (Abdullahi and Osman, 1989) notified farmers were ‘tampering’ with the gates of the minor section. This practice has only increased in strength. Fortunately in Tuweir minor the off take operator is a full time worker in the day time, he has no any farm except a piece of vegetable plot inside his guarding place, so that the off take gate is relatively protected from farmers’ interfere during the day time at least. But it was observed that in other parts of the Gezira scheme, called Rehana major (at K177), in Abu Doam minor canal a tenant was opening the off take to this minor, claiming that the operator was absent that day to open it (09-Aug-2010, field visit to Rehana major). On 14-Aug-2010 also, in the same major but on a different minor, another farmer was observed while closing the off take of his minor, the reason being that his Abu XX got too much water (Field visit to Rehana major). But what should be notified is that to allow other FOPs to benefit from the flow this farmer did not close his Abu VI. It is doubtful that the examples mentioned concern the only farmers who interfere with the operation of off takes. And what is the consequence to other downstream farmers? I believe that at present, this practice is spreading throughout the Gezira scheme, which results in up- and downstream water distribution issues that lead to conflicts between farmers (farmers’ interviews in Tuweir minor).

Another practice that farmers have directly involved in is pumping on the main or major and minor section. The latter seems obvious during times of water shortage, and many farmers in Tuweir minor approved the practice. In the past, especially last year, there has been pumping. For this year also there were several farmers preparing to pump. In other parts of Gezira, more than three pumps were installed in a minor near Barakat head quarter office (observations on 07 and 19- October-2010), as the official said, ‘that canal has a problem’ so, is that rehabilitation? But also pumping directly from the main Gezira canal was observed (02-Aug-2010, field visit to Bekaa (at km108) near Tayba division box).

Figure 3.9: A farmer operating a minor off-take Figure 3.10: Pumping from the main Gezira canal

In Tuweir minor, farmers do what they think is important to irrigate their Hawasha on the minor cross-section and at the NSWs (Figure 3.11&12). Here what should be notified also that, these practices are an individual farmer’s practices (see chapter 7). Hence, one can understand those downstream farmers of the individual farmer could be affected negatively in unreliable/unequal water quota. So, these features can be indicators to evaluate the current operation in the area. The pictures below show what farmers did at the first reach NSW and at the sixth FOP of the minor section of Tuweir minor to raise the water level to push water to their hawashas.

Figure 3.11: Farmers closing a NSW with iron sheet (25-Sep-10)

Figure 3.12: farmers create water head with mud on the minor (31-Aug-10)

3.4.2 Field Outlet Pipes (FOPs) Operation

FOPs are controlled by farmers, there being no 'Ghaffir' who operates the FOPs at all at present. Every farmer opens his/her number FOPs when he/she wants to irrigate. As mentioned on section 3.1 above, when the NSWs were designed in the scheme, rotation among FOPs was in consideration. However, at the moment, as many farmers explained, especially since the last three to four years, there is no planned schedule or rotation among FOPs at all. Observations during the field work along the whole minor length at different times confirmed this situation (Table 3.1). The Table shows that almost all FOPs, (Figure 3.13) were opened at the same time, except fallowed lands. If any FOP is observed closed, it is for a short time only. Another farmer can be expected to open it soon. Especially in the peak irrigation period, starting from September, these FOPs are opened for 24 hours continuously. This is without considering two nakoosies FOPs ('illegal' FOPs- see chapter 7), from Tuweir minor. These nakoosies FOPs supply water for the upstream minor command area. They are operated like the normal command FOPs, even their flow condition is always better than that of the normal FOPs.

Closing of the FOPs is controversial in case no one needs irrigation. If one opens the gate another will continue irrigation after a while. Such that the first 'operator' may not close it, while usually the subsequent irrigator also leaves the FOP open. Here, also farmers have complained about female and 'outsider' farmers. As they justified, it is difficult for female farmers to open/close FOPs. 'They may ask someone to help to open it, but no one waits for them to help close it again.' To this allegation female farmers replied that, usually they can irrigate when they found it open, but they can also open or close it if necessary. In addition, farmers who landlords called 'outsiders' are those who came from in other parts the country like from western Sudan and Chad. Most of these farmers don't have their own land. Hence, the tenants believe, these farmers have not 'enough experience and concern' to manage the system properly. I doubt whether this is a lack of experience in operating the FOPs. Rather there is a lack of 'concern or motivation', but this also applies to the 'real' owners.

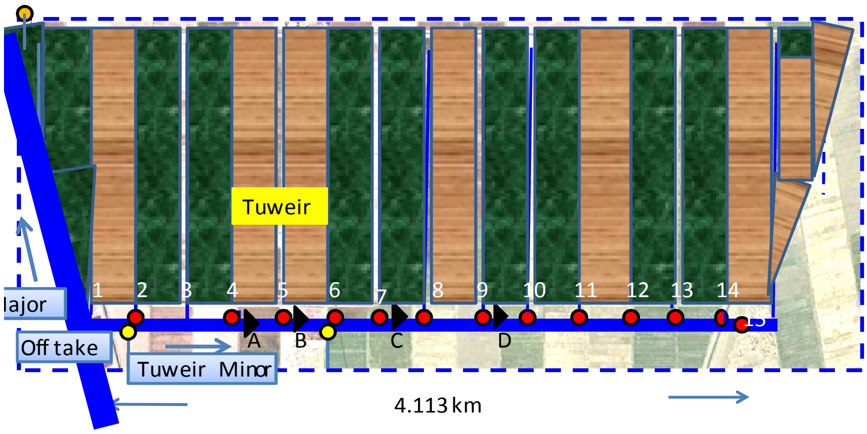


Figure 3.13: Field layout of Tuweir minor

FOPs with pipe | Cultivated area | Nacooisi FOPs
NSWs | Uncultivated area

Table 3.1: Round Trip Observation in the Tuweir minor

Observation Dates	Operation situation of FOPs		Remarks
	Open FOPs	Closed FOPs	
24-Aug-2010	FOP1, 2,3,7,9,10,12,13	FOP6	No flow to FOP15, because water cannot reach and the farmer use from the head minor canal breakage flows
03-Sep-2010	all	0	
12-Sep-2010	all	0	
17-Sep-2010	Except FOP1	FOP1	
20-Sep-2010	all	0	
21-Sep-2010	all	0	
25-Sep-2010	all	0	
29-Sep-2010	All except FOP6	FOP6	in the afternoon it was opened
02-Oct-2010	FOP1,2,3,7,9,13,15	FOPs 6, 12	FOP12 was immediately closed

Moreover, the downstream farmers do not ask the upstream farmers to close their FOPs, as they do not have any working rule that governs between numbers. But beyond the sights of upstream users (stealing), downstream farmers sometimes close the FOPs by themselves (communication with farmers). I think, this is more complicated due to ownership issues. There are different groups of farmers in the consecutive numbers(sharecroppers, owners, renters, even different owner- some may buy/sell only 2 feddan lands, some other are inherited) that make difficulty a rotation among numbers. But in the past at least in four adjacent numbers owners were almost the same farmers- easier to deal among numbers just like dealing within a number: since each owner had crops in each of the four numbers.

Within a number- as mentioned above 'sudd-mud' at the middle of the Abu XX is old practice or it was the designed operation of the Abu XX. Tuweir farmers also said that, the practice in the past was based on proper schedule with good follow-up by the water guard. However at present it is randomly in everywhere of the Abu XX section by anyone who faces water shortage to irrigate his/her field. It was observed and farmers also confirmed that some farmers built a sudd-mud at the beginning of the Abu XX, or after three or four Abu VI, without a pre-discussion with downstream farmers. When farmers asked if they can do a sudd-mud after their Abu VI; their response was 'yes I can make when the water level drops to reach to my field, no need asking the downstream farmers'. But, if a neighbour farmer is irrigating the sudd-mud head will be created after this farmer. Indeed farmers are doing this just to irrigate their crops, to cope with the water shortage or lacks of good management at the upper levels.

In this scenario, many downstream users should wait until few upstream users' finishes their irrigation. Or if the downstream users fill a small water can reach to their field they will remove it without any discussion to whom that built it, unless those farmers, who built the head, be around and negotiate to continue their irrigation. This can be 'hot conversation or conflict' between them. Because, the one who built it also consider it is his/her right till finishing his/her irrigation.

Generally, during my stay in the area and from farmers interview I understood that, the movement to make a discussion or to solve a problem about the operation of the Abu XX or any problem (like maintenance) that are obstacles to access irrigation water is from downstream to upstream users, except within adjacent tenants. Indeed the adjacent tenants' relation was observed more significant between close relations or relatives. Hence, the upstream users do not go to downstream at all, unless otherwise a close social relationship between them (Figure 3.14). Its impact will be discussed in chapter 4& 5.

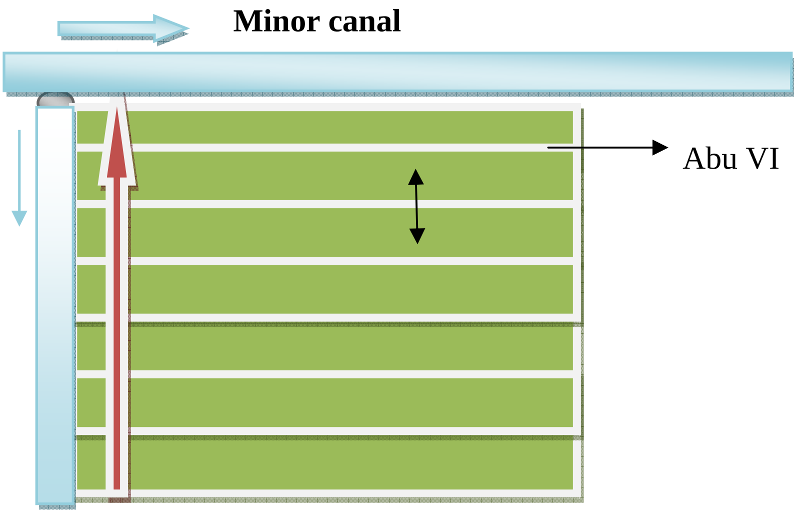


Figure 3.14: Farmers communication within a number in Tuweir minor: *the white arrow represents farmers movement to communicate with other farmers is upward while the black represents in both direction between adjacent farms*

3.4.3 Operation of Abu Sitta(Abu VI)

Abu VIs are the smallest field channels that convey water from Abu XX to crop fields through a 'tegnant'. It was designed to irrigate 10 feddan lands; later has reduced to five, then four feddan plots capacity due to crop rotation changes. Now it is reduced to mostly 2 feddan fields by farmers-with two reasons. One is because of the water amount in the Abu XX has reduced, and as the same time the level of the hwasha increased due to siltation and poor land preparation, hence farmers have to dig more than one Abu VI per their 4 feddan hawasah to irrigate. The second reason is because of a hawasha fragmentation to owners, renters or sharecroppers and different crops within a hawasha, even some Abu VIs are designed for one feddan lands. Because, farmers have dugout additional Abu VI to irrigate the different crops separately.

Abu VI supplies water to a 'bigger' furrow called 'tegnant'. Depending on the amount of water flow into the Abu VI, usually 1 up to 4 tegnants can be opened together. One tegnant irrigates a small plot of a hawashas called 'rubat' here: water flows in to the plant root zone through small furrows along the rows of the plant. The sizes of the rubats are different with the sizes of the hawashas.

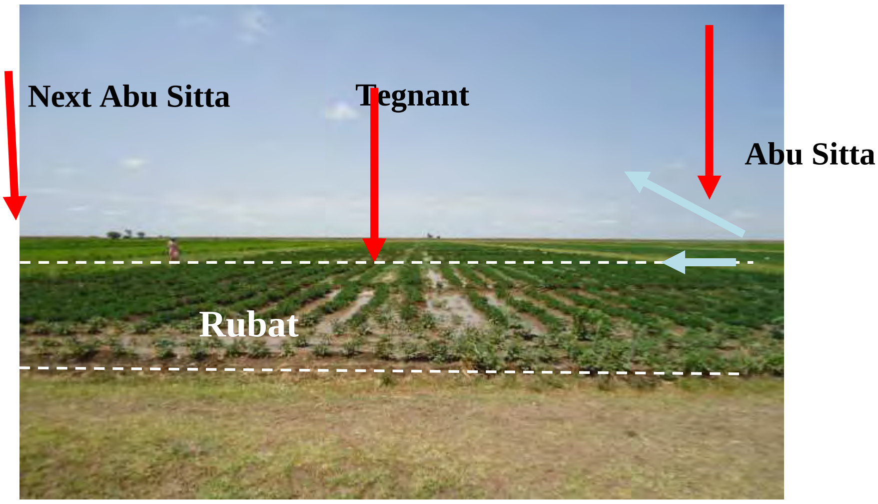


Figure 3.15: Operation at field level of Tuweir minor (Field Irrigation method)

However, farmers suffer from a number of flaws in operating their Abu VI. Most farmers leave the Abu VI opened at night. Even during the day time usually the farmers working time is from 7:00-11:00 am in the morning and from 4:00 pm to 6-7:00 pm in the afternoon. From 11:00 am-4:00pm they go to home for lunch and rest. During this time most of them leave their Abu VI open. As a result water flows in the wrong direction: to the neighbouring hawashas, or to the road. I investigated this in depth during round trip assessments of the two numbers for more than seven times and while walking inside the farm to chat with farmers. During this time, in most cases no one has been around to irrigate his farm, while the Abu VI were opened. 'Some farmers also explained their crops stunted growth is due to over-irrigation caused by their neighbour, or their Abu VI breakout flow during the night and or within the break time.' In this case the downstream hawasha of the same number had been more affected directly by the flood. But indirectly all of the downstream farmers would be affected due to unequal water distribution.

3.4 Conclusion

Implications of the present operation on distribution changes**:** generally good management of the system with happier and motivated users might refer good water distributions among them or in the system. But many farmers in the area seem they are not happy and not motivated with the new management changes which states they shall manage their hydraulics units- they are thinking they have no enough knowledge and experience to take over the responsibility. Second they have no finance to carry out all the activities alone without support. Thus first of all with this sense of responsibility how they can manage the water? Motivation and sense of ownership is important for water management. This amplified with the current poor managements of O&M activities. At present no one is controlling the system to have reliable, equal and scheduled water distributions among farmers. In Tuweir minor was observed that, while the upstream farmers had been irrigating more or less their demand relatively on time, based on their plan, the downstream farmers had been suffering in water shortage more than a week. Hence, conflicts between farmers was realised an outcome at the end of September in the area, as well as, the vision of producing maximum and quality yield by everybody cannot be met in this situations. Farmers also claim on it that especially last year in Tuweir minor, they gained lower yield than before (farmers interviews). Moreover the following conclusions are drawn.

(1) Tenants have virtually always interfered in water management at the minor and Abu VI level. Particularly after independence a variety of forms of interference can be observed:

(a) Opening and closing FOPs and minor off takes; in the Past (before independence) who is called off take operators, Ghaffir and BI had been discharging their responsibilities satisfactorily in their levels. So that farmers could not, or they not need to interfere in operation of the off-take and FOPs.

(b) Destroying FOPs, NSWs and minor off-takes: starting from the 1960s following the diversification and intensification policy, farmers have started to destroy FOPs, NSWs and off-take structures to get water to their plot and it has become worst onwards.

(c) Constructing illegal intakes which is called nakoosi on the minor and the next Abu XX channel, as well as deploying pumps at both minor and major canal levels has become a phenomenon.

(2) The infrastructure of the system in general has deteriorated which has limited water management possibilities. In figure 3.3 as the plates show, non-functional NSWs and FOPs clearly influence operation. Of course this clearly links to maintenance; no maintenance was done in Tuweir minor since long time.

(3) This practice has led to a situation of water supply insecurity (that is further compounded by the siltation problem, see next chapter). As a result tenants and other water users tend to hoard water whenever it is available.

(4) The transfer of responsibilities for water management to WUAs has not resulted in an improvement. Rather WUAs have been established in a top-down haphazard manner: so far they have only been involved in fee collection. Since the fees collected do not seem to make any difference with regard to water supply security or maintenance activities, people are not motivated to pay.

Chapter 4 Water Distribution in Tuweir Minor Canal

The Gezira Scheme gets its irrigation water from the Sennar and Roseires Dams on the Blue Nile River. The annual water discharge of the Blue Nile is estimated at an average of about 50 billion cubic meters measured at Roseires (Ahmed 2000-cited by Eldaw 2004). Based on the Nile water agreement between Sudan and Egypt in 1959, the allocated water for is 18.5 billion cubic meters (37% of Blue Nile). The Gezira Scheme is entitled to approximately 35 % of this share, which is 6.5 billion cubic meters (Eldaw, 2004). This has been used to irrigate 50% of the gross area in a season (about 1 million feddan land can be irrigated in a season).

In this chapter, since the main actors operating the Gezira system (which includes water distribution) up to the present time have already been mentioned in chapter three, we would like to continue on water distribution in theory (that is how water was intended to be distributed among users); and in practice our focus is on Tuweir minor in 2010 based on practical observations and interviews. The impacts of water distribution changes and conclusions will be also presented.

4.1 Water Distribution in Theory

From the Sennar reservoir water is released in to two parallel main canals with a combined maximum daily discharge capacity of 31.5 million cubic meters i.e. 168 m^3/s the old Gezira and 186 m^3/s the 'new' constructed canal to serve Managil extension which run in Northern direction to the first group of canal regulators at 57 kilometres from the dam (World Bank 1990). After this junction the canals are called Gezira and Managil Main canals and run in different directions to their targeted areas supplying water through various levels of canals to irrigation fields. Basic characteristics of the various levels of canals are given in Table 4.1 below.

Table 4.1: Detail information of the Irrigation System in GS

Canals	Number	Capacity(m^3/sec)	Length (km)	Av. width(m)
Main	2	354	261	50
Branches	11	25 to 120	651	30
Majors	107	1.2 to 15	1,652	20
Minors	1,500	0.5 to 1.5	8,119	6.0
Subtotal	**1068**	- - - - - - - -	**10,683**	- - - - - - -
Abu XXs	29,000	0.116	40,000	1.0
Abu VIs	350,000	0.05	100,000	0.5
Total	**380,068**	- - - - - - - - - -	**150,683**	- - - - - -

(Source Ahmed, 2009)

Indenting (Required water requesting)

As mentioned in Chapter three, the principle of water distribution at each level up to the minor canals was based on the BIs request to the Sub Division Engineer (SDE). The request is made before the coming planting season. The request is made on the basis of the crop water requirements which are calculated by BIs. Actual distribution was by considering the canal water carrying capacity which is checked by the respective Engineers at each level, such that, too much of the water is needed for the crops calculated by the BIs with the canal capacity, which is checked by the engineers, the two actors need to negotiate to reach consensus.

During the planting seasons the request from BI to SDE occurs on weekly basis, on Tuesday as early as possible before 1:00 pm, but not later than 2:00 pm. After 2:00 pm indenting will not be considered for the afternoon change, it would only be implemented in the next morning's alteration. This procedure helps to maintain a steady uniform flow throughout the week in all the canals; and the indent is expressed in cubic meter per day (MOIHP, 1934). If a need arise to adjust the indents, it will be sent to the Division Engineer on Saturdays. And the adjustment should balance changes on different area within a major. So in this way farmers can irrigate according to their schedule.

Normally the above described indenting has become the norm with a long time history. Reports show that it has not been practised accurately since 20 years ago (Ahmed, et al, 1988). They found many unclear indenting records, such as high peak indenting in October regardless of small area coverage for wheat during this time; peak crop water requirement records during the peak rain period of August. As many other researchers have mentioned also, water distribution in the scheme is continuously altered from time to time (Wallingford, 1991) due to different reasons. HRS and Wallingford (1988) reported that the indenting has not been perfect without any change effected in the case of rain. For instance they reported for Kab El Gidad major, in the case of Tuweir minor, a severe reduction to less than 50% of the indent that lasted for over seven weeks in the 1987/88 season. And the World Bank reported that 'usually claims of inequity caused by siltation and weed infestation are frequently being made by farmers' (World Bank, 1990, p. 4). All these indicate the indenting practice has become less effective than in the past.

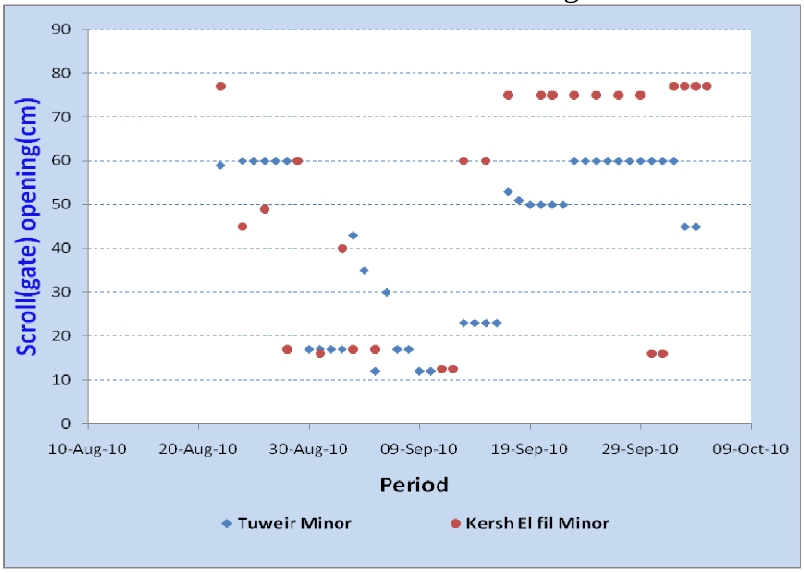
4.2 Water Distribution in Practice: causes of water distribution changes

Nowadays indents are totally gone. WUAs have placed the previous BI, but they are not working in the same way as the BI. At presently WUAs, probably at the beginning of the planting season, based on their past experience they may send an overview of the type of crops that will be grown in their respective area to the respective body-engineer. Commonly the crops are: sorghum and groundnuts as summer crops; wheat and recently 'kebkebe', which is a kind of pea as winter crops. To some extent vegetables are also grown in both seasons. These crops are known by the engineer as well. But, no crop water requirement based calculation at the block or minor level is undertaken. How much feddan land will be covered and which crop will be planted is not known to decide on the amount of water to be released to each area or block. No weekly request and no adjustment indenting in case of rain or peak crop water demands are made (interviews and observations). The off take operator will made a request to the respective engineer when he faces a serious problem like a canal breakout flow. But he will not make any request to facilitate a reliable, equal, on time water distribution according to the crops' need or call for adjustments to have healthy and productive plant growth. In this section, water distribution between minors, numbers and within a number will be presented as follows.

4.2.1 Water Distribution between Minors, in Kab El Gida Major

Without going through further analysis, the above explanation of ineffective indenting can create unequal water distribution between minors. Currently the water discharge which is released to each minor is based on a rough estimation instead of the theoretically restricting indents according to the crops need and canal capacity. Minor off take operators might be also influenced by some powerful farmers and they may not have the experience to operate correctly. For instance, the off takes of Tuweir and Kersh El Fil minors are operated by one operator, who has no experience of canal operation. I doubt if he is distributing water fairly to these two minors. Simply from the observed gate opening of the two minors in the field, one can see the difference between these two minors (Graph 4.1). It shows the Kersh El Fil minor gate was fully opened most of the time on the observation dates, while the Tuweir minor gate was mostly opened at a quarter or third hand of Kersh El Fil minor opening. My Differences do not originate from the exact/allocated water needs of these two minors, but simply from farmers' request to the operator. It is difficult to assess whether this is fair, as the operator also said the Kersh El Fil minor farmers come to him more frequently than the Tuweir minor farmers, to force him to open their minor fully. This kind of water distribution is also practiced in other upstream and downstream minors of Tuweir minor within the Kab El Gidad major. These indicate that the system has become a mess throughout the scheme.

Evidently in some minors, it was observed that farmers themselves opened their minor off take, this raises the question fair water distribution can be effected among them?



Graph 4.1: Gate opening of Tuweir and Kersh El Fil Minors

4.2.2 Water Distribution between Numbers, in Tuweir Minor

To understand this situation observations and some discharge estimation of all Tuweir minor's FOPs and Abu XX were made for about 8 times. During this assessment water distribution differences between numbers was realised. Some of the practical reasons for the difference that I understood during this assessment are presented below. These practices are important factors in water distribution differences among users not only between or within numbers but also can be influential factors between minors and majors. These practices are treated below.

Farmers operation of Field Outlet Pipes

Since farmers have their own perception of their crop water satisfaction, one may irrigate his crop with too much or too little water (World Bank, 1990). In Tuweir minor canal farmers were complaining about this situation as 'one takes more water than his crops need while others are suffering from water shortage within the minor/number'. Figure 4.1 show that two farmers in this minor were irrigating their crops fully. That means they need to open the FOPs or their Abu VI for a longer time than the others. Yet it was not observed that all of the farmers in Tuweir minor were irrigating their crops like what these farmers did. Since nor all farmers irrigate like these two farmers, it is questionable whether water distribution is done in a fair manor. These two farmers' actions clearly can affect water availability for downstream users.

At FOP1 **at FOP6**

Figure 4.1: Two examples of Farmers irrigating their fields fully

Differentiated management concerns amongst various types of Farmers

There are different groups of farmers in the Scheme such as owners, sharecroppers, labourers and renters. These groups have their own sense of ownership and responsibility in managing the system (structures or the irrigation water). Also they have different irrigation management experiences. In this scenario unequal water distribution between them is almost inevitable through one may leave the gate open to acquire more irrigation water than others; another one may not care about what will happen to others the next day due to his action. Many owners in Tuweir argued that water management failures are experienced in the area, because most of the sharecroppers have insufficient experience to manage the water.

However, I argue that, rather than experience, many sharecroppers do not own land. So, they want to maximize their yield as much as possible in a season. To do so they operate the system in any way, that helps to satisfy their crops' need according to their perception of on timely basis. In addition this group of farmers have not been working in a fixed hawasha, number or minor. Instead they may change to another hawasha, number or minor every year. Hence, they may not care for what problem will occur next, in one specific area as far as no rules have been developed to control their irrigating behaviour. Moreover, this group is not the only hoarder of water. Also the other groups (renters, owners or labourers) display the same behaviour of carelessness/selfishness. Figure 4.2 below shows some farmers' actions on the minor and Abu XX section to irrigate their farm, which affect water distribution patterns for downstream users.

Besides differences in management concern, many farmers practise additional income generating activities outside the village. Usually many land owners give their land to the other groups (sharecroppers, renters, labourers) when they are gainfully employed outside the scheme. However, I have met sharecroppers who are employed in Khartoum in addition to their farm work as a sharecropper. In such cases, their wives or children will handle the farm work. But their wives and children may not have enough experience on how to irrigate; hence misdistribution of water will result.

Nakoosi

'Nakoosies' are FOPs/Abu VI which farmers employ to irrigate by diverting water from downstream minor or Abu XX to upstream numbers or hawashas. These practices are illegal and beyond the minor or Abu XX canals' designed capacity though it is one of strategies farmers use to irrigate their higher level lands almost at the tail of every hawasha. There are two nakoosies FOPs from the Tuweir minor that have been used to irrigate the upstream minor command numbers, Wad Hezam minor canal. There are 15 and 12 normal FOPs in Tuweir and Wad Hezam minor respectively. Within Tuweir minor there are many Abu VI from downstream Abu XX to in upstream number. Such practices have been observed frequently in all planted numbers of Abu XXes of the Tuweir canal during the field work stay: from number 4 Abu XX to number 3 hawashas; from 8 to 7 (total 6 Abu VI); from 11 to 10; and from number 14 Abu XX to number 13 (about 10 Abu VI). Certainly these practices have significant impacts on water distribution differences between users of different minors and within the same minor (since not all of the farmers use nakoosi and it is not encouraged). However, it is one kind of farmers' coping mechanism to irrigate in case of water shortage and distribution problem (see chapter 7).

Other practices

Other practices comprise of water use making a sudd- mud across the minor or Abu XX sections to back up the water levels and the closing of NSWs, to push more water through the upstream FOPs or field inlet. These are also sources of water distribution differences among the farmers (figure 4.2). These practices can be sources of conflict between farmers.

Using the canal water for household purposes is another practice in Tuweir minor (see Figure 4.3 below). Since, Tuweir villagers have no access to water taps; they use water from the minor canal for domestic purposes. One day I observed that villagers opened a fallowed FOP to divert water to their village, to irrigate ornamental trees inside the village and to serve other purpose like house building, while the downstream farmers in the same minor were suffering of water shortages. These practices may seem simple or normal in other places but they have significant effects on decreasing the level of water in the minor and creating inequitable water distribution between users.

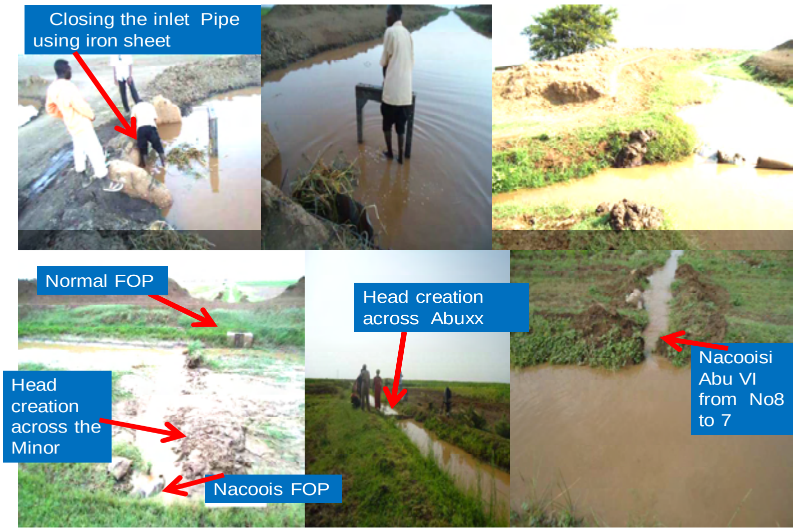


Figure 4.2: Nakoosi and different farmers' actions on a minor and Abu XX channel*:*
Those have clear influence of water distribution among users.

(a) **(b)**

Figure 4.3: Using the Canal water for household purpose

N.B. (a) shows a boy who is fetching water for house building purposes. I observed this practice many times. The second photo (b) was a case where farmers had opened a fallowed land FOP to ferry water to their village directly. As the same time there was water shortage in downstream farms (in the peak period, on September 25-2010).

Maintenance induced effects on water distribution

In many ways (lack of) maintenance can produce water distribution differences among numbers/minors. For Tuweir minor as will be explained in detail in chapter five, no silt removal has taken place after the middle of the minor since at least three years ago. This affects the reliability/equity or on time distribution of water for downstream farmers.

On the other hand, may be in some places only, when the water level is lower in the canal, the accumulated silt raises the water level, though it is an indicator of the poor water management in general. Before excavation was done in the Tuweir canal, the upstream users were accessing more water, since the accumulated silt raised the minor water level, such that water was easily discharge into upstream FOPs. But after the silt removal, the water level in the upstream section of the canal decreased dramatically. This produced differences in water level between FOPs within the minor canal (Figure 4.4). As a result the amounts of water delivered to these upstream FOPs decreased, and relatively the discharge into downstream FOPs improved (Table 4.2 and Graph 4.2). Though it might not be a general case for other places and might not be long lasting, it was a problem for upstream users at that moment.

However, in general except for the above exceptional case, as figures 4.4; 4.5 and 4.6 indicate from the available water in the canal, the upstream users enjoy the lion share of the water at the expense of downstream users, because of poor management. In addition it was obvious to observe that after any irrigation of upstream users, there was excess water flowing to the road or to the fallowed land while the downstream farmers are not able to irrigate their crops. All in all this results in unequal water distribution among users.

(a) FOP1 when excavation was started on Sep 21 (b) OP1 after excavation on Sep 25

Figure 4.4: Water distribution difference because of sediment management example on FOP 1

N.B. *The first photo(a) shows in FOP1 even water was flowing out over the suck-mud and this was most often the case before sediment removal. But after the silt was removed, the water level in the minor canal decreased as (b) shows, then the amount of water discharging into this Abu XX decreased dramatically, so that farmers create a head across the minor.*

Table 4.2: Water distribution estimation between FOPs of Tuweir minor canal

Hydraulic level	Field Outlet Pipe (FOPs) from the head to tail	Area / feddan	Date of Observation (2010)							Average	-(+) 30% correction Factor
			03-Sep	12-Sep	17-Sep	21-Sep	25-Sep	29-Sep	02-Oct		
			Estimated Discharge (at the head of each Abu XX) in liters/second								
Upstream FOPs	FOP1	60	26	32	0	0		10.13	25	15	11-20
	FOP2	90	0	51	116	56	25	60	44	50	35-65
	FOP3	83	48	0	68	53	45	100	19	48	33-62
	FOP6	90	0	0	54	40	0	0	0	16	11-20
	FOP7	90	111	11	94	82	11	43	45	57	40-74
	Average		**37**	**19**	**66**	**46**	**20**	**43**	**27**	**37**	
Downstream FOPs	FOP9	90	27	0	12	6	44	96	68	36	25-47
	FOP10	90	16	0	13	26	61	83	100	42	29 -54
	FOP12	90	0	0	10	0	23	0	0	5	3-6
	FOP13	90	15	0	69	0	58	50	74	38	27-49
	Average		**15**	**0**	**26**	**8**	**47**	**57**	**61**	**30**	
	FOP15	80	This FOP is a tail, much stored water , since the channel is bigger and difficult to estimate the discharge								

Source: Round trip Assessment of the Minor during the field work

Graph 4.2: Water distribution in upstream and downstream parts of Tuweir canal

The above Table (4.2) is a rough estimation of discharges in operated (cultivated land) FOPs in 2010 season in Tuweir minor during round trip observations of the specified FOPs on the specified dates. The estimation was supported by simple flow measurements using orange method. The unmentioned FOPs in the above Table are left fallowed or winter crop numbers' FOPs (i.e. there is no water flow into these FOPs during study time). Generally the Table shows water supply at downstream FOPs was less than that of upstream FOPs before excavation was done. But after the excavation (after Sep 21-2010), the discharge to downstream FOPs (FOP 9 and FOP 10) was better than to upstream FOPs (FOP 1) because of the above mentioned sedimentation effect (Figure 4.4).

The values in the 'average column' of Table 4.2 indicate that FOP 1 and FOP 6 in the upstream part have less discharge than downstream FOPs except for FOP 12. But the case especially which pronounced in FOP1 before the minor silt removal is; there was always much water flow into this FOP. Evidently, excess water flooded to the adjacent fallowed number when this FOP was partially or fully closed. It is evident in the Table that, there is area size difference between the cultivated FOPs. However, there is no functional discharge controlling structures that help water to deliver according to the area coverage of each FOP. For instance FOP 1 and FOP 3 have no pipe at all; the water runs into their Abu XX without control only controlled with mud filled-sack. In addition, as already mentioned in chapter 3 under 'FOPs operation' session, there was also a case though FOPs were observed closed, after a moment these FOPs would be observed open, but for the sake of time I have not measured them back. So in reality there is not water shortage in these upstream parts. However, in downstream FOPs such as FOP 9, 10, 12 and 13 zero refers to the fact that the FOP was already opened, but there was no water that can be delivered to these FOPs. Especially FOP 9 and 12 face a problem of water to discharge into their Abu XX. As a consequence many 'nakoosies' channels from FOP 10 and FOP 13 to FOP 9 and FOP 12 respectively have been observed. Also during these round trip assessments, it was found that there are differences of water distribution between upstream and downstream parts of an Abu XX (see examples in Annex).

FOP1- at the head **FOP10- downstream**

Figure 4.5: Grass covers difference because of water distribution difference

Road between Number 3 and 4 **Road between Number 13 and 14**

Figure 4.6: Excess water flow in upstream Abu XX

Moreover, photos in Figure 4.7 below show that water distribution differences between upstream and downstream parts along the Tuweir minor section. That means if the upstream FOPs are opened then the downstream FOPs cannot get water at all or less water, which is not enough for the farmers to irrigate their fields. As stated in the previous chapter, this situation has been aggravated because there is no water distribution schedule in operation among FOPs. Consequently water inequity can always be observed between upstream and downstream parts of Tuweir minor.

Figure 4.7: Water distribution difference in Tuweir minor Section (Plates were taken on September -17-2010)

4.2.3 Water distribution differences within a number

This is also a significant issue in the area: farmers who have hawasha at the head of an Abu XX recieved water relatively more reliably and on time than the downstream farmers. To assess the situation it was observed that for more than seven days in two numbers of the Tuweir minor: one in the upstream and another in the downstream. It was clear that downstream farmers can get water only after the upstream farmers have finished their irrigation in each of the numbers (Figure 4.7). That means that the downstream farmers in a number have no reliable irrigation water on time. As a result many downstream farmers have been forced to irrigate their crops too late or insufficiently. More than one week delay, it was observed in number 11. Table 4.3 below shows interview results from some farmers in Tuweir minor about the time lines of irrigation. Indeed it is according to their perception of irrigation interval. That is based on what they think a good interval or problematic for their crop according to their experience. Accordingly, here, irrigation delay refers the time from which farmers want to irrigate but they could not able to irrigate because of water shortages in the area as that time. Hence, long delays can have negative effect on the plant.

Table 4.3: Farmers claim of irrigation delayed due to water distribution in Tuweir minor

Farmers	Farm Location	Irrigation delay (days)	Date of interview	Remarks
1	Number 11	4	06 Sep-10	the off take was closed
2	Number 14	7	06-Sep-10	the off take was closed
3	Number 10	5	26 Sep-10	Still she has not got water to irrigate
4	Number 11	16	24-Sep-10	He started to irrigate on this day but he expected yield Reduction because this delay
5	Number 14	30	27-Sep-10	Irrigating on this day
4	Number 11	9	22-Sep	Not yet get water to irrigate
5	Number 3	6	28-Sep	The water distribution changes (decrement) arises after excavation
6	Number 10& 11	5	26-Sep-10	Started irrigation on the 28th of Sep
7	Number 11	15	30-Sep	She start irrigation on this day
8	Number10 & 11	4	24-Sep	This farmers started irrigation on 30- Sep-10

Source: interviews with farmers in the Specified numbers of the Tuweir Minor

This result was confirmed through observations in these two numbers - number 3 and number 11. Of course relative to the downstream number, number 3 farmers were irrigating on time when they want to irrigate. Only some downstream farmers' hawasha of number 3 were faced with the problem after excavation, but the problem was not serious like number 11 farmers. At least there was water in number three Abu XX up to the tail, while number 11 Abu XX was dry completely after the middle. I observed in number 11 that, starting from 12 September 2010, water flow to this Abu XX was limited and many farmers were complaining about it frequently, because their irrigation was delayed from a few days to more than 15 days as the above Table shows.

Farmers also confirmed water distribution variations within the number-between the head and tail end farmers. I met Abdulhaman whose farm is at the head of Number 11 on September 19 while irrigating his sorghum plant in this number. The tail end farmer in the same number, who is called Hawa Silma, only managed to get water to irrigate on September 30. Yet she wanted to irrigate two weeks before that day. But no water at all was available in the Abu XX before September 30 for more than two weeks (observations and interviews) particularly below the middle of the Abu XX channel. Hence, it is at least 11 days difference of irrigation between these two head and tail farmers. For this difference the reason might be socioeconomic or power. Most owners were working at the head while, if one goes to the downstream, the number of sharecroppers is more significant. On the other hand head- tail issues of water distribution are significant. Obviously, at the head farmer can capture the amount of water available regardless of power /socioeconomic factor. Here, with different scales there is a difference in accessing irrigation water at each level of the number between upstream and downstream hawashas.

This is because, as one can imagine that as there is no plan for irrigation scheduling between farmers to irrigate their farms turn by turn, the head farmer might even be irrigating twice before the tail farmer does not irrigate once. One farmer, who is called Ahamed, whose farm is at the tail end of number 3, claims that 'usually the head farmers irrigate two times, while I do not irrigate even once'. There are no working rules to govern each farmer to irrigate fairly. However, the problem is more severe for downstream farmers than upstream tail end farmers within the minor. As mentioned, I have observed the two numbers for about 7 days, and I found that there was even mismanagement of water (excess water flow and Abu XX breakout flow, say on September 17-2010) in the upstream FOP, while the Abu XX of number 11 ran dry after a few Abu VIs from the head. Thus the effect clearly results unequal water distribution between farmers.

4.3 Impacts of the Observed Water Distribution Pattern

First an introduction on the main effects, namely yield reduction and increased conflicts will be provided. (What about on-going socio-economic differentiation between head and tail end farmers? As well as, what about changes in cropping strategies as a result of water insecurity?)

Table 4.4: Yield difference between the past and last year (2009/201010)

Farmers	Farmers location in the minor	Crop type	Previous seasons Average Yield		Average Current yield		Average Yield Reduction	
			Suck/feddan	Kg/ha	suck/feddan	Kg/ha	suck/feddan	Kg/ha
1	FOP 9 & 10	Sorghum	13	3095	4	952	9	2143
2		Sorghum	10	2381	2	476	8	1905
3	FOP7	Sorghum	13	3095	2	476	10	2381
4		Sorghum	10	2381	2	476	7	1667
	Average		11	2619	3	714	9	2143
5	FOP 1	Groundnuts	27	6429	18	4286	20	4762
6	FOP 10	Groundnuts	20	4762	8	1905	13	3095
7	FOP 2	Groundnuts	30	7143	25	5952	5	1190
	Average		26	6190	13	3095	9	2143
9	FOP 2	Wheat	14	3333	4	952	10	2381
10		Wheat	13	3095	1	238	12	2857
	Average		13	3095	3	714	11	2619
1 feddan=0.42 hectare			1 suck=100 kg					

Source: Interviews with farmers mainly based on the situation last year (2009)

Yield reduction

Though it is difficult to justify, since there are many factors affecting yield reduction (like inputs (fertiliser, land preparation, pesticide usage, selective seeds and management)), many farmers in Tuweir canal claim that their yield reduction from time to time is mainly because of poor water distribution between upstream and downstream parts of the minor and Abu XX and even within a hawasha/Abu VI. So, even if it is not easy to assess the water distribution impact on yield quantitatively without detailed research, Table 4.4 provides some clue of yield reduction which was deducted from interviews with farmers, in Tuweir minor, especially considering last year's water shortage problem over the past their good harvest time. Most farmers claim that due to last year situation in Tuweir minor most farmers did not get yield at all. But as explained above, it does not mean the yield reduction is only because of water distribution differences. Indeed, simply from the above observed water distribution difference between users, yield reduction is expected. Omer

Elwaded, (1986, who sited Hamid Fakki et al, 1984) stated that clear yield reduction originates from inequitable water distribution for cotton plants within the scheme depending upon the location and the level of major, minor and Abu XX field channel.

Conflict between farmers
Unequal water distribution creates frictions between upstream and downstream farmers in a minor or number. Some farmers told me that they have found their Abu VI was closed by someone. By default they know who did that, so they have experienced conflict with that person. Otherwise they should watch their Abu VI in the evening or they should look for other options, like a pump. Between who are using nakoosi and other practices like creating a head/close NSWs and the impacted downstream users by these practices conflict is obvious. Of course, they said they have been resolving the conflict soon, through their close social relationship like Religion. But one reality is usually at the tail end of the minor, most of the farmers are sharecroppers while at the head end of the minor, most of them are owners. This can be a reason that tail end farmers could not equally negotiate on water right or other management claims like maintenance as the head end farmers.

Unequal water distribution has also forced farmers to spent additional costs such as pumping and labour. Farmers in Tuweir minor said, last year they used pumps to irrigate, and downstream farmers always use pumps for the winter season crops. But it costs them a lot of money, renting a pump is about 42 US $ at present currency per one and half days pumping. This is too expensive for most farmers to buy their own pump. In addition when the amount of water decreases in their Abu XX farmers need a longer time to irrigate than with a normal flow. That way they incur additional labour or labour costs.

4.4 Conclusions

The past relatively formal and restricted water indenting according to the crops need and the canal capacity estimation has become a theory rather than a practice. Nowadays such practice is gone instead water is released to each level jus as a habit, no scientific approach crop water calculation over canal capacity balance at all. As a consequence of unequal, unreliable and unscheduled water distribution to users has become a practice. This does not mean the past system was absolutely had followed a scientific way; however, at present in many cases the water management in the Scheme has become worse than in the past.

Factors such as operation of the FOPs by every farmer and their irrigation perceptions, lack of concern /sense of ownership while managing the system and their different practices to cope up water distribution changes (see chapter 7); mismanagements of the system by officials like poor operation and maintenance; and absences of working water management rules for users are aggravating the situation of unequal water distribution within a major/minor/number.

In Tuweir minor, there is water distribution differences between numbers, usually upstream farmers get relatively good amount of water than downstream farmers. Such variation was also observed within a number. Usually the downstream farmers get less amount of water. To get a better amount of water they should wait until the upstream farmers finished their irrigation. The way of excavation has also impact on water distribution as can be seen in Table 4.2 in Tuweir minor. After the minor excavation the downstream farmers got relatively good amount of water. However, some upstream numbers get limited amount since the water level in the minor drops down when the sediment removed.

The impacts of this unequal, unreliable, or unscheduled water distribution have long term and short term effects on users. In a short term effects it can clearly reduce yields; arise conflicts between farmers or expose farmers to additional costs, like renting/buying pump to get irrigation water, then finally deterioration of the irrigation infrastructures as a whole. Further more in a long term effects of water distribution changes, farmers have been leaving their villages to seek a job outside the scheme; the remaining farmers are changing their cropping patterns. That is a focus on less risk bearing crops (sorghum).

Chapter 5 Maintenance of the Minor

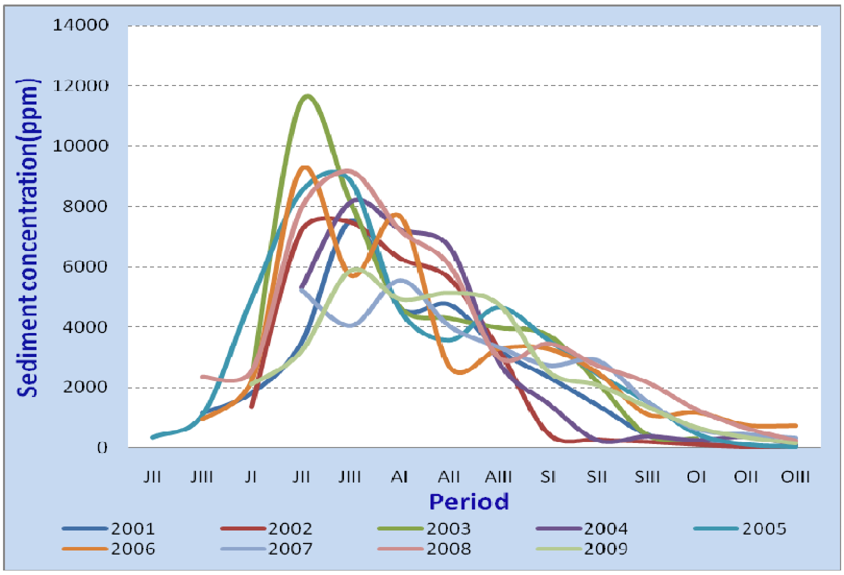
Before the 1970s the maintenance issues were less sensitive, since siltation was not recognized as a serious problem in the Scheme (interview with Engineer in HRS on August 17, 2010). However, starting from the late 1970s siltation has become the biggest constraint affecting the operation of the scheme (World Bank, 1990). It led the scheme to deteriorate (Ahmed, 2009). Even though most of the government expenditure has been on silt removal, it has been beyond its capacity to control it. The management and technical gaps have been also aggravating the situation.

Appreciating these negative impacts of siltation on the scheme, the Ministry of Irrigation and Water Resource (MOIWR)-HRS (Hydraulic Research Station) started an intensive Sediment Monitoring Programme in 1988, in collaboration with HRL –Wallingford. The programme covered 52 locations in the Gezira Scheme and the Blue Nile River. Their cooperation ran for two years. There after HRS has continued the silt monitoring programme up to the present though it covers a limited number of locations, only at Sennar and K57 (the pool of the two main canals). Measurements of sediment concentrations in the major and minor canals were stopped after the programme ended in 1989. The limited data about sediment concentrations in the scheme make a concise assessment of the siltation problem impossible. In this chapter an indication of the seriousness of the silt problem will be explained based on the above described HRS silt concentration measurements, yearly records of volumes of silt excavated in the Gezira Scheme (HRS, 2008) and my own daily silt concentration measurements and observations in Tuweir minor and Kab El Gidad major in September 2009.

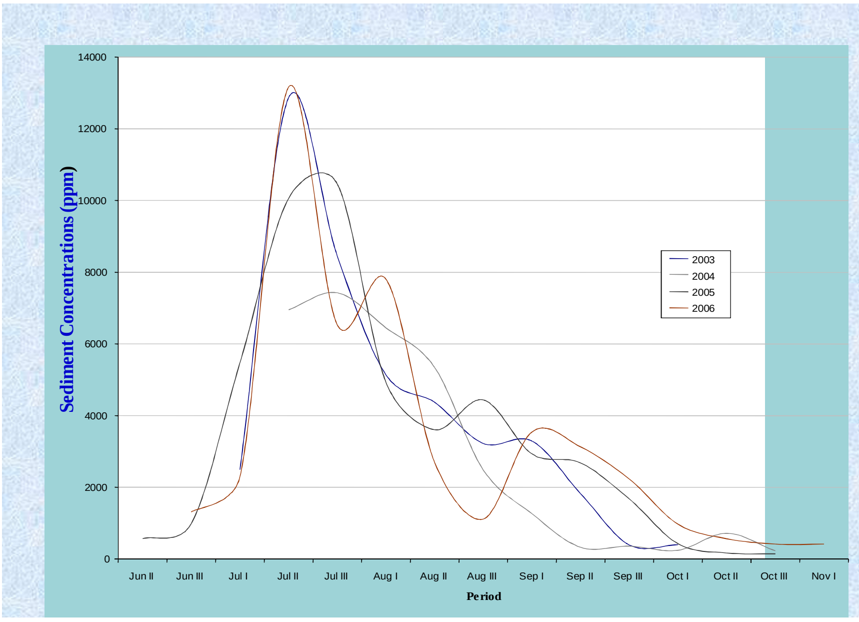
This chapter describes the siltation situation in the Scheme starting from late 1980s and maintenance activities (mainly de-silting) being undertaken at the lower levels of the scheme. The sub-sections summarise the causes, impacts and costs of siltation (section 5.1.1-5.1.3). Under maintenance activities, maintenance activities divisions between actors, the excavation situation and cost recovery conditions of Tuweir minors (minor and Abu XX and Abu VI) are elaborated. Finally conclusions are drawn.

5.1 Sediment loads in the Gezira Scheme

Based on MOI records, Ahmed (2009, p. 4) reported that in the 1933-1938 season the mean sediment concentration of water that entered the GS main Canals in August was only 700 ppm, while it had increased to 3,800 ppm in 1988/1989, an increase of more than five times. However, during the 1990s the mean August sediment concentration levels reached to about 8,000 ppm, more than 11 folds the concentration level in the 1930s. The sediment monitoring data collected by HRS of MOIWR, also show that the peak sediment concentration in the Blue Nile downstream of Sennar in 2003 (Graph 5.1), was more than 11,000 ppm. In the same Graph the sediment concentrations in 2007 and 2009 are relatively low. This might be largely because of a low erosion rate in the upper catchment areas of Blue Nile. The Blue Nile has high yearly and seasonal variation (Wold bank 1990, P.14). On the other hand the peak sediment concentration that entered the Gezira main canal from 2003 to 2006 is on average 12,000 ppm (Graph 5.2), many fold increases over 1933/38. Especially in 2006 it highly increased about 13,000 ppm. And these maximum sediment concentrations have been recorded mainly from July II to August I (Graph 5.2).

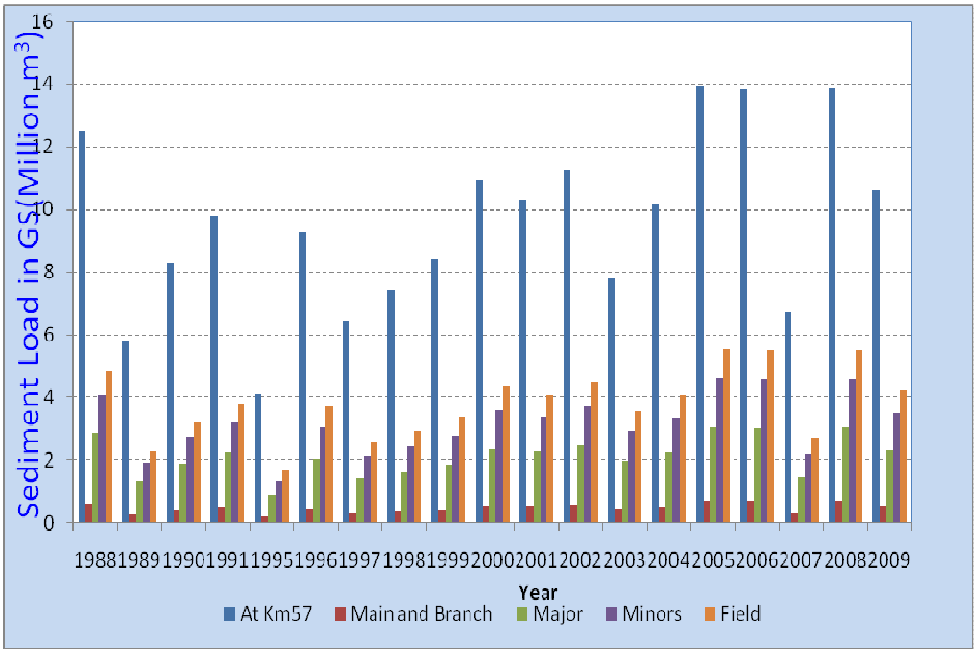


Graph 5.1: 10 days Average sediment concentration of the Blue Nile at downstream of Sennar
(Source, hydraulic Research Stations-HRS)



Graph 5.2: 10 days average sediment concentration in the Gezira Main Canal at Sennar (from 2003-2006)
(Source: HRS-Presentation of Younis, 2008)

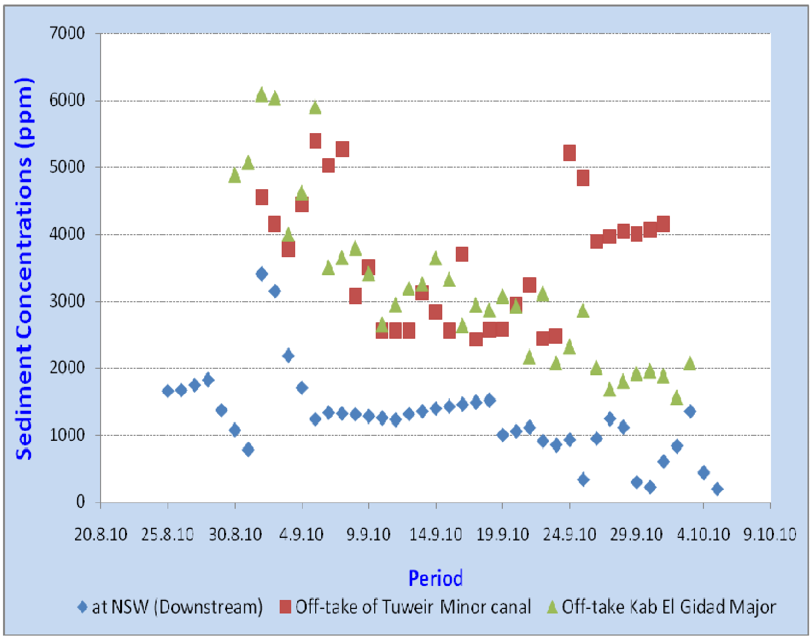
The sediment load entering at Sennar is distributed into various canals of the Scheme in different proportions. Graph 5.3 below show this sediment deposition at different levels of the scheme. For the seasons from 1988 to 1991 the data source is World Bank report. Sediment concentrations for 1995 to 2009 seasons are taken from the scheme sediment concentration data as reported by Younis in HRS. Then, to distribute the Scheme sediment concentration to each level (from main to field canals), the sediment entering proportions into the different levels which were studied in 1988 by HRS and Walingford is used. I adapted these proportions as reported by Younis. To mention, these proportions are 5% of the total sediment which entered the scheme deposits at the main and branch canals; 22% at majors, and 33% at minors while the remaining 40% goes to the fields (Younis, 2009). But would be this proportion valid over many years is questionable. It is not clear whether sampling has been taken yearly or not, in what condition- at the same location, same discharge and time are exactly the same as the previous years? Is any correction factor developed in deviation of sampling condition? These all are not clear. So, the accuracy of the Graph 5.3 at present situation is questionable. I believe in this regard detail researches have not been taken, since from 1988s the figures are almost the same. However, here it is used to estimate the sediment load roughly and to have an overview in each level especially at the minor.



Graph 5.3: Sediment load to different levels of Gezira Scheme (from 1988 to 2009)
(Source: from 1988 to 1991 (WB, 2000); from 1988 to 1994 and from 1995 to 2009 HRS)

Generally the trend shows that the sediment load is increasing though variations have existed from year to year, especially between two consquetive years 1988 and 1989; or 2005 and 2006 there is large variations. Mainly this can be due to the rainfall situation of the Blue Nile catchment areas and/or variations in the operation of Sennar dam. If rainfall is less in the upper catchment areas of Blue Nile River, the incoming sediment with the River will be less, and then less sediment is transported to the scheme. On the other hand if the amount of rainfall is less in the command area of the Scheme, the system is forced to release the maximum volume of water to satisfy the crops' demand, so that much silt will be transported into the scheme. At the same time when the Sennar dam is opened in the peak season (July-August) due to crop diversification in the scheme, the sediment load at the various levels will be increased. Moreover the time and ways of sampling can also bear considerable influence on the variation that the graph 5.4 shows.

Furthermore, during the field work stay, to estimate the sediment concentrations at the major and minor levels, point silt samples were taken daily for a period of 30 days at three locations: at the off take of Kab El Gidad major (upstream of the regulator gate), at Tuweir minor off take, again in the upstream part and at the third NSW of Tuweir minor. Though the sampling period was almost at the end of the peak sedimentation period that has been reported by HRS researchers, still the results indicate significant amounts of sediment concentrations.



Graph 5.4: Sediment concentration in Kab El Gidad major and Tuweir Minor in September 2010

Especially in the beginning of September 2010, it was more than 6,000, 4,000, and 3,000 ppm at the Major, Minor and NSW respectively (Graph 5.4). The spike in Tuweir minor arround 25 September could be because of excavation disturbances and/or rainfall during sampling. From 26 September to 3 October 2010, the 'zig- zag shape' in the NSWs is due to excavation disturbance and variable water flow conditions of the minor (sometimes good flow other time zero). In this regard the trend in the major is almost uniform because the flow in the major is not influential as the NSWs.

Besides siltation in the scheme, there are also different types of aquatic weeds which are growing in the scheme, mainly in minor canals. They produce serious impacts on siltation; in turn siltation facilitates their growth by supplying nutrients and support (Ahmed, 2009). These weeds can be classified in three categories such as: floating, submerged and emerged (Ahmed *et al.*, 1989). The weeds limit water flow to the extent water cannot reach to the tail end of minor canals (World Bank, 2000). These weeds highly infested Tuweir canal to a degree that it is hard to see the water level or the flow in the canal (Figures 5.1 and 5.2). During the research time, it was noticed that one of the reasons proffered by farmers for water shortage at the tail end is because of the prevalence of these weeds. They also affect the operation of the FOPs.

Figure 5.1: Weeds at first reach of Tuweir minor

Figure 5.2: weeds in the last reach of Tuweir minor

5.1.1 Causes of siltation

The increases in sediment concentration are attributed to different reasons (World Bank, 2000 and Ahmed 2009), such as the diversion of the maximum volume of water that can be carried by the main canal to service the successive extensions (e.g. the Managil Extension of 420,000 ha) of the scheme to its present size, and increased crop intensity from the 1960s. Hence, the current operation of the Scheme is very different from those anticipated during the design (see chapter three). The amount of water discharged to the system at Sennar dam has increased more than three- fold from 2.0 billion m^3 in 1957/1958 to 7.0 billion m^3 in 1997/1998 (Wold Bank 2000). This additional amount of water carries an additional amount of silt. Second, planting time has been moved forward, occurring one month earlier than the previous seasons. Before 1960 no water entered the scheme in late July and early August when sediment concentrations are at their highest in the Blue Nile River. However, nowadays water enters the scheme during that time. Third, the capacity of the Roseires and Sennar reservoirs to trap silt has been reduced since their dead storages have silted up. Finally, there is increased erosion in the upper Blue Nile catchment areas in Ethiopia. Canal bank erosions within the scheme (Figure 5.3) and debris which are carried by wind form additional causes for siltation (Figure5.4).

Figure 5.3: Canal banks erosion in the Gezira main canal

Figure 5.4: Floating debris which might affect Flow Velocity

5.1.2 Impacts of siltation

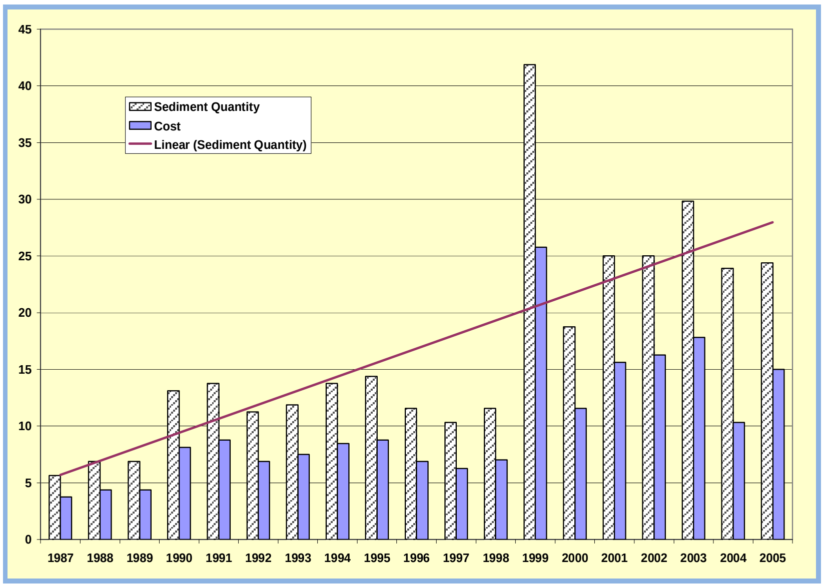
The deposition of sediment in irrigation canals and its subsequent built-up of aquatic weeds results in losses in production of great magnitude. The effects are manifested in water shortages in the tail end numbers that clearly affects potentially obtainable yields and some areas have been taken out of production, due to an increase in land level because of sedimentation. For instance, in Tuweir minor on average at least 16m*16m rubat land at the head and tail of each hawasha cannot give any yield. First of all the seed might not germinate (Figure 5.5) because water cannot reach it. Second, if the seed do manage to germinate, the yield will often be too low (observations and farmers interviews). One may say that this can be attributed to poor land levelling. However, it is because of excessive silt deposition into the fields that also affects the land levelling.

Figure 5.5: Bare land at the tail of a hawasha due to increased land level

To cope with those impacts major efforts have been undertaken by the Sudanese to clear silt from the canals. Over 60% of the total maintenance budget has been invested on de-silting, yet much less investment has been made available for structure maintenance and de-weeding (World Bank, 2000). Despite the intensity of these efforts, they do not match the rates at which silt is accumulating in the canals. Such problems were confirmed in the field, in Tuweir minor canal. No maintenance satisfaction by farmers was observed in the area, since the problem has been affecting them.

5.1.3 Amount and costs of sediment removal at scheme level

The trend in quantity of removed silt and its cost from 1987 to 2005 (Graph 5.5) shows that from 1999 onwards higher amounts of sediments have been removed. The amount of removed sediment increased from 11 million m^3 in 1998 to 41 million m^3 in 1999. But the amount of sediment load entering the Scheme (Graph 5.3), shows that the 1999 season was comparable with the 1988 season and less than the amount entering in the 1996 season which is the maximum record in the scheme. So, where did the extra sediment removed come from? Erosion within the scheme is not significant enough to produce such an effect. Rather it is likely that the recorded amounts of 'removed' sediment are untrue. One reason is, the responsibility of decision making on sediment amount to be removed. Mostly engineers deal with the excavator instead of taking exact measurement. Finally they agreed upon on the amount of silt removed what the excavator stated since no exact measurement done before (personal communication with HRS engineer, on 12 October 2010). So, this cannot be removed sediment. If this much sediment was removed no any canal feature would be seen in the Scheme. Instead it is one of the management failures indicators. Ahmed argued that '...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' (Ahmed, 2009, p.7). And the amount of money paid was based on this reported fake sediment removed amount.



Graph 5.5: Quantity (million cubic) and cost (million US$) of sediment removal in GS (1987 to 2005) *(source: HRS by Younis, 2008)*

5.2 Practices of maintenance observed at Tuweir minor canal

5.2.1 Division of maintenance responsibilities at minor and scheme level

As explained in chapter 3 on the operation of the scheme, again for maintenance activities, the management of the Gezira Scheme had been divided between the MOIWR and the SGB, a parastatal corporation which replaced the Sudan Plantations Syndicate in 1950. The MOIWR was responsible for the maintenance of the main system (main, branch, and major canals) and minor canals, and the SGB for the Abu XX (World Bank, 1990). SGB was also responsible for the maintenance of the irrigation structures (at minor level) and other infrastructure which includes a railway network of 1,050 km in length, used to transport cotton and agricultural inputs. However, all main works on regulator gates and pumping stations including regular maintenance, repairs and installation of replacement parts was carried out by the Mechanical and Electrical Department of the MOIWR (*ibid*). However, in January 2010, all MOIWR management concerns of the scheme were transferred to the previous SGB or to SG-2010. In turn the SG-2010 hired private companies which carry out maintenance works and assist in the operation of minor canals (the whole history about this change is already mentioned in chapter 3).

Pre 1950s maintenance of the irrigation networks routinely was carried out by the irrigation department of the Government between April and June, but the overall control resided with the Sudan Plantation Syndicate. De-silting and de-weeding was done all round the year except for rainy periods. Then after 1950 the MOIWR took over the responsibility and the practice continued up to 2009. The MOIWR used to carry out maintenance activities from March 15 to May 25, annually. The maintenance comprised surveying of the canals, and identifying the types of excavating machine that can be used for de-silting or de-weeding; measuring of the cross-section to know how much silt should be removed and checking out the structures whether they need maintenance or not (Interview with the former Division Engineer, on October 12-2010, Khartoum). Maintenance work was usually done under the daily direction of the Assistant Engineers and Technical Assistants of the MOIWR (World Bank 1990).

Before 1974, the Construction and Mechanical Divisions of MOIWR were responsible for the maintenance of canals, drains and roads and construction of irrigation structures. But later it was found too difficult to carry out these activities under the auspices of the MOIWR. Therefore, in 1974, the Construction and Mechanical Divisions were removed from MOIWR and established as two separate Branch corporations: the Earthmoving Corporation (EMC) and the Irrigation Works Corporation (IWC). Both were constituted as semi-autonomous bodies empowered to work in the private sector and even outside Sudan. They effectively became contractors to the MOI for maintenance work in the Gezira.

The budget to carry out maintenance activities in the scheme is assigned by the federal government. But generally it responds ‘late’ and releases ‘insufficient’ funds (Adeeb, no date). Because of this MOI was not able to cope with the removal of silt and clearance of weed. Indeed, following the introduction of the individual account system in 1981 land and water charges were determined every year to recover in principle: the administrative costs of SGB and MOI, the operation and maintenance costs of the irrigation system and the capital replacements of part of the irrigation system (Eldaw, 2004). The water charges from tenants were collected by the SGB until 1995. But the collected land and water fees by the SGB were insufficient for the MOIWR to cover the costs of the desired maintenance works (*ibid*). The average recovery rate from 1985 to 1988 was 75.5% (Wold Bank, 1990). This in turn led to the deterioration of the irrigation infrastructure and low level of service provision to tenant farmers (World Bank, 2000). The SGB was aware of these problems and the difficulties faced to collect land and water charges. Hence in 1995 the responsibility for collecting water charges from tenants as well as the actual operation and maintenance of the irrigation system in the Gezira was transferred to the irrigation work corporation (IWC.) However, the IWC failed to undertake these tasks in a satisfactory manner. Therefore in 1999 the responsibility was handed back to the SGB (Eldaw, 2004 and Wold Bank, 2000).

At this time (1999), in the face of the continued serious deterioration of the Scheme, all relevant stakeholders, like the SGB, local consultants and the MOIWR and Ministry of Agriculture (MOA) became motivated to find a solution that could revert the scheme back to its historical state of success. They attributed the problem of water management to the financial shortfalls that were caused by inadequate recovery of water costs. So they proposed to strengthen the means of water cost recovery and revising water costs to ensure the financial viability of the scheme, itself a precondition for improved management of the scheme (Eldaw, 2000). On the other hand consultants from the Wold Bank associated the solutions for water management with the need for institutional changes in the Scheme. As a result they recommended the establishment of Water User Associations (WUAs) to be the primary responsible organisation for the operation and maintenance of their minors (Wold Bank, 2000). As a result the Government, considering these inputs important to restore the Scheme to its past good management performance, declared an Act in 2005, which facilitates the handing over of the responsibility of O&M works to farmers. Gradually WUAs were introduced progressively at each minor. In 2007 the Tuweir farmers were grouped into a WUA and started taking over the responsibility of operation and maintenance of their minor canal. However this institutional change did not result in the resolution of the scheme’s problems, rather the water management problem has intensified.

Also, reports show that the MOIWR faced technical and financial limitations to carry out accurate sediment load measurements or to undertake the necessary maintenance activities in the Scheme. Adeeb (no date, p.4) argued that ‘the available mechanical arsenal of silt removal is composed of aging machines imported hurriedly without technical support nor qualified operators. Some powerful companies refrained from operating in Gezira Scheme due to unjust repayment of debts. MOIWR has lost qualified engineers to private companies, special assignments, consulting firms and immigration. The standard procedures of, neither calculation of accumulated silt in a canal nor the handover of the silt clearance job are practiced any more’. Moreover, at present many FOPs and NSWs have been non-functional since the 1970s in many areas of the scheme, many roads have become inaccessible, labour intensive aged regulators prevail in the scheme. These are some of the indicators to poor maintenance in the Scheme.

Many maintenance problems were observed in the area, yet no one seemed to respond in an adequate manner. For instance, in Tuweir minor, there had been a pipe breakage at the second night storage weir (Figure 5.6, a). For more than two months the water was flowing to the fallowed adjacent number and the breakout flow was increasing from time to time. Especially on the last three days before temporary maintenance took place, the breakout flow to this number was about one third of the total available water flowing in the minor to downstream. As a result, the downstream farmers became victims of water shortage. So much water was flowing out of the system that half the numbers contained at the scene of the leakage were flooded to the extent that the Tuweir villagers were fetching water from it for household purposes (Figure 5.6, b). This leakage and resulting flooding could result serious crop damage for at least half of the flooded number where crops had been planted.

Meanwhile, when farmers were asked why do you not maintain it? Their response was ‘we cannot afford money to pay it, it is too much for us, and instead we have been asking a solution to ‘responsible bodies’, but no one gave us a solution’. Here, you may ask who the responsible body is. It was already observed that in principle (Gezira Act 2005) is stated farmers are responsible for their minor O&M activities but at the same time farmers are claiming they cannot afford it, especially just before harvest. However, later when the problem got too serious, farmers themselves organised Tuweir village school children to maintain it. Then the young students put soil filled sacks and stones over the gap, so that the problem was contained in a temporary fashion.

The same problem was also observed in Wad Hezam minor, which is upstream of the Tuweir minor; the breakout flow from this minor flooded into the final three numbers of the tail of Tuweir minor. As a result, some of the Tuweir minor farmers were forced to plant late and some other left their Hawasha for winter crops even when they had wanted to plant summer crops (interviews with downstream farmers, September 4/2010). The tail end number of the Wad Hezam minor was left fallow, possibly because of this problem (Figure 5.6, c)

(a) (b) (c)

Figure 5.6 Maintenance situations in Tuweir minor

(a)-the broken pipe at the 2nd NSW; (b)-Water fetching from the flooded water caused by the breakage; (c)-Flooded water at the tail of Tuweir minor from Wad Hezam minor breakage (the picture was taken after the problem had been resolved, but one can still observe some flow).

Basically, the 2005 Act states that the full responsibility for O&M would be handed over to the farmers after rehabilitation works would have taken place. But where is the rehabilitation? The only thing I heard about this was that a Rehabilitation committee had been established to do all the necessary rehabilitation works for three years, including activities like de-silting and replacing the old and damaged gates of the system. However the Committee is alleged to have stopped working soon after their inauguration, due to a lack of finance. As one member of the committee confirmed in the first year the MOF released small amounts of money, but for the second year nothing was released (interview with one of the committee members, August 17-2010, HRS). In Tuweir minor no rehabilitation activity had been observed, despite the fact that many FOPs have disappeared or are seriously damaged. In addition many non-functional NSWs exist in the Scheme.

5.2.2 Maintenance activities at Tuweir minor in the 2010 season

It seems that only de-silting with as underlying principle ‘let the water flow into FOPs’ actually takes place. Evidently, the de-silting that was carried out by Taiba company in the 2010 season at Tuweir minor, including other minors of Kab El Gida major, took place in a random fashion (‘here and there’) during the growing season (routs from 1 to 9, see figure 5.7). The decision to de-silt was based on the severity of the sedimentation problem as the Engineer persuaded the Tuweir minor farmers. However farmers complained that, sometimes de-silting of a minor depends on the activeness of the WUA in a minor. If the WUA is relatively influential in a particular minor, de-silting might take place in that minor earlier than in others. Unfortunately Tuweir Minor’s WUAs were not so active, failing to secure early maintenance. This all reflects that the Companies cannot cope with maintenance activities in a systematic way. Instead the maintenance strategy in minimalistic aiming to minimize sediment loads in order to prevent complete stoppage of water flows into FOPs. Hence maintenance assessments or de-silting for the minors in Kab El Gidad major were not carried out before planting as in the past. This uneven sediment clearance between minors also can be a source of unequal water distribution among minors. The one which is cleaned first can get a relatively good supply of water while the one cleaned last hardly gets sufficient water, since the sediment load reduced the capacity of the canal.

In addition I noticed that in Tuweir minor, the excavation was done in late September at a time when most farms needed water to irrigate their crops. As a result of the excavation, the off take could be closed only partially in the day time during excavation time. Then all the FOPs were opened and almost mudded water, due to excavation disturbance, entered into FOPs in the day time to some extent and fully during the Night. The latter phenomenon produces a problem in terms of Abu XX siltation and rising up of farm level.

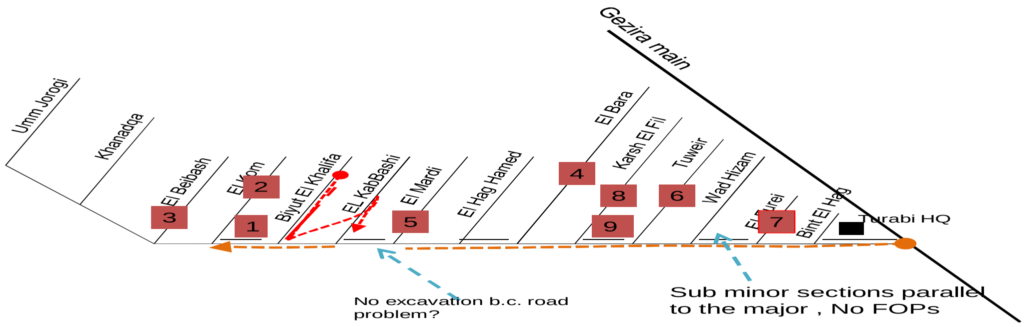


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Figure 5.7: Excavation movement in Kab El Gidad Major and its minors:
(Source: Interviews with excavator driver and observations).

In the above Figure, the numbers from 1 to 9 represents excavation sequence:1 refers to the first excavated minor canal and 9 is the last excavated canal so far we were in the field.The Red broken line represents excavation was done by different excavator companies rather than Taiba company; the Orange line refers the major excavation. It was continual to the direction of the arraw as the excavator driver confirmed.

Moreover, sediment removal was only based on observation and just for the immediate resolution of pernicious blockages or else to evade persistent complaints from farmers (Interviews and observations). Hence maintenance was only undertaken on an ad hoc basis. Canal clearance was limited in extent, covering only the head or one side of the minor cross-section, or at the pool of the major off-take, instead of full maintenance of a whole canal section to allow for good water distribution. Earlier I argued that no measurements were taken in Tuweir canal to facilitate the last excavation that took place in September 2010. Also no maintenance assessment was undertaken before the excavation. Evidently, the measurement and excavator driver men were informed to do the work at the last minute, *viz.* in the afternoon just one day before excavation would take place. I met the man responsible for taking measurements three days before the excavation would take place: at that time he had no idea about the imminent Tuweir canal de-silting.

Furthermore, this measurement man had been recently employed, just four months ago, directly after completing his high school education. He had no relevant work experience before; except for one month training that was given by his employer company (Hadaf-private Company but some people also said it is a security company). His responsibilities are to 'jump' into the canal to measure the amounts of sediment load and to follow the excavator man to monitor the original cross-section and assess the quality of work. He admitted that to do the work precisely is not yet easy for him, so mostly the decision to remove sediment was made through observation with the Engineer. Actually it was done in this way during the 2010 excavation season. After the joint observation, the excavator driver is told to remove this much length of the canal instead of the measured amount of sediment. This practice was also confirmed by the previous measurement man, one of the MOI personnel who were retrenched due to the new change. He claimed that 'no measurement has been taken this year except telling the driver how much length of the canal section he should clean'. Fortunately the newly hired measurement man is this man's son, who benefits from the experience of his father. In fact taking accurate measurements has not been practised for long time (Ahmed, 2009).

5.2.3 Excavation situation of the Tuweir canal

The excavation situation at Tuweir minor is explained mainly on the basis of observations in the field. The de-silting of Tuweir canal was done as follows:

- ❖ At the first two reaches de-silting was done at both sides of the minor section;
- ❖ For the next two reaches only one side had been cleared, with the sides of field outlet pipes (FOPs) done in a hurried fashion that raises a question of quality;
- ❖ And the last reach, which covers half the length of the minor canal, was left without any clearance.

Yet the latter stretch of minor canal has been infested with aquatic weeds (Figure.5.8). Also weeds and sediments were removed together though it was supposed to be cleaned separately with different machines.

(a) Both sides cleaned **(b) one side clearance** **(c) no clearance**

Figure 5.8: How excavation looks like in Tuweir minor (it took place in late September 2010)

The quality of excavation is questionable (see Figure 5.9, c and d). Though farmers always seriously want excavation of their minor, they also confess that they experience no relief whether excavation is done in their minor or not. The farmers observed that the problem of limited water supply due to siltation returns within less than a month after excavation. Hence the effects of excavation activities do not even last the duration of one season. In addition to the above mentioned main reasons for poor maintenance (technical and management inefficiencies), the quality of silt removal is negatively affected by the piles of removed sediments at both sides of the canal banks. These piles make it very difficult for the excavator to drive along the banks, so that the driver spends much of his time trying to level the road to facilitate machine movement (Figure 5.9, a). In some instances the driver is forced to leave parts of the cross-section without cleaning at all, due to the inability to remove the accumulated silts on the canal bank. As a result the driver just cleans whatever section he can access. On the other hand the quantity of silt removal will be reported and the cost will be paid is based on the amount which is suggested by the engineer to have been cleaned. Another problematic aspect of the way excavation was done is that ideally the excavator should put the removed sediment back on the road, and remove the piles of past removed sediment along the canal banks (Figure 5.9 b). In practice this does not happen aggravating the problem for the next sediment removal and creating a transportation problem for farmers. Moreover, due to rain or winds part of accumulated sediment erodes back into the canal or onto the farm plots, adding to the sediment load in the canal and incrementing land levels on the farm plots.

(a) (b)

(c) (d)

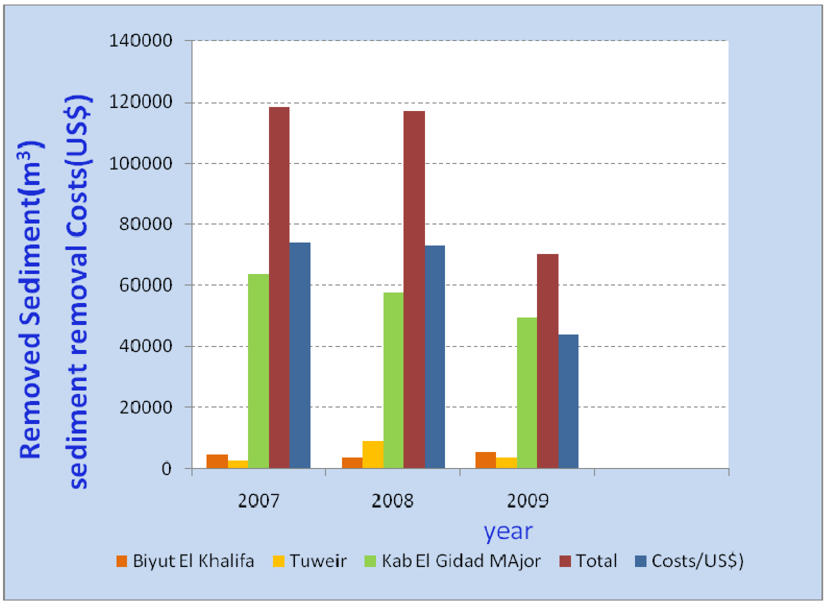
Figure 5.9: Tuweir minor excavation situation:

(a)- Levelling the road; (b)- accumulation of removed sediments on the road and (c)and (d)- canal cross-section before and after 10 days of excavation

5.2.4 Cost recovery of Tuweir Minor

To estimate the degree of cost recovery for Tuweir minor in the last three years, from 2007 to 2009, Graph 5.6 is presented based on rough data furnished by the MOIWR office in Turabe and my own estimations of the amount of cost could be recovered. First to estimate the collected water charges from tenants in Tuweir minor during the three seasons, I estimated 12 numbers of 90 feddan land size (comprising 75 % of the total command area) had been planted on each year. Also it is estimated that 70% of the water charge had been collected for the seasons 2007 and 2008. However, in the 2009 only 50% is estimated. For this season many farmers were claiming crop failures due to water shortage. So, it might resulted significant negative impact on water charge collection in 2009. The amount of charge per feddan is estimated lower amount, that on average for all the main crops 35 Sudanese Pound (14 US$) in 2007, and 30 Sudanese pounds (12US$) for the 2008 and 2009, since it is realised growing cotton had been decreased during these years. Instead much sorghum has been growing which has less cost recovery amount (Table 5.1).

Accordingly, in Tuweir minor, the total estimated potentially collected water charges for the three seasons could be 32670 US$(see Table 5.1 below), and the amount that might be invested for the canal maintenance of the three years, could be on average 9,328US$ based on Graph 5.6 that is 29% of from the total potentially collected money in the minor. On the other hand, as explained above, maintenance is almost only de-silting, so this amount of money could be invested on de-silting. Then there was 71% of extra collected money left for other purpose during the three seasons. Hence, I can say that the amount of charge could be collected from farmers can be enough to their minor maintenance at least for de-silting.



Graph 5.6: Sediment removed and removal costs from 2007 to 2010 in Kab El Gidad Major and its minors
(Source: MOI-Turabe Office). N.B the total (the red column) refers sum of all the removed sediment in the major itself and in all its minors. Here Tuweir and Biyut El Kalifa minors are presented representing head and tail minor canals of Kab El Gidad major

Table 5.1: Estimation of cost recovery in Tuweir minor for the last three years

Year	Removed Sediment (m^3)	cultivated land (feddan)	charge /feddan (US$)	collected water charge (%)	Collected Water Charge (US$)	Total Maintenance cost/ (US$)	Tuweir Maintenance Cost (%)	Estimated Recovery (%)
2007	2635	1080	14	70	13230	1647	12	803
2008	8902	1080	12	70	11340	5564	49	204
2009	3388	1080	12	50	8100	2118	26	383
Total	**14925**	**3024**			**32670**	**9328**	**29**	**350**

(Source: Graph 5.6, which is from MOIWR office-Turabe and farmers interviews and estimation)
N.B.:-*Cost of sediment removal per m^3=0.625US$ (taken from 2009 estimation by Ahimed 2009);*
The removed sediment was collected from Turabe Office and charge per feddan was collected from farmers' interviews

5.3 Maintenance of Field channels (Abu XX and Abu VI)

Before the onset of the IMT era, the responsibility of Abu XX maintenance before planting resided with the SGB, whilst during the growing time it was farmers' responsibility, with follow ups done by field inspectors. There were also penalties imposed on those tenants, who failed to do maintenance in time or according to specifications. But following to the management transfer, the full Abu XX maintenance responsibility was transferred to the farmers around 2007. Each individual farmer has to maintain or cover the cost his/her part that is the Abu XX length that lays in front of his/her hawasha at the beginning of the planting season. Since the cost is low when distributed amongst all tenants, on average about 5 Sudanese Pounds per feddan, almost all tenants can afford it. Yet, the tenants face obstacles in getting the job done, like timely securing an excavator for the work, and a lack of technical support. And, during the growing season it was observed that no one maintains his/her part in a responsible manner. Anyone cleans anywhere along the Abu XX, when s/he experiences a water flow problem to his/her Abu VI. In this scenario the tail end farmers within a number, may clean others part many times during the growing season. On the other hand the head end farmers may not clean even once.

There seems to be no working rule that allows each farmer to take over his/her responsibility. The tail end farmers respond that, when they face a problem they should clean the head end farmers' Abu XX parts. When they want to irrigate, they do not have another option, just one farmer alone may clean all the water flow obstacles along the Abu XX. On the other hand, the head end farmers claim that 'much of the silt or weeds always concentrate at the head of the Abu XX. So why should we clean it alone? The other farmers should help us'. Basically, since the head farmers can get better water flow to irrigate than the tail end farmers, cleaning the Abu XX is not their issue. But in the past every farmer would clean his part including the road, otherwise a penalty would follow, which was double the money spent on labour to clean his part by the field inspector (communication with farmers).

Figure 5.10: Abu XX cleaning by farmers:
These two Farmers are examples who have Hawasha after the middle of an Abu XX but they were cleaning at the head of the Abu XX (in the first FOP)

Abu VI maintenance is the individual farmer's responsibility. As in the case of Abu XX, the first maintenance is done by an excavator but with a different machine. The cost is 10 Sudanese Pounds per Abu VI. But for most farmers the Abu VI is situated at a lower level than their farm plot due to over digging to divert enough water from the Abu XX and incremental elevation of the farm plot level due to siltation.

Farmers clean the Abu VI during the growing season only to avoid serious water flow obstacles. Most farmers purposely keep the grass growing along the banks of the Abu VI, to cut later for their animal feed. So always the Abu VI channel looks full of grass and this affects the water flow and capacity of the channel when the water flow increases. Consequently the neighbouring farmer's hawasha is often affected with inundation due to the low capacity of the weeded Abu VI channel.

Figure 5.11: Maintaining Abu VI by a farmer

5.4 Effects of Maintenance on Tuweir Minor canal

The maintenance failures in the scheme, in particular in the Tuweir minor have effects on water distribution inequity among users and contribute on high sediment accumulation on the lower levels up to field level. The sediment load obstructs the water flow in the minor at different level. At the head of a canal or Abu XX, the water velocity is relatively high. Therefore, the upstream users can get relatively more water amount than the downstream users. But it decreases when it goes in downstream

On the other hand the amount of sediment entering into the lower levels, forces farmers to shift to use different illegal strategies to irrigate their crops. For instance as the sediment load entered to the field increases, farmers are forced to dig deeper and increase the number of their Abu VI channels. They have also used undesired practices like nakoosi, making sudd- mud on the minor/Abu XX section to raise the water level that increases the discharge to their hawasha. On the other hand, finding these coping up strategies are on the expenses of farmers time and or money.

One of the key causes for the above mentioned sediment impacts on inequity water distribution, channel and field silted up is the poor maintenance situation of Tuweir canal. For instance, as mentioned in section 5.2 half of the canal in the downstream part has not been cleaned for four years, as well as, there was no satisfactory maintenance in the upstream part (observation and interviews with farmers and excavator and the previous and new measurement men, on August 29 and September 17 & 21, 2010). The maintenance in the lower levels is also poor. That could have significant contribution to aggravate the problem of unequal water distribution and illegal practices by farmers.

5.5 Conclusions

Sediment load

Though variation has been existed from year to year, siltation has increased highly in the scheme. One of the reasons is maintenance and operation management failures in both technical and institutional dimensions. Sediment has impacts on operation of the system. It results unequal water distribution between users at each level of the canal networks. As well as, it increases maintenance and operation costs or management insufficiency. High sediment load needs high maintenance and operation investments which have been beyond the capacity of the government since from the 1970s.

Maintenance of the minor level

In 2010 season maintenance in Tuweir canal was poor, only de-silting, that results in water distribution problems among farmers (see chapter Four- 'water distribution among numbers' session). Generally poor maintenance is losses of production. Because, it affects water distribution, it decreases channel capacity to deliver water to fields; sediments deposition to the cultivated field. However, no fast response for sediment removal, maintenance of broken and damaged FOPs. Neither, farmers take their new responsibility that is stated by 2005 Gezira Act.

Abu XX maintenance

Abu XX maintenance is the responsibility of all farmers explicitly at the beginning of the planting seasons. But during the growing seasons it is the responsibility of anyone who face water flow problem to his/her farm. This in turn magnifies upstream-downstream issues of farmers' interaction (conflict, unfair labour demand) within a number.

Removed Sediment and cost Recovery

The amount of sediment removed report in the Gezira Scheme cannot be a good indicator for the amount of sediment entered to the scheme. The removed sediment amount is more than the amount coming into the scheme. So, it seems a fake because it completely deviates to the amount of entered sediment in the scheme. But the reality is that much amount of sediment was not removed, rather it would be a deal between the engineer and the excavators' company or the driver. It can be also over estimation of the sediment load in the canal then the report of sediment removal relies on that report. In anyways it has significant impact on the scheme budget allocation.

On the other hand the amounts of money that can be collected from farmers seem enough to cover the maintenance costs if it is done in the current situation (i.e. if the way of maintenance just removing silt or weed). As Table 5.1 shows, the estimated cost recovery over three years of Tuweir minor is 350%. However, for only de-silting, for complete maintenance the recovery will be less than 350%.

Chapter 6 Water Availability and Crop Performance

In the previous chapters I tried to give current situations of O&M-activities and water distribution, particularly in the Tuweir minor canal. Here I want to link these factors influence on crop performance of the area. Therefore, this chapter includes, in section 6.1 the main crops in the area and the rotation system changes, decision makers in crop choice and what the rotation system is, Tuweir farmers' views of crop choice freedom and Impacts of conjunction cropping in a number; in section 6.2 it comprises- crop performance, water availability, the system performance, crop liberalization and the market and cost recovery. In the conclusion-section 6.3 I summarise crop pattern refers head-tail water distribution problem, water variation situation which determine the cropping pattern and the vicious cycle of the Scheme.

6.1 Crops and Crop Rotation in the Scheme

6.1.1 Crop Types

Crops that are grown in Tuweir minor canal are Sorghum, Groundnuts, Cotton and Vegetables in summer; Wheat, Vegetables, and a recently introduced crop which is locally known as 'Kebkebe' in winter. The following Tables show crop calendar and specific planting date for the main crops in the Gezira scheme.

Table 6.1: Crop Calendar in the Gezira Scheme

Month crops	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cotton			H				P					
Sorghum				O&M-Activities		P				H		
Groundnuts						P				H		
Wheat		H								P		
Vegetables			H			P			H	P		

(Source: Hussen and Adam 2008 and field observation) N.B. P= Planting month/ date, H= harvesting month/date, O&M= months of operation and maintenance activities take place in the scheme. There is always land preparation within one month before planting. Vegetables planting and harvesting is not in a specific month. It varies from farmer to farmer. The colure parts refer growth periods, white one is off time, no plant

Table 6.2: Summery of the Crop Calendar

Crop Type	Sawing date	End of date	Total growth days
Cotton Else	July 20-Aug 7	March 31	237
Cotton	July15-31	March 31	244
Sorghum	Jun15-Jul15	October 10	90-110
Groundnuts	Jun1-15	October 20	127-142
Wheat	Oct 15-Nov15	Feb 28	146-176

(Source: Draft thesis on optimal sowing and ending dates of season of main crops in Gezira scheme page-19,)

Despite the establishment of the scheme for cotton plantation (World Bank 1990), at present cotton is almost disappearing from the area. For instance, in Tuweir canal, in 2010/2011 season only 12 feddan land cotton was grown, which is only 3.4% out of 350 feddan cotton area size (100%) that used to be grown in the last rotation system before 2007 (Table 6.3). In another minor of the Kab El Gidad major called Biyut Khalifa (downstream of Tuweir), where my clique MSc. Student-has worked his research, there was no cotton plant at all in 2010/2011 season. In Tuweir minor the cotton numbers were mainly replaced by sorghum and to some extent by other crops such as vegetables and winter crops (Table 6.3).

Already for a long time, vegetables have been grown either in conjunction with groundnuts or in place of wheat or other winter crops (World Bank, 2000). This is true for Tuweir minor canal; vegetables are grown in groundnuts' numbers or hawashas. But farmers grow vegetables mainly in upstream numbers (from number 1 to number 4). This is expected to happen because of relatively better water supply in the upstream numbers than in the downstream part. The following Table 6.3 and figure 6.1 show the 2010 summer season crop coverage in Tuweir minor canal. As the Table shows, despite the single crop type within a number in the past, at present it was observed that up to four crops are grown in one number.

Table 6.3: Crop cover in Tuweir canal in 2010 Summer season

Number	Farm size /feddan					Total size in Feddan
	Sorghum	Groundnuts	Vegetables	Left for winter crops or fallow	Cotton	
1	20	34	14	0	0	68
3	4	71	15	0	0	90
4	12	63	6	0	0	81
7**	46	0	4	32	8	90
8	90	0	0	0	0	90
10**	72	0	0	18	0	90
11	90	0	0	0	0	90
13**	52	0	0	38	0	90
14	14	76	0	0	0	90
16**	0	0	4	72	4	80
Total	403	244	43	160	12	859
%	47%	28%	5%	18.6%	1.4%	100%

Source: own observation

N.B.:

- *The star signs indicate what the cotton number would be in 2010 if it were based on the past rotation system.*
- *The percentage of each crop is calculated out of the size of planted numbers in summer in 2010/2011 season which is 859 feddan over their respective cover. The remaining (un-mentioned) numbers in the above Table (Numbers: 2, 5, 6, 9, 12, 15, 17) were left for winter crops or fallow. However, up to October 05 only number 2, 12 and 17 were not prepared - so probably these numbers might be fallowed, while land preparations have been done for the other numbers.*
- *The proportion of vegetables represents which is grown purely in a plot- which is not included vegetables which were grown in conjunction with groundnuts hawasha. so the total vegetable cover grow in the area is expected higher than 5%. On the other hand the percentage of Groundnuts is expected to be less than 28% because vegetables are grown mutually in almost any a groundnuts hawasha, and it is considered as groundnuts plot.*

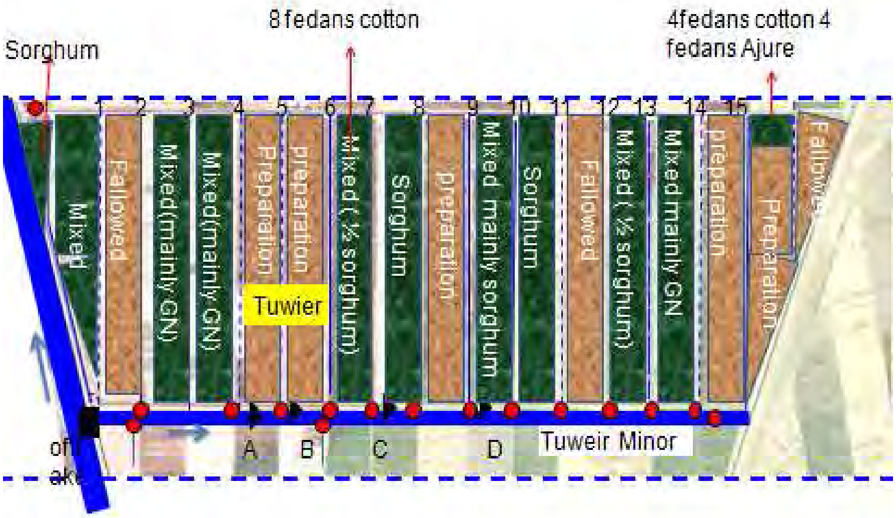


Figure 6.1: Crop map of Tuweir canal

N.B. In the figure numbers from 1-15 represents FOPs; letters From A-B refers NSWs; the rectangular shapes with different colour between two FOPs is called number; mixed crop refers to more than one crop is grown in a number or hawasha; Preparation refers to land ploughed for winter crops; fallow refers to numbers where land preparation was not observed up to the end of the research period (October /4/2010)

6.1.2 Crop Rotation

In the Gezira Scheme, crop rotation changes have taken place at various times. From 1925 to 1932, a three course rotation was practised: Cotton, Sorghum and Lubia/fallow. Because of disease infestation of the cotton plant in 1932/33, it was changed into a four course rotation system. One rotation unit comprised 8 numbers (the Gezira scheme hand out, 1933). While, Eldaw (2004) and World Bank (2000) reported this rotation unit as a rotation by itself that is instead of a four rotation as reported in the Gezira Scheme hand out (1933), they considered it 8 rotations. However, the types of crops that were rotated at this time were four, such as cotton, fallow, sorghum or Lubia.

The biggest crop rotation change took place as a consequence of the diversification and intensification policy, which came in to practice during the 1960s. This policy aggravated the rotation system to an 8 course rotation (Table 6. 4). But later, in the 1975/76 season, the rotation was changed into four crop rotation system by excluding the fodder crops Lubia and Phillipisara (Table 6.4). This system continued for six years, until the 1980/81 season. Then it was replaced by a five course rotation in 1981/82 season by introducing additional fallow for fodder (farmer's interview, Oct-30-2010), being practiced more or less until the 2007/2008 season. Then the 2005 Gezira Act, came into-fore the responsibility for crop choice and decision making regarding to where and when crops should be grow was transferred to farmers. Unfortunately from 2007 onwards there is no formal way of crop rotation as in the past. Hence, farmers have been facing additional problems since from the declaration free crop choice to then. This crop choice decision, now it is influenced by individual farmer interest, whereby some farmers have kept the past rotation, and others not. As a result it was observed that more than one type of crop was grown within a number that previously had been devoted to only one specific crop.

Table 6.4: Crop rotation practiced during different eras

Years	Number of Rotation	Crops grow	remarks
1925-1932/33	3	Cotton, Sorghum and Lubia /fallow	
1933-1960/61	4	Cotton, Sorghum and Lubia/ fallow	1/3 sorghum and 2/3 cotton coverage
1961-1975/76	8	Cotton, sorghum, groundnuts, wheat, Lubia, phillipisara, fallow	
1976-1981/82	4	Cotton, Groundnuts, sorghum and fallow	
1982-2007	5	Cotton, Groundnuts, sorghum and fodder/fallow	
2007-now	Mixed up	Sorghum, groundnuts, wheat, 'kebkebe', 'Adess', fallow, vegetables,	

(Source: Eldaw 2004 and The Gezira Scheme Hand out for new personnel)

6.1.3 Crop Choice and Rotation Decisions

The crop rotation decisions and crop choice was determined by the syndicate up to 1950. Then after, the responsibility was transferred to the SGB (World Bank, 2000 and Eldaw, 2004). This responsibility of the SGB continued almost up to the last three, four years, that is until the establishment of the water users associations in each minor, in 2007. When this responsibility was given to the farmers, it was believed that it can solve the problem related to crop choice and marketing.

Previously, the decision on every aspect of crop management such as: crop choice, rotation, and marketing was under the SGB. It was uniform throughout the scheme regardless of environmental and socioeconomic difference from place to place and/or from farmer to farmer. These were sources of inefficiency and difficulty for farmers who wished to allocate their resources to their most substantial benefits (Eldaw 2004). Thus, to avoid the problem, the World Bank proposed an 'efficient solution' that is 'for tenants (in groups) to take responsibility for their own choice of crop rotations in accordance with their own evaluation of the soils and micro climate on their land' (World Bank 2000, p. 21) and assessment of the market.

Hence, from 2007 onwards through the established WUAs, farmers have been responsible to take decisions on what they want to grow. This was thought, helps farmers to achieve more economical and profitable crop production in their own minor canal units. However, the reality in Tuweir canal shows, the expected achievements and benefits as anticipated by the Worlds Bank have not been realised yet (Observations and interviews with farmers). This was evidently seen in Tuweir minor canal situations and many farmers were claiming that, the change was sources of other problems like lack of support from the government rather than solving the limitations that was realised in the past.

6.1.4 Farmer Views on their Crop Choice Freedom in Tuweir Minor

Regarding their crop choice farmers have different views, which were scrutinised during the field work. Some of them dislike the present five rotation system and crop choice freedom. Instead they appreciate the past four rotation system, which was effected from 1975/76 to 1981/82. One reason given by farmers for disliking the change was that, during the change of the four rotation to five rotation system, those farmers were given a hawasha outside their village in different minors, even within their minor at least one of their hawasha was assigned far away from their four other numbers. Hence, they had to go a long distance to attend to their crops, which made it difficult to give follow-up on a daily basis. In addition, it has brought them extra labour demands. Indeed,

water management performance has also been affected by farmers who could not attend their farms frequently.
Another group of farmers appreciated the present freedom of crop choice by themselves. They believe that ‘it is good to grow what we want, because depending on our capacity to afford inputs or other management costs (labour) we can choose crops what we can grow easily ’(farmers interview on September 7/6 2010).

However, almost all of the farmers with whom I have talked about this issue, had negative reactions on the consequences of crop choice freedom propaganda. The idea of crop choice freedom is, that farmers can make decisions on which crops they will grow in the season, keeping one crop in a number as in the past. But, the implementation is a far cry from this idea; rather it results in planting one crop in conjunction with different crops within a number/hawasha (see Table 6. 3 and Figure 6.1 above).

6.1.5 Impacts of conjunction cropping in a number

Here what is important is, basically planting one crop throughout one number in a season was designed to make it easier to enforce water application schedules to each number and hawasha (Personal communication with the Former Block Inspector on August 09-2010). This is because obviously different crops have different planting dates, length of growth stages, and watering intervals and durations; so that, they need to be irrigated at different times. Furthermore, uniform crop establishment throughout the number helps to achieve efficient water management, as well as, farmers will have free time to clean their Abu XX channel during the cut of water into that specific FOP (interviews with head of WUAs of Tuweir minor, on September 03-2010).

But when different crops are grown in a number, one plot’s crop may have already maturated while another still needs irrigation. In this case water might enter into the matured crop plot. That results in crop damage, which will further lead to yield reduction and conflicts between farmers. On the other hand some crops are sensitive to insects, and they will be infested soon when grown in combination with other crops in a number. For example as many farmers expressed Okra is known as on insect attracting plant when grown in combination with other crops like groundnuts, so the latter will be damaged by the insects.

Moreover, the ‘freedom’ is one of the important factors in many farmers stopping to grow cotton. Some farmers in Tuweir minor claimed that though they want to grow cotton, they are afraid to grow it because they fear this disease infestation that might come from adjacent farms affecting their cotton plant. On the other hand the government cannot come to spray insecticides just for one or two hawashas of cotton plants in each number. I realized in many ways how this change affects the farmers’ attitude towards cotton. For instance, one female farmer requested me to stay in the area and to become a farmer. I replied, if I can grow cotton, is that good? But her answer was ‘cotton is not good, it is better to grow groundnuts’ and her reason was the marketing problem that faced them 2 years ago (interviews with female farmer in tail end on September 1). Though the reasons given by farmers are different, the overall concept of refusing to grow cotton by many farmers is related to the change in crop rotations.

6.2 Crop Performance

As already mentioned in the previous chapters is there sufficient water for every farmer to grow his or her crops? Is equal water distribution between head vs. tail farmers? Is the irrigation water schedule meeting farmers' actual needs? All these aspects are questionable in Tuweir minor: no irrigation schedule exists between farmers, and up-downstream issues of water distribution and maintenance all influences crop performance. However, in addition of irrigation water, factors such as: performance of the system, marketing, and the physical factors such as soil, fertiliser, land preparation, crop variety, agronomic practices during crop growth and marketing can affect the performance of crops.


(a)-On September 25-2010 **(b) on September 2010**


(c) –On September 29-2010 **(d) on September 29-2010**

Figure 6.2: Crop Performance examples in Tuweir minor

N.B. plate (a) sorghum plot in number 9; plate (b) sorghum plant in number 11; plate (c) and (d) groundnuts plot in number 14. In all the four plates the crop seems to wilt, even the first 'rubats' plants of plates (a) and (d) had already dried. As mentioned above the cause might not be only water but also can be agronomical, for instance I observed a farmer on plot (b), he was broadcasting fertiliser late but after broadcasting the fertiliser, he could not get water to irrigate so that aggravates the situation, the fertiliser might evaporate or cannot reacted with the soil because no water to do so (this is called cooking. It can kill the crop)

Since, it is difficult to qualify quantitatively the effects of each factor in this research; I will try to explain how the crops in Tuweir minor have been influenced with irrigation water availability or distribution, performance of the system and Crop liberalization and the market especially in the 2010 season.

6.2.1 Water Availability in the Area (water distribution performance)

When I start with last year's situation (2009/2010 season), many farmers in Tuweir minor mentioned that last year, there was water shortage in the area. A female farmer in number 10 said 'last year my crop totally failed. Even it was not possible to use a nakoosies or pump to irrigate because there was no water flow at all in the Abu XX or minor channels'. Again on this year situation many farmers explained as follows.

On September 26/2010, I met three female farmers who were sitting under a big tree near Tuweir village (Figure 6.3). They were chopping their Okra harvest. All of them have farms in different numbers in the Tuweir minor. One female's hawaha is in number 1 and the second female's farm is in number 4 and the other female farm is in number 11. I asked them what problems they have faced in their area. The one who have land at the 1st and 11th numbers said 'there is water shortage'.

But the one at no. 4 said 'no problem I already irrigated the day before'. The two farmers who had faced a water shortage problem again mentioned the cause of the problem as: the farmer whose plot is in number 11 said she irrigated her farm at the end of 'Ramadan fasting' (on September 8-9/2010). Now, though she wanted irrigation water 5 days before, she could not get water. She hoped she would get water up to the end of September (within four days). She was worrying because, her crop may only last up to the end of September but after that it would be a problem, the crop might dry or the yield will be decreased. The farmer in the first number has faced a problem after the excavation was done in the minor, on September 21, since their Abu XX was full of silt and weed. After excavation the water couldn't enter their FOP (the canal bed level was lowered).

Figure 6.3: Interviewed female farmers' picture

Another farmer in number 14 (at the tail of the minor) also confirmed that the problem of water shortage. He said that 'the main problem is siltation'; he explained the consequences as 'no water to irrigate'. 'Though I irrigated on 15 Ramadan' (around August 25) no water till today'; 'I wanted to irrigate at the end of Ramadan' (on September 7-9). Therefore his irrigation had delayed for more than 20 days-from Sep 7 up to Sep 27-2010, he could not get water to irrigate.

In addition the following Table presents observations of Abu VI in number 3 and number 11, on two selected plots to get detailed information on irrigation intervals. As the Table shows, I made observations on different days during the irrigation period of September. Especially in number 11, I found, there was serious a water shortage problem during that period. But relatively in number 3 most plots were already irrigated and the rest had been irrigating. Some water problem for downstream users of number 3 emerged after the excavation was done. Because as already mentioned in chapter 5, when the silt is removed the water level in the minor decreased, and it was also aggravated since the Abu XX was full of weeds and silt.

Table 16.5: Water flow observation in number 11 on different dates

Location of plots/No of Abu VI along the Abu XX	Observation Dates in number 11					
	19Sep-2010	20 Sep-2010	21 Sep-2010	22 Sep-2010	25 Sep-2010	26 Sep-2010
Head (Abu VI 1-15)	5	3	0	2	7	3
Middle (16-30)	0	0	0	0	2	3
Tail (31-45)	0	0	0	0	0	2

N.B.

- *Each Abu VI irrigates 2 feddan land (=approximately 0.84 hectare)*
- *Values, greater than 0 in the Table indicate number of Abu VI where water flows.*
- *0 indicates no flow in the Abu VIs, in that specific location (head, middle or tail) and on that specific date because no water reached the course, yet many farmers were waiting the water to irrigate*
- *In this situation the tail end plot got water on September 30 (observation).*

(a) - on September 17 **(b)- on September 19**

(c)- on September 21 **(d)- on September 21**

Figure 6.4: Water Flow situation on Number 11 on different dates

***N.B. (**a)-Abu XX section after the middle; (b) Abu XX Section at the tail; (c)-the minor section at the FOP of number 11; and plate (d)-water flow to the Abu XX at the head. From the figure especially plate (b) shows the water looks green (algae), which indicates there was no water flow in this channel for several days at least. Plate (c) also shows the canal section looks dried (cracked soils), this is also indication of there being no water flow to downstream end for at least a few days.*

Table 6.6: Water flow observations in number 3 on different dates

Location of plots/No of Abu-Sitta along the Abu XX	Observation Dates in number 3			
	17Sep-2010	24 Sep-2010	26 Sep-2010	01 Oct2010
Head (from plot 1-16)	9	2	3	1
Middle (16-32)	4	0	0	2
Tail (33-48)	4	0	0	5

N.B: 0 indicates almost all of the plots were already irrigated, except some problem was observed in downstream plots on Sep 24-2010 when there was a water shortage problem.

(a) On Sep 18-2010 **(b) On Sep 18-2010**

(c) On Sep 21-2010 **(d) On Sep 28-2010**

Figure 6.5: Water Flow Situation on number three on different dates

N.B. Plate (a)-is at the tail of a hawasha in the downstream part of no. 3. Plate (b)-is in the same number at the upstream part of the Abu XX. Plate (c)-fully irrigated hawasha at the middle of number 3. Plate (d)-the water distribution problem that faced at the tail of number 3 Abu XX after the excavation was done.

Table 6.7: Irrigation turns, intervals and duration

Crop type	Average Irrigation turns	Irrigation interval	Irrigation Duration
Sorghum	5	It is variable depending on the availability of water , the first interval is not more than 20 days and the next intervals will decrease respectively for each crop	It also varies from 1 to 3 or 4 days depending on the amounts of discharge in the area/2 feddan.
Groundnut	8		
Cotton	7		
Vegetables	9		

(Source-farmers' interviews)

Table 6.7 shows average number of irrigation turns based on farmer's experience in Tuweir minor. It addresses the practical situation of irrigation turns, interval or duration in the area. It depends on the availability of water in the area, not on the recommended crop water requirement or interval. For instance farmers said, they need only 1 day to irrigate their 2 feddan land (0.84 hectare) when the water flow in their Abu XX is 'good' but the same plot size needs 3-4 days when the flow is small. The interval is also dependant on the water flow or availability in a specific minor or number.

Therefore, as the above interviews, plates and Tables show; and as mentioned in the previous chapters, the availability of water in the area is questionable. If one asks a question is it reliable? Is that equitable among farmers? Timely basis /Scheduled distributions? The answer is no. Because, it was observed, also many farmers were complaining about irrigation delays in their area- as already explained in chapter 4. There are also upstream and downstream issues between and within the numbers (see Tables 6. 4 & 5). That is, when the water is good at the upstream end, sometimes completely no water is available in downstream end of the minor or the number (Figure 6.4). On the other hand no rotation exists between FOPs in the area. One can understand that the available water supply cannot satisfy all the FOPs, so that means it cannot be available to each farmer equally on time. So, one farmer may irrigate fully on timely basis, the other will irrigate late may be with a small supply. Clearly these all will result in crop failure or poor crop performance in the area.

6.2.2 Performance of the system (M&O situations)

If the irrigation infrastructure is not well maintained, the performance of the irrigation (technical) will be poor. In the above case of the three women, the female farmer in number one claimed the water shortage was related to the maintenance problem of their Abu XX. The man in number 14, his argument of water shortage blamed maintenance because in the downstream part of Tuweir canal maintenance has not been done for more than three years, and their canal is full of weeds that prevent the water to flow, even if water is enough in the minor. As can be seen in chapter five, canal and Abu XX breakout flows or breakage has become a serious problem in the area; what is the consequence then? It is directly or indirectly affecting crop performance. A farmer at the tail of Tuweir canal planted his cotton crop on August 21, because his land was flooded by a breakage of the upper minor, wad Hezam minor (interviews on September 04-2010). Thereafter, he feared his crop might not give the expected yield.

6.2.3 Crop liberalization and the market

Now performance will here be related to crop liberalization and the market-so actually to a farmer's aim to increase or maintain a high agricultural productivity for market purposes. Here in the scheme as a whole from the beginning of the scheme establishment, cotton had been the single important commercial crop (World Bank, 1990, 2000). However, Eldaw (2004, p. 1) reported that 'long-term developments of performance indicators for major crops in the Gezira Scheme reveal a steady decline and/or stagnation of output of cotton, wheat and groundnuts'. As explained above, the World Bank assumed if farmers determine the crop liberalization by themselves, they can produce crops based on the market profitability. However, farmers are focusing on non-commercial consumption crops (sorghum). Amazingly at present the situation of the cotton crop has been changing. Cotton has depended out of the market, because many farmers in the scheme have stopped growing it. The reason includes poor performance of the system (water distribution and M&O situations). As explained above now farmers in the area-in Tuweir minor are focussing on consumption crops. So, on one hand farmers cannot follow crop liberalization and marketing thinking because of unreliable water availability in the area. On the other hand inability to grow commercial crops because of water shortage results agriculture failure. Since farmers will be suffered in money scarcity to buy inputs and to pay water fees

6.2.4 Cost recovery

Performance can be also related to the farmer and his/her capability to pay for the maintenance of the system: it might be a physical constraint for the farmer to pay. Farmers said in Tuweir minor that they could not pay cash money for maintenance costs because they are getting less income from agriculture. Even to pay water fees it is difficult for them before harvest. As the WUAs' responsible man for finance said: because of lasts year's crop failure due to water shortage many farmers could not pay the fees (interviews on September 4/2010). On the other hand as Eldaw argued 'inefficient recovery of overhead costs at the tenant level, have made it impossible to replace the aging irrigation infrastructure and exacerbated maintenance problems of the silted canals. As a result, inefficient and wasteful water distribution became the rule and expansion in acreage and productivity of crops was limited' (Eldaw, 2004 p.2). That is because of poor harvests or less income from agriculture, farmers could no longer cover the cost. If the cost cannot be recovered, the system cannot be maintained well-which in turn aggravates the poor crop performance.

6.3 Conclusion

Generally water availability and crop performance in the area has been going down particularly in recent years. Indeed many crop rotation system changes have taken place in the scheme. But the recent change has more effect on the water distribution and performance of the system. As a result crop performance highly affected, for instance marketing situation of cotton crop has been changed, which was important cash crop to generate income for farmers. It had been helped them to buy inputs and other management costs like water fee. From the realities stated in this chapter we came up with the following conclusions.

1. **Crop pattern refers head-tail water distribution problem**

As can be seen in Table 6.3 there was water distribution problem in the tail end than in the head end. Groundnuts and vegetables were grown in the upstream part of the minor, where obviously has relatively good water supply. However, when we go downstream along the minor, sorghum is the single grown dominant crop. Indeed this is because, it has less water demands (see Table 6.7), and less risky in case of water shortage than the others. Indeed, in the Table 6.3, one can realise two exceptional cases, a groundnuts number at the tail- No. 14 and 4 feddan vegetable again at the tail end- in No. 16. But the reasons for those exceptions are: it was found that in No. 14 most of the tenants are a female farmer that is common for African women farmers producing relatively high value crops in any case. However, the fact is, because of water shortage in almost every hawasha the first and last rubats land plants have not survived. As well as, the 4 feddan vegetable in No. 16 was, this farmer had not used water from the Tuweir minor, he was irrigating from the flood flow which came from the upstream minor canal breakage. If there were no canal breakage flow water into this number, I do not think this farmer could grow vegetables from the Tuweir canal water supply.

2. **Water supply situation increasing determines the cropping pattern (cotton, vegetables in head end, sorghum is increasing to downstream)**

Again in Tables 6.3 and 6.7, there are clear cropping pattern differences between numbers of the Tuweir minor because of the water differences. Sorghum has less water turns (Table 6.7). As a result the proportion of grown sorghum in the area is the highest-47%, while the highest water demand crop which is vegetables were only 5%. The most valuable cotton crop in terms of market is only-1.4 %. And on most of cotton plots, sorghum was growing. Generally, one can understand that, water distribution performance has been determining the cropping pattern perhaps not the market or crop liberalization.

3. **The system has entered as a vicious cycle of O&M**

Crop liberalization was meant as a kick start to enter the O&M by allowing farmers to increase income through changing cropping patterns. This has not wished. Rather insecure and unreliable water supply have forced to farmers to switch to less water demanding, non-marketable crops (sorghum). As explained above, the World Bank assumed if farmers determine their croping pattern, they can produce profitable crops based on the market and what they can afford. So that since the crop production will be increased, they can pay the O&M fees, then O&M practices cost can be covered by farmers to do good O&M activities of the scheme (the virtuous cycle).

However, the realty has become the reverse (the vicious cycle), farmers could not follow through the dash lines(the virtuous cycle). Whereas, the farmers crop choice emerges from the water availability in the area. As Tables 6.3 & 6.7 show, their focus is on the less risk crop towards a water shortage like sorghum. Therefore, since they are not getting good income, they could not pay O&M fees. Results in dificult to improve O&M activities. This leads to unreliable, unequal and insufficient water distribution between farmers and finally poor crop performance in the area. The following figure represents Virtuous and Vicious Cycle of O&M.

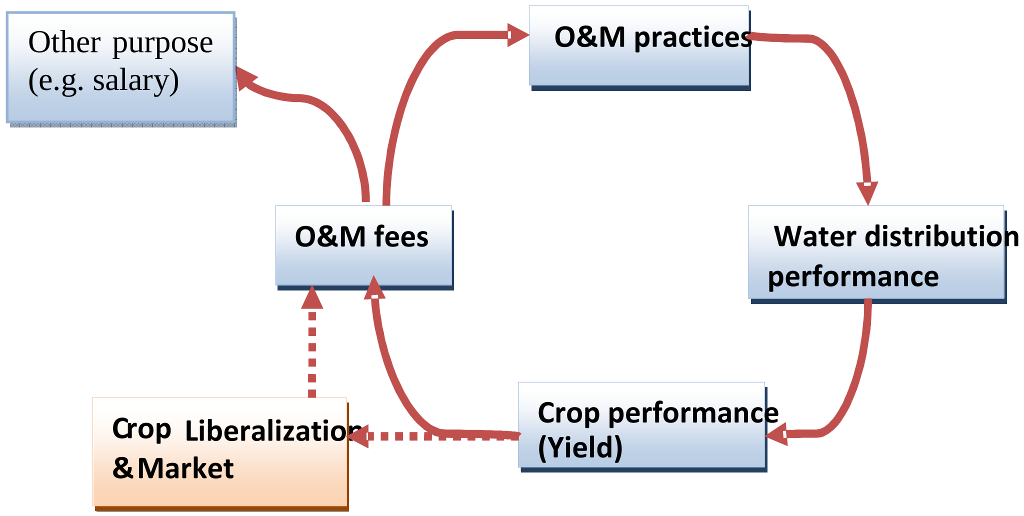


Figure 6.6: Virtuous vs. Vicious cycle of O&M

Chapter 7 Farmers' Coping Strategies in the Tuweir Minor system

This section describes the different farmers' strategies that have been devised to cope with water shortages, sediment accumulation and management failures affecting their crops performance or yield. Hence, I will discuss in section 7.1, an overview of farmers' coping strategy; in section 7.2 specific farmers responses (strategies) to recent management changes; finally section 7.3 concludes links the coping strategies to place, time and individual/collective farmers' actions and socioeconomic differentiations in strategies in the area.

7.1 Farmers' coping Strategies

Farmers' strategies are developed by individual or groups of farmers to cope with short or long term problems of water shortage or other management aspect such as maintenance or irrigation problems. These coping strategies produce negative or positive impacts on one or groups of farmers at different locations in the system. It is also defined by Abdalla, et al (1988) that it is undesired practices mainly during water shortage periods that are developed by the farmers with a view to save his/her crops. As they mentioned, these practices include: use of 'Siphon', construction of nakoosies intake, breaking or raising of the night storage weirs (NSWs), disappearance of the FOPs, building of small sudds-mud in Abu XX and minor canals (*ibid*). In addition Abdullahi and Osman (1988, p. 391) reported that at times of water shortages, farmers were involved in , stealing of water, bribing the ghaffir to get water and tamping with the water levels to irrigate their crops on time. This has been also their strategy to overcome the problem of water shortage. Therefore these practices are farmers' mechanisms to secure irrigation water for their crops. Presently, more or less the same practices are taking place in Tuweir canal to cope directly or indirectly with water shortage problems. Therefore I shall divide these practices into coping strategies to deal with siltation and water distribution problems and management failure coping strategies.

7.1.1 Strategies to Cope with Water Distribution and Siltation Changes

The above practices, called 'undesired practices' by Abdalla, et al (1988) have been practised in cases of water shortage. Of course the water shortage may be caused by water distribution or siltation changes rather than water supply shortage sparse. This is what is happening in Tuweir minor at present. To overcome these problems farmers try their best to irrigate their crops applying both 'desirable' or 'undesirable' practices. Thus, regardless of the impacts of the practices on other farmers or on the system itself, the practices comprise farmers' strategies to foster good crop performance. These practices or 'strategies' are not new. Rather they have been applied for a long time, at least since 1988, and evidently the NSW breakages were begun in the scheme during the 1960s. Some farmers in Tuweir minor responded that some of the practices like nakoosi construction and NSWs breakages were practised even before they started to farming in the area i.e. when they were children, 30/40 years age (farmers interview on August 22-2010 and September 10-2010).

Some of the practices that were observed in Tuweir canal during the field work stay are: construction of nakoosies, increase in Abu VI, sudd-mud building, or NSWs breakage, pumping, crop choice change and different in planting dates, farm work transfer to other sectors, and Abu XX maintenance relations. These practices will be treated below.

a. Establishment of Nakoosies from the minor:

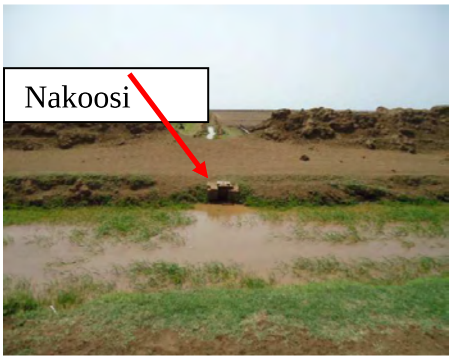
Nakoosi means: authorised alternatives way for farmers to convey water to the field. It also entails involvement and authorization from SGB and MOI. This practice was defined by Abdalla et al,(1988), as a practice caused by water shortage to irrigate the Hawasha of 10 or later 5 feddan lands (actually this recently changed to 2 or 1 feddan land) to irrigate from tail to head, instead of from head to tail using the next Abu XX through Abu VI. Nakoosi inlets often irrigate the whole 90 feddan number from the next minor by breaking the minor canal bank through installed FOPs. So, it can be seen illegal inlet since it is built out of the canal's capacity. As these writers mentioned, the reason behind the construction nakoosies according to some officials were: the bad condition of the minor canal. However Tuweir minor farmers mentioned additional reasons like,

- ❖ A way to overcome some obstacles in between the head of the minor and the farm, like villages: this is observed for Tuweir minor, the Barakat village was built in the middle of a number, and then hawashas downstream of the village cannot get water from the Wad Hezam minor easily. So, the affected farmers constructed a nakoosi with permission from the SGB officers (interviews with the nakoosi user on September 2010).
- ❖ Dealing with the increment of land levels in fields caused by sediment settlement many years which forces the farmers to irrigate from the next channel. Many farmers believe that despite the illegal nature of nakoosies, they offer a good solution to irrigate higher level farms.
- ❖ To overcome water distribution problems emanating from non-functioning FOPs, due to deferred maintenance some FOPs are not good enough to deliver water to the Abu XX channel. In such cases farmers are often forced to use a nakoosies from the next Abu XX.

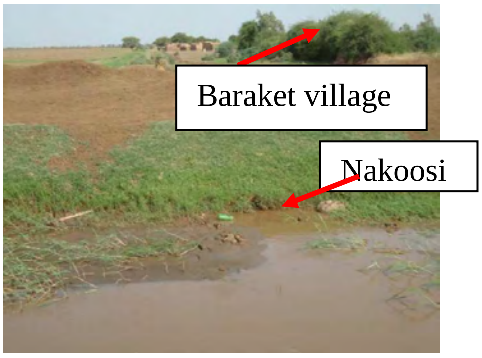
A distinction can be made between nakoosies in the minor and nakoosies in the Abu XX as discussed below.

Nakoosi from the Tuweir minor:

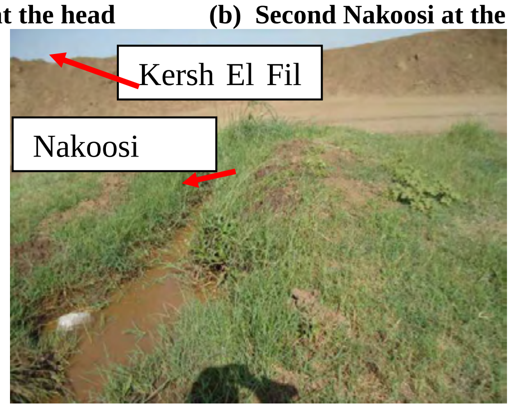
There are two nakoosies FOPs from Tuweir minor that supply water to Wad Hezam minor numbers (minor upstream of Tuweir). And in turn there is one nakoosi from Kersh El Fil (minor downstream of Tuweir) that supplies water to Tuweir minor number. The nakoosies from Tuweir minor to the head minor are located in the head and middle section of the Tuweir minor. These nakoosies were constructed a long time ago.



(a) First Nakoosi at the head



(b) Second Nakoosi at the middle



(c) Nakoosi from Ker el fill to Tuweir minor number 1

Figure 7.1: Nakoosi FOPs in the Tuweir and Kersh El Fil Minor

The first nakoosi (Figure 7.1.a) was developed about 45 years ago with permission from SGB. The reason was this nakoosi user faced problem to irrigate his 6 feddan land by gravity from his minor

(Wad- Hezam minor). This farmer's hawasha is located at the tail of a number, but its level is too high making it difficult to get water. Therefore the farmer asked permission from the SGB to build his FOP from Tuweir minor. Though it was developed for 6 feddan land presently more than 50 feddan lands are supplied water from this nakoosi. These users perceive the nakoosi is as their right and property. For instance the first user rebuilt (maintained) the FOP six years ago. As he explained, though the other users of the FOP did not contribute money to help him in maintenance, they are operating the FOP at any time when they want to irrigate. When he was asked a question, about his relationship with Tuweir minor users, he replied: 'I have no any relation with them and no one has a right to stop my irrigation, because my grandfather built the FOP with permission' (interviews on September 23-2010). Also, the normal users indicated that they know it is a big problem to those downstream users, but since the nakoosi was built with permission from the SGB, 'we could not stop the nakoosi users'. Instead they proposed to build additional nakoosies for them, as a substitute from the neighbour downstream minor. Since, they have been affected by the nakoosies especially when the water level drops in the minor (interviews on August 22 and Sep 29-2010).

Again, the second nakoosi (Figure 7.1.b) was built with permission from the scheme management (SGB) in 1972. The reason for the construction of this nakoosi was the unreliable water supply from Wad Hezam minor of a tenant who wished to develop fruit trees on his hawasha. The latter were situated farm from the minor canal with Barakat village located in between. Hence, the farmer asked the office to build a nakoosi for developing a garden (grape, orange, lemon and other fruits). Surprisingly this nakoosi was first developed just for 3 feddan lands, but at present it is used to irrigate 30 to 40 feddan lands. Since it was built by permission these farmers exert the right to operate the nakoosi at any time when they want to irrigate. Now the first farmer is not growing the fruit trees any more, instead he is growing vegetables (observation and interviews with him on September 2010). The farmer considers himself lucky, because his nakoosi FOP is situated at low level lands. As a result he can get a good amount of water by gravity regardless of the water level in the minor. Moreover, the Tuweir canal users cannot deny water to him because he built it by permission. However, though the Tuweir minor farmers as mentioned above could not stop the nakoosies users explicitly, they complain nakoosies since it affects them (other farmers and the nakoosies users' interviews on September 06, 17, 23 / 2010).

The third picture shows (Figure 7.1.c), the Tuweir minor users are in turn using a nakoosi from the next minor (Kersh El Fil minor). This nakoosi irrigates the first Tuweir minor number, 20 feddan hawashas from the tail end upwards. As users said it was also developed by permission with a similar reason mentioned above- the tail hawasha suffered water shortage when the water level drops down in their minor, since the level is getting higher at the tail (farmers interviews on August 31-2010). Generally, these nakoosies constitute a materialised version of farmers' strategies allowing them to irrigate when the level of their farm is too high to get water from the normal minor by gravity. But as can be understood, clearly these extra inlets produce significant effects on the downstream users.

In addition these users have created hydraulic property of these nakoosies. The users themselves are responsible to carryout maintenance of these FOPs. As stated above, even one of the nakoosi users has totally replaced his nakoosi FOP by his own expense. But for normal users (those using the designed FOPs on their minor) it is hardly to maintain their FOPs even. I have not observed maintained or replaced normal FOP by users rather than exploiting them for their daily water demand.

Nakoosi from Abu Ishreen

These are constructed and used to direct irrigation water from the next Abu XX within the same minor; this seems to be a widely used practice in Tuweir minor. Especially in the downstream numbers nakoosies are common. And farmers use it when the level of their land at the tail of the hawasha is too elevated due to silt accumulation. Some of the FOPs (FOP 9 and 12) have also a problem with water supply due to lack of maintenance. As a result many nakoosies were observed from Abu XX 13 to 12 and from Abu XX 10 to 9. Another phenomenon that I observed is in the period of water shortage farmers were trying to irrigate using the nakoosi, since the flow in the normal Abu XX is too low to reach to the tail of their hawasha. And many farmers confirmed that nakoosies constitute a good method to irrigate the higher level lands especially during times of water shortage.

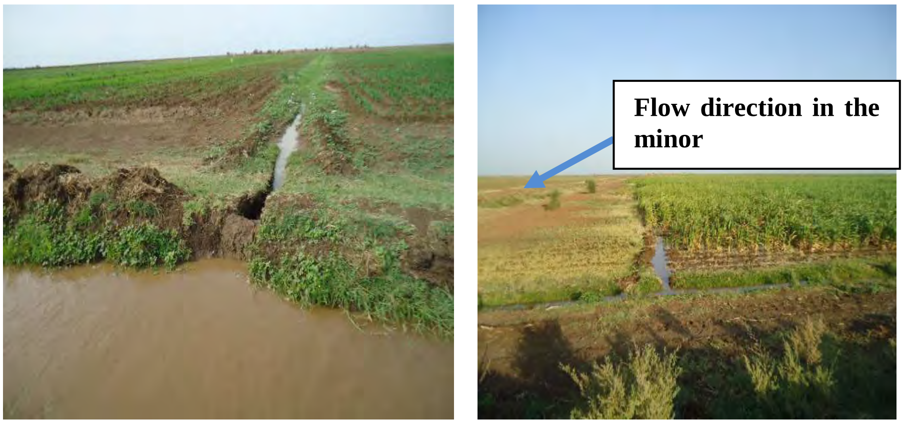


Figure 7.2: Nakoosi from the neighbour Abu XX

a. Many Abu-Sittas per number

In the past there were 9 Abu VI in a number (90 feddan land), i.e. one Abu VI supplied water for 10 feddan hawasha. Later on it was split into two, i.e. one Abu-VI per 5 feddan hawasah. Still the maximum number of Abu VIs would be 18 per number. Presently there are more than 45 Abu VIs in one number (observation in Tuweir minor); on average one Abu VI per each 2 feddan plots. One of the reasons for farmers to dig additional many Abu VIs is the rise of their farm level by sedimentation and poor land preparation. They are not able to irrigate the entire farm using one Abu-VI per 10 or 5 feddan hawasha as in the past (number 3 and 11 farmers' interviews on September 18 and 19, 2010). Another reason as can be seen in chapter 3, is subdivision of plots amongst the tenants (inheritance, renting or sharecropping). Fortunately the type of soil in the area is clay that prevents deep percolation, but it is also a hot area, more water is expected to evaporate from 45 Abu VI channels than from 9 Abu VIs channels. Also it can be expected that water losses due to excess irrigation will increases when using more Abu VIs. This further compounds the water shortage problem.

b. Methods of irrigation and use of other farmer's Abu Sitta (Abu VI)

Farmers of course are trying their best to irrigate their farms in case of water shortage or farm level problems. For a long time, they have used a method called 'tegnant'(dike or bund) or 'jadwal' to irrigate their farms part by part through the Abu VI course (Abdullahi and Osman, 1988). These methods are especially important when the water level drops in the Abu XX i.e. when small amount of water are supplied to their Abu VI. Indeed these methods can help to irrigate the crops uniformly if farmers follow them restrictedly.

Farmers have also used the next or the upstream neighbour farmers' Abu VI course to irrigate parts of their farm. Not all farmers can use others' Abu VI, only close relatives are using it. The ones, who neither use others' nor allow their Abu VI to be used by someone, complained that the method forms a source of conflict among farmers. Because one may leave the Abu VI channel opened whilst water enters to other people's hawasha unnecessarily.

Figure 7.3: A farmer making a tegnant

c. **Building Sudd-mud (small dam) across the minor and Abu XX sections**

Many farmers build small dams in the minor or Abu XX at the point immediately downstream, of their Abu XX or Abu VI respectively (Figure 7.3 a&b). Clearly farmers build these to raise the water level, which helps in turn to increase the amount of discharge supplying their respective channels. Usually, they construct these small dams when the water level drops below the level of their intake channel. The drop may be caused by a water distribution problem in the supply channel or siltation of their intake channel. This practice forms a cause of disagreement between the upstream and downstream farmers at each level. Yet farmers do not stop it since they want prevent their plants to die.

(a) Sudd–mud in the Minor **(b) Sudd-mud in the Abu XX**

Figure 7.4: Sudd-mud construction:

These two plates reflect many farmers' common practices in Tuweir minor.

d. Breaking the NSWs and FOPs, closing these gates using sack and Night irrigation

In Tuweir minor as mentioned in the previous chapters, there are no functional NSWs. And some FOPs have been disappeared since long ago. But no maintenance has been done yet. Farmers indicated the reason for the damage is to create free water flow without any control particularly in water shortage periods. The structures have been broken by farmers (interviews with farmers, on September 2-2010). The existing FOPs have no any scroll to operate easily. Farmers are operating the FOPs by using a thread or putting a sack of mud at the inlet pipe. This is laborious and one cause of in-efficient water management in the area. Anyway farmers damaged the structures to cope with water shortage problems in their farm or number.

At the NSWs in Tuweir minor it was observed that farmers were putting iron sheet and a sack of mud to close the intake pipe at the downstream and of the structure. Of course, these actions were done without of downstream users. So as soon the downstream users see this, they will remove it or a conflict might occur.

During periods of water shortage, farmers also irrigate at night. In September and October there are often water shortage, since it is the peak irrigation time for most crops in the scheme. In this time farmers need to attend their farm at night because if they want to irrigate their plot at night, other with attended farmers will close the open Abu VI to irrigate their own farms. Hence farmers who need to irrigate should stay at night to watch those other farmers' actions. But farmers indicated that before September they do not necessarily irrigate at night, since they can irrigate at the day time (Farmers interview both up-downstream on September/27 and 28/ 20-2010). But it was observed that farmers left their Abu XX and Abu VI open at night in August too. Basically, by irrigating at night the water use efficiency can be increased. Since no one closes the off-take at night, and NSWs no longer functional. If farmers did not irrigate at night water normally would run to waste at night. On the other hand irrigate at night could be also a sources of water use inefficiency and conflict in the area when everyone leave his/her Abu XX or Abu VI open and if the water flows into irrigated neighbour hawasha.

(a) Closing the Intake pipe at the NSWs (b) Disappeared FOP

Figure 7.5: Making a head at the NSWs and Disappeared FOP

e. Pumping

This is another practice in Tuweir canal through which farmers cope with water shortage problems especially during the winter season. Some, farmers are using pump to deliver water from their own minor or from the next minor (both up and downstream farmers' interviews, on September 04 and 21). This practice is expensive, since it requires a high capital investment, which is beyond the capacity of many farmers. However, in Tuweir minor, some farmers have their own pump to use for themselves and renting it to some other farmers. Still renting is not affordable for all farmers in the area (Number 11 farmer's interview on September 14-2010). However, it is one option for those farmers who can afford it, to escape from water shortage consequences for their crops. It is also widely spread throughout the Scheme starting from September/October. Therefore, it is a source of unequal water distribution between farmers. The ones who can afford it can irrigate on time from both minors but the one who cannot afford it may not get water to irrigate at all.

f. Crop Choice and Planting Date Differences

The most demanding crop in watering is cotton. There are also some indications that cotton is by far more sensitive to changes in watering than other crops cultivated in the scheme. In general cotton requires water every 12 to 15 days (Abdullahi and Osman, 1988, page 394). On the other hand sorghum is less water sensitive crop and it needs less water as compared to cotton or other summer crops in the area. In addition sorghum bears less risk than cotton for any crop failures, since the input cost of sorghum is less than cotton. Moreover, some farmers in Tuweir canal argue that lack of trust on the current water distribution and situation situations prevent them to grow cotton (WUAs head interviews on September 02). And it was observed that most farmers' previous cotton plots by the 2010 season were covered with sorghum. So, this shift in cropping pattern explicitly or implicitly constitutes farmers' strategy to avoid the risk of water distribution insecurity that is expected by farmers to occur in the season.

Flexible planting dates form another way to tackle water shortages. As farmers said, if they plant early the expected water shortage in September or October does not affect them as serious as when they plant late. So, they prefer to plant early. But for some farmers, covering input cost on time is a constraint to follow early planting strategies (farmer's interview on Aug 27-2010 at the middle). On the other hand, as long as no irrigation turns between farmers, if all of the farmers plant together, water shortage will arise. But at the current situation of Tuweir minor farmers, all farmers cannot plant as the same time. Because of finance shortage to buy inputs and prepare land on time, many farmers also pant late.

g. Abu Ishreen Clearance

Usually farmers at the head end do not clear their Abu XX part as long as they can irrigate without any problem. While farmers downstream of those head end farmers, usually should come to the head end to remove the silt or weed that affects the water flow to downstream. Hence it is strategy practiced by both groups of farmers at the head and downstream of the head. Of course the head farmers should remove the Abu XX section in front of their farm, but since they know someone of the downstream users will come to clean it, since they are affected more by the problem, the head farmers let the work to those downstream farmers as a strategy. On the other hand, the downstream farmers also know the responsibility of cleaning lies with the head enders, but they are not negotiating with them since that costs time (fearing that in the meantime their crops might fail). Hence by default those downstream farmers clean the upstream Abu XX section (many farmers' interviewing in Tuweir canal). Whilst this is unfair, the practice continues to avoid water distribution conflicts.

h. Transferring farm works to others: sharecroppers, renters, labourers

For various reasons tenants partially or fully give their plots to sharecroppers or renters or labours. The reasons are various.

- ❖ Some tenants are getting old and do not feel able to irrigate a crop twice yearly
- ❖ Others tenants are fed-up with agriculture and interested in a 'better life' in the city occupying less menial professional (especially young people)
- ❖ Yet others indicted that irrigated agriculture has become less productive due to the water distribution problems or on-going siltation, seeking a job outside the village or opening retail shops in the village.

The plots that freed-up are readily taken by sharecroppers, renters or labourers who often do not have access to their own plots. Why farmers apt for either of the option i.e. advantages and disadvantages of each method is disused below.

Sharecropping

This is a practice through which land owner transfers his/her hawasha's/s' agronomic works to a farmer who would like to work. Both the owner and the sharecropper have their own reasons or strategy. The reason for the owner is as specified above, while the sharecroppers are those who have no land or both land and money to invest. There are various sharecropping agreements within different farmers. The two most common agreements which are assessed in the Tuweir minor are:

1. The land owner supply land and cover all the input costs (seed, fertiliser, pesticide if needed), land preparation, Abu XX maintenance before planting, water fees and harvesting cost if it is by machine. And the sharecropper handles all the necessary agronomical works starting from planting: watering, sawing, and weeding. Finally they divide the yield into two equally.

2. The second agreement is divided every cost equally between them, but usually the owner cover every cost first during planting and growth, then the sharecropper will pay it back after harvest, i.e. after dividing the product equally.

Here, both owners and sharecroppers indicated that, sharecropping is more advantageous to land owners than to the sharecroppers, because the owners can get a yield without any farm work. So that the owner can spend their time on other income generating works. Moreover, the right to choice crop to grow is for the owner, the sharecropper should agree or find someone that wants to grow the same crop as his interest. Hence, as the sharecroppers also pointed out, sharecropping is an option for farmers who have no money to buy or rent a land.

Sharecropping has also some disadvantages on water management in the area. I.e. some sharecroppers do not have experience to operate their FOPs, Abu XX or Abu VI, which leads inefficient water use. In addition, since most sharecroppers have no their own land. To satisfy their demand, they want to produce maximum yield on a certain plots. Hence, they are intentional to exploit the water over others, which results unequal water distribution between farmers in the area.

Renting

Renting is an agreement where a payment is made for the temporary use of the land owner's hawasha. The renters need to pay the agreed amount of money before planting. Therefore renting is possible to those have cash money to pay beforehand. On the other hand, the owners rent their hawasha when they need cash money in advance. All the costs, such as water or maintenance fees, land preparation, and input cost are covered by the renter. So, the product (yield or biomass and grass for animals feed) belong to the renters. As both the owners and renters indicated, renting is more advantageous for the renter if there are no water shortages or other risks which might lead a yield loss in the area. But the owner can be also benefited from the cash money he got in advance.

Similar to sharecroppers, the disadvantages of renting is related to lack of experience on water management by some of the renters and an interest of getting maximum benefit from the land by most of them. Because, most of them have no their own land, to get a maximum yield they affect the irrigation system, by using much amount of irrigation water through improper operation.

Labours

This is a process of owners or sharecropper or renters' hire daily workers, to help them in farm work. Usually, these workers are hired to do agronomic works like sawing, weeding, harvesting. Thus, their influence on water management is less significant. However it does not mean some farmers still do not let labourers to operate the FOPs or to irrigate the farm. In this case, problem related with their experience can affect the irrigation system in the area.

Owners

In this context, owners are the hawasha (farm) owners who work on their farm by themselves.

It was observed that many of the land owners are working in the upstream parts of the minor, while most of the sharecroppers and the renters have been working in the downstream parts. This indicates that water distribution differences between the up-downstream parts influence owners' interest to work on their land. But, the sharecroppers or renters have no preference on upstream or downstream water distribution differences.

It is expected that owners have more experience in water management in the area, in both operation and concern for futurity of the system. Therefore, they have relatively sense of ownership while managing the system than the other groups (sharecroppers, renters or labourers).

7.2 Coping with Management Changes

Farmers in Tuweir minor complained about the management changes effected by the Gezira Scheme Act of 2005. They argued that it is one cause of farmers' lack of trust and lack of incentive to invest in agriculture anymore. As a consequence they are looking for other options what seem more promising. One of these options that most farmers in Tuweir minor adopted is to stop growing cotton. As they indicated, before the enforcement of the Act the inputs and land preparation of cotton had been covered by the Sudan Government. Now farmers should handle everything by themselves, without government support. Actually there are credit suppliers through the WUAs. But farmers refused to loan money. Because they are afraid of the risk failing to turn back the money to loaners in case of crop failures. Then many farmers choice has become to stop to grow cotton. And instead they substitute other crops in place of cotton like sorghum. As mentioned before, sorghum requires less input costs and less risky and can be eaten directly (food security).

Moreover, due to the management changes, many farmers gave their farm to other workers –to those sharecroppers, renters, labourers, then they left their villages to somewhere else (town or city) to seek other income generating jobs (Interviews with farm on Sep30-2010). They are not happy about the change with many reasons. As one farmer said, in the past to control disease risk which is caused by irrigation, the government supported farmers' health care follow up. However, presently 'in spite of farmers being exposed to diseases that are caused by working in the farm and operating the FOPs, no one give them health care which results farmers to be in bed' (September 30/2010).

7.3 Conclusion: the different coping strategies linkage and impacts

Generally, all the strategies applied by tenants point at a level of flexibility and ingenuity on the part of the tenants. The strategies show how tenants try to make the best of a basically bad situation. Particularly they show how a system that suffers from heavy sedimentation and a break-down in effective management (water distribution) strategies is still working to a certain extent. On the other hand one can observe a shifting over time from short term strategies to long term strategies by tenants diversifying their livelihoods away from irrigating agriculture since it becomes too risky. Since, farmers' strategies are different depending on the type of farmer, I will summarise these differentiations by presenting geographical differentiation along the minor, individual versus collective actions, as well as time based and socio-economic differentiations.

7.3.1 Geographical differentiation

Strategies like constructing a nakoosi, building a sudd-mud, or closing the NSWs and clearances of the Abu XX carry head-tail dimensions. Generally the tail end farmers or any downstream farmers, who are immediately downstream of these actions, will be affected significantly. And these farmers do not agree with upstream farmers' actions. Hence, it is usually done out of sight of the downstream users, though everyone knows it, as well as everyone does it at his/her corresponding level of the irrigation network.

The impacts of these strategies apply not only on one individual farmer but on many other farmers downstream within a minor or number. Some of the impacts are:

- ❖ Inequity in water distribution between farmers, since the benefit might be only for a few or one individual farmer;
- ❖ Emergence of conflicts between upstream-downstream farmers at each level;
- ❖ Additional workload to those farmers at the downstream end: some farmers leave the built sudd-mud, or the closed NSWs, or open nakoosi FOPs as it is after finishing their irrigation.

So the downstream farmers need to check where the problem is and remove it by themselves, which gives them extra work;

- ❖ It affects the minor system as a whole; especially the nakoosi from the minor section was built beyond the design capacity of the minor canal, which results in canal damage. The NSWs breakages and disappeared FOPs have produced negative impacts on the whole system performance.

7.3.2 Individual versus collective coping strategies

Almost all of the farmers' strategies reflect individual farmers' interest and actions. Only occasionally do some close groups of farmers discuss informally to undertake some of the actions together, like building a sudd-mud in the minor. But the negative impacts lay mainly on groups of farmers such as downstream, tail end farmers. On the other hand the benefits of the applied strategies accrue mainly to individual farmers. Only in some cases do the benefits accrue to groups of farmers for instance, the nakoosies in the minor have been used by more than one farmer. Also the creation of a head at the NSWs will benefit the upstream users.

According to Wade's finding in collective action in South Asia farmers' unity is based on intensity of water scarcity, their unity is significant where the amount of water is in average condition along a canal (Wade, 1988). In instances of extreme water scarcity or abundant water supply farmers do not perceive the need for collective action, since it does provide benefits. In this case usually collective action by farmers is undertaken at the middle of the canal. Similarly though the unity between farmers in the middle reach of the Tuweir minor is not clear for me, in Tuweir minor there is no farmers' unity at the two extremes positions (upstream and downstream) of the minor. At the tail farmers did not have cooperation because there is no (chance for more) water. In contrast, at the head end farmers have no unity because the water supply is relatively good, allowing each farmer to irrigate within some time difference.

7.3.3 Time based differentiation

A distinction can be made between immediate, medium and long term strategies.

Immediate action
Immediate actions comprise strategies such as digging out the Abu VI, or constructing a sudd-mud across the minor or the Abu XX. These are usually applied when the farmers face immediate water shortage problems. For example, the sudd-mud will be removed soon after a particular farmer finished his/her irrigation.

Medium term
The use of pumps, seasonal crop changes, and changes in planting dates can be grouped as medium term strategies. These methods can be used at least for a season. Say, if a farmer chooses to plant a less risky crop like sorghum, he cannot change the sorghum crop to plant another crop on the same plot in the same season.

Long term
A long term strategy that was observed is the out migration of farmers (who often become absentee landlords). These farmers leave their village moving to the city to find other work, rather than relying on irrigated agriculture. The chance to come back to the village to continue agriculture is rare. Even some of them already sold their hawashas. The change in cropping pattern can also be considered a long term strategy, as is reflected in the demise of cotton growing in the scheme in recent years. Constructing nakoosi intakes and taking responsibility for it also comprise long term strategies. For instance the two nakoosi FOPs in Tuweir minor have been used for almost 40 years.

7.3.4 Socioeconomic differentiations in strategies

There are socioeconomic differences between farmers in applying the different coping strategies. How wealth status can affect the use of different strategies by different farmers is summarised below.

Wealthy Farmers

Though use of a Pump offers an easier and a faster way to irrigate than digging out a nakoosi in water shortage periods (September, October and winter season), it needs high investment to buy and rent. Therefore, only wealthy tenants can make use of it, and not the poor farmers. Wealthy tenants can also move away from irrigated agriculture at any time when they have lost trust in O&M-activities or management in the system.

Moreover, wealthy farmers have a chance to get access to irrigated land (because they can buy tenancies as well as keep their own tenancy). They focus on growing cash crops like cotton and vegetables. Since, inputs and labour demands of these crops are high, only rich farmers can afford to plant at the appropriate time. Moreover, these crops carry a high risk in periods of water shortage or market failure. Only rich farmers can overcome the risks of crop failure through using pumps in water shortage periods. And, since they are food secure, they can also sell their products when they get a good market price. For instance, in Tuweir minor there are two plots of cotton, one with four feddan, the other with 8 feddan. The owner of the 8 feddan cotton plot is a rich farmer as I understood from interviews with him (interview on August 27, 2010). He has a truck to transport his cotton to wherever good markets are available. And he covered the capital outlay for his inputs with no problem.

Poor farmers

The poor farmers have low chances to get access to irrigated land. And they use their land for food security purposes preferring to grow sorghum rather than cotton, since the latter is too expensive (input costs). The cotton farmer introduced above replied to my enquiry about why other farmers did not grow cotton in the Tuweir minor: ‘most of the farmers have no cash money at hand to buy inputs and cover land preparation costs’ (interview on August 27, 2010). Though this is not the only cause for the drastic decline in cotton cultivation in the area, it is true for the poor farmers, since they could not grow cotton without any support. They refrain from using credit, since they are afraid of water shortage or O&M problems that might affect their crops; because at the end of the day, they may not be able to turn the money back to their creditors.

Chapter 8 Conclusions and Recommendations

In this chapter I will present the main findings from this research and I will formulate recommendations based on the research results. Here, I will try to answer the main question of the research, relating to why and how farmers in Tuweir minor canal cope with O&M related problems that affect their crops, and how these strategies are shaped by the increased rates of siltation and management changes. To do so, I will answer each sub research question divulging which changes in O&M management occurred in the past and the present. More in particular I will show how recent changes endorsed by the 2005 Gezira Act, *viz.* the establishment of WUAs and freedom of crop choice, affected O&M practices in Tuweir minor. In the process of doing so, I will explain water distribution differences between numbers and hawashas and how crops performed as well as farmers' different coping strategies to overcome the difficulties caused by a combination of increased siltation and the unpredictability of water distribution. Finally the O&M management gaps observed in the Study area will be discussed.

8.1 Operation of the irrigation system in the Tuweir minor: past and present

The scheme was designed to serve 50% of its gross command area in two consecutive growing seasons (summer and winter). Then 50% of the cultivated area can be irrigated at the same time on the basis of a 14 day rotation. In other words 25% of the gross area is irrigated in 7 days and the remaining 25% in the next 7 days. The system was designed to irrigate 24 hours per day. But it was not achieved, since the tenants were uncomfortable with irrigating at night. Considering the farmers' resistance to irrigate at night, without a change in command area only day-time irrigation (from 6:00 am to 6:00 pm) was adopted from 1937 onwards. At this time, for day time irrigation night storage structures were constructed to store enough water at each specific length (reach) of canal based on the slope of the minor canal layout. Then farmers could irrigate their farms with a 14 days rotation applied.

But later, in the 1960s, a crop diversification and intensification policy was implemented in the Scheme. This policy affected the designed irrigation system. At this time a higher water supply was required to satisfy the crop water demand throughout the extended areas. From then on, tenants had to acquire additional irrigation water to prevent their crops' failure. One consequence of this need was that they started to damage the constructed NSWs and FOPs, whilst some were forced to irrigate at night. Presently, the Tuweir minor in the Kab El Gidad major displays evidence of all the above mentioned practices. All the NSWs have been rendered dysfunctional, which implies that water in the minor is flowing day and night without any form of control being exercised. Indeed when farmers want to create water head upstream of each NSW they have used a sack or metal sheet to control the water flow to downstream part. Equally the FOPs have not been working well. Almost all of the FOPs have no scroll to operate their gate; farmers are using thread rods rope to operate them. Two FOPs out of a total of 15 have no pipe at all. Moreover there is no regular operation of the off take or the FOPs. Many have been opened for a prolonged time at the same time. As a result water cannot reach each FOP in the minor in equal measure.

The management of the irrigation system seems a mess. Indeed from the beginning during the time of the Syndicate, it has been managed by two groups: the agriculturalists and the irrigation engineers. The agriculturalists were responsible for managing the lower levels of the irrigation system from minor canal downstream. They were in direct contact with the tenants. In contrast the irrigation engineers (Civil Engineers) were more concerned with the technical aspect of the irrigation system mainly at canal levels above the minor. The decision to release water to farmers' fields was made jointly by the engineers and agriculturalists. However, the engineers' direct focus has been on irrigation structures (canals). They were not in direct contact with farmers. Indeed farmers had little say in the operation of the system, until the recent empowerment through the IMT movement. The IMT movement has not managed to empower them in the right way. So far, the new set of IMT policies, endorsed under the 2005 Gezira Act, has not been effective to enable tenants to become real responsible decision makers on their irrigation system.

Until the 1950s, the irrigation management was performed by the Sudan Gezira Board (SGB) and the Sudan Planters Syndicate. Then from 1950 to 2010 the management had been handled by the Ministry of Irrigation and Water Resources (MOIWR) and the Sudan Gezira Board (SGB). The water control from the dam to the minor off-take was performed by the MOIWR (manned with mostly civil & irrigation Engineers). SGB staff operated the irrigation system from the minor off-take to the Abu XX. Both MOIWR and SGB had their own divisions. The MOIWR had 7 divisions, which were divided into 23 subdivisions. Again the SGB was divided into 18 groups and 114 subdivisions (Blocks). There was a parallel contact between the MOIWR and SGB divisions and sub divisions. For instance the subdivision Engineer dealt with the Block inspector. In principle, the latter had to request water from the Engineer based on the crop water demand estimation. Then the former focused on the canal capacity to supply the water in line with the request. But it was clear that the calculation of the crop water requirement as well as the canal capacity estimation could not be done in a scientific manner. It proved too complicated to consider each specific farmer or crop whilst also allowing for adjustments necessitated by rainfall. Indeed in most cases it amounted to little more than a general estimation. Also the release of irrigation water to each canal level has been mostly achieved on the basis of experience gained in working the system.

At field level, release of water from the Abu XX to Abu VI and its control within the field has been the responsibility of farmers. To do so farmers interacted directly with the FOP operator who was called Ghaffir under the SGB. However, starting in the 1960s Ghaffirs have operated the FOPs on the basis of bribes or personal deals with key tenants. Presently the operation of the FOPs is completely under farmer control. Moreover farmers go upstream to operate and manipulate control structures at the main levels of the system; at least such has been the case for the minor off-take.

Later on in 2005, the Sudan Government has endorsed the IMT concept in close consultation with the World Bank. The concept underlying IMT is to transfer the responsibility for O&M to farmers. Freedom of crop choice as well as the performance of O&M activities at the lower level was left to the farmers through the establishment of WUAs around 2007. However, the reality in 2010 is the WUAs have not been effective in performing their assigned tasks in the Scheme. This also applies to the WUA in Tuweir minor canal. The only thing the WUA is really doing is the collection of water fees from farmers. But even that has proven to be no easy task for them. With regard to the other assigned tasks it can be observed that WUA members have no knowledge how to manage the water supply; how to interact with farmers; they have no had technical trainings, and more generally both the tenants and WUA members did not grasp the concept of IMT or they do not believe in it. The only thing that WUA members said was that the Government had ordered them to be elected by farmers. The introduction of WUAs represents a clear case of a top down approach. Generally farmers believe IMT is part of a government strategy to remove its support from them. So, the transfer of water management responsibilities to WUAs has not resulted in an improvement. Rather WUAs have been established in a top-down, haphazard manner: so far they have only been involved in fee collection. Since the fees collected do not seem to make any difference with regard to water supply security or maintenance activities, people are not motivated to pay.

8.2 Maintenance of the Tuweir minor canal: past and present

Sedimentation has steadily increased in the scheme affecting its operation. This increase in siltation has been attributed to different reasons. First, following the diversification and intensification policy in 1960, the need to operate the system beyond its capacity for a long time, including the peak sedimentation time, has allowed increased silt loads to enter the canal system. Second, an increment of the actual sedimentation rate which comes from the Blue Nile's catchment area has occurred.

Sedimentation has become a significant problem from main to lower levels of the irrigation network. It has at least produced the following impacts in the area.

- Ineffective operation of the system, which results in unequal water distribution between users at each level of the canal network. Particularly it has produced more significant effects to the tail end parts; to the extent that they do not get irrigation water;
- Poor performance of the infrastructure such as canals, distribution structures (off-take, NSWs and FOPs) and roads;
- It has also produced a negative effect on the cultivable area size. In Tuweir minor on average about 1 rubat land (16m*16m) per each 2 feddan land (0.84 ha) hawasha were left out of crop production because of sediment deposition on the farm;
- Yield reduction and cropping pattern changes, most farmers in Tuweir minor said that since 2008 there was substantial yield reduction. Since 2007, the Tuweir minor farmers have not practiced the previous rotation system. As a result their cropping pattern has been changing. Now, farmers are restricted by water distribution and sedimentation changes to what they grow.
- Increased levels of conflict between farmers. If farmers do not get enough water, they start to play with other people's shares, i.e. in response to shortage; farmers develop different coping mechanisms to save their crops. For instance in Tuweir minor, most farmers were complaining about other farmers' action in mid-September, because they have found obviously their Abu VI channels were closed, built a sudd-mud, as well nakoosi Abu XX upstream of their Abu VI channel, this was a possible cause for conflict.
- To remove the sediment load, funds have to be mobilised. However, because of increasing sediment loads at each level of the canal network, O&M costs have risen since the 1970s to a point beyond the capacity of the government.

Despite the negative impacts created by increased levels of sedimentation, there has been a lack of proactive maintenance and operation activities to control it. The current responsible maintenance companies do not seem to be handling the maintenance problems in the scheme. Rather they seem preoccupied with their security mission. However, it is almost impossible to control the water problem with security arms. Hence, maintenance activities, which comprise maintenance and repair of FOPs, NSWs, canal cross-sections and other irrigation infrastructures, have been scaled down to comprise de-silting only.

In 2010 season, the maintenance performed on Tuweir minor was poor. Excavation was done only on half the canal length. The other half of the minor canal was left behind despite the fact that a lot of grasses have overgrown it. The little maintenance that has been done seems to be informed by the principle of letting a modicum of water flow. Also the little work that was done provides a bit of relieve from farmers who continue beggaring the responsible bodies for their canal to be maintained.

Generally Abu XX and Abu VI maintenance are the responsibility of each farmer. However, with the exception of the period preceding planting, almost no farmer takes his/her responsibility for maintenance. Instead maintenance is only performed by those who face a problem of getting sufficient water to his/her plot. This creates a high work pressure for the downstream farmers within a number. The Abu VI maintenance is also affected by a serious limitation. Farmers want grasses to grow inside the channel for their animals to feed on. That affects the channel's water delivery capacity, which might damage the neighbour farmers' hawasha.

One of the aspirations of the 2005 Gezira Scheme Act is, to enable farmers to cover 100% of the O&M costs of their hydraulic unit (minor canal). The principle which would allow this to happen was to leave farmers themselves to decide to grow more profitable crops. That in turn would empower them to request companies to undertake O&M activities for their minor or Abu XX on their own expenses. However, after the implementation of the Act in Tuweir minor, the reality is that farmers could not even cover the previously set rate of 15% of the target water charges. One of the reasons for this failure to collect money is that due to poor maintenance of the canal system, farmers are suffering from water distribution problems. Then, finally their unpredictable and chaotic access to water results in low profitability. Moreover, there are no profitable markets for their crops which even further compound the finance issue. Farmers try to manage the de-silting through- some people bribe excavator drivers; others put pressure through the WUA to request for canal cleaning from the Engineer; farmers also talk to the engineer directly when they get him. For instance in Tuweir minor on September 20/2010 since farmers got the Engineer around, the downstream farmers talked to him to beg for maintenance of the minor (see chapter 3).

8.3 Water distribution between and within the 22 numbers along Tuweir minor

Unequal, unreliable and unscheduled water distribution to users has become a general practice. Though it is difficult to claim that water distribution in the past was planned well and optimal, there was at least a relatively formal, predictable and specified water indenting system (roughly corresponding with estimated crop water requirements and the canal capacity). However, currently such practice has gone. No scientific approach of crop water calculation takes place nor does the canal capacity feature in the balance at all.

Factors such as the operation of the FOPs by farmers themselves as well as their irrigation perceptions negatively affect the water supply security experienced. Furthermore a lack of concern or sense of ownership, while managing the system and farmers' different strategies to cope with water distribution changes and maintenance failures contribute to an unequal and unpredictable water distribution both along the minor and at Abu XX level. Finally mismanagement by the officials or O&M companies and the absence of working water management rules for users are important factors which are affecting the water distribution patterns negatively within a major/minor/number.

The interplay of these factors has created unequal, unreliable and unscheduled water distribution between numbers of the Tuweir minor canal. Generally, the upstream FOPs have received the lion share of the water supplied to the minor, while the downstream parts have suffered of water shortage. The same head-tail differences occur between farmers within a number. Basically, it is found that these differences were not caused by water supply problems at higher levels in the system.

The impacts of the water distribution changes produce both long term and short term effects on the water users. Among the short term effects there are yield reduction, a rise in the number of conflicts between farmers, additional costs for particularly tail end farmers to rent or buy pump sets to get access to irrigation water, and finally a deterioration of the irrigation infrastructure as a whole. The long term effects of the water distribution changes are that farmers have been leaving their villages to secure employment outside the scheme, whilst the remaining farmers are changing their cropping patterns by focusing on less risk bearing crops (like sorghum). Indeed these are farmers' ways of overcoming the current water distributions changes in the minor.

8.4 The crop map and crop performance in Tuweir Minor

In the 2010 season sorghum was the most dominate crop in the Tuweir minor (covering 47% of the total cropped area). In contrast, cotton, the crop for which the Gezira is famous in Sudan, covered only 1.4% of the cultivated land in the Tuweir minor. Vegetables had also a low coverage of land of about 5%.The rest was fallowed and left for winter crops Moreover, there are clear crop pattern differences between the head and tail end because of water distribution differences along the minor. Groundnuts and vegetables were grown in the upstream part of the minor, where a relatively good water supply is available. Whereas, moving towards downstream along the minor, sorghum is the single grown dominant crop (which has less water demands). Number 14 is exceptionally dominated by Ground nut as stated in chapter 7. These observations point out that the water supply situation increasingly determines the cropping pattern.

Generally, one can observe that contrary to the believes motivating the implementation of IMT policies in the Gezira, water distribution performance has been determining the cropping pattern and not the market or the new freedoms acquired through crop liberalization. The system has entered a vicious cycle of O&M. Crop liberalization was meant as a kick start to break the vicious cycle of O&M by allowing farmers to increase income through changing cropping patterns. This has not materialised. Rather insecure and unreliable water supply (key factor) with other input factors indeed have forced the farmers to switch to less water demanding, non-marketable crops (sorghum).

Therefore, the World Bank assumption that if farmers determine their cropping pattern, they can produce profitable crops based on the market, which then increases crop production and revenues so that farmers can pay the full O&M fees resulting in the performance of good O&M activities in the scheme (the virtuous cycle) has not been met yet. Rather the opposite has happened whereby unreliable, unequal and insufficient water supply to farmers has resulted in poor crop performance in the area, further deminishing any preparedness on the part of the farmers to foot the bill of canal maintenance. In part this vicious cycle has been fed by a lack of viable crop markets.

8.5 Different Strategies to get water to and from the fields

Farmers do their best to cope with water distribution, sedimentation and management changes. Generally if farmers refrain from practising these coping mechanisms their crops will die. Hence, these strategies represent farmers' efforts to secure their livelihoods. The following list presents farmers' strategies in Tuweir minor canal; most of them are not new but rather represent their long time strategies.

- Construction of Nakoosi (illegal material ways of drawing water from a minor or Abu XX)
- Increasing the number of Abu VI
- Change in methods of irrigation and use of other farmer's Abu VI
- Building Sudd-muds (small dams) across the minor and Abu XX sections to push up water levels so as to squeeze more water to one's hawasha
- Breaking the NSWs and FOPs, closing these gates using sacks and Night irrigation
- Pumping
- Crop Choice and Planting Date Differences
- Abu XX Clearance
- Transferring farm work to others: sharecroppers, renters, labourers
- Seeking another job in town rather than agriculture.

8.6 The influence of coping strategies on siltation and water distribution changes at Abu Ishreen and minor level

Though these coping strategies have highlighted farmers' efforts to protect themselves against the negative impacts of siltation and water distribution and management changes, they also directly or indirectly influence the way the system works and sometimes puts farmers against each other. The farmers' strategies impacts can be categorised into the following main points.

Individual versus collective effects
In Tuweir minor, almost all of the farmers' strategies reflect individual farmers' interest and actions. According to Wade (1988) farmers only undertake collective action at certain intensities of water scarcity, whereby extreme scarcity on the one hand and abundance of water on the other hand do not incentivize farmers to undertake collective action. In the case of Tuweir minor collective action is only significant at the middle of the canal. Similarly though the unity between farmers at the middle of the Tuweir minor is not clear for me, there is no farmers' unity at the two extreme ends (upstream and downstream) of the minor. At the tail end farmers did not have cooperation because there is no chance that such cooperation will result in more water (since the water availability in the downstream reach is not promising). On the other hand their collective actions would at most result in marginal corrections on their water situation. To the contrary, at the head end farmers have no unity because the water supply is relatively good, each farmer can irrigate within some time difference. Each individual farmer's action produces negative impacts on all farmers at the downstream end of such action and on the irrigation system.

Geographical differentiation (upstream, middle and downstream)
Strategies like constructing nakoosi, building sudd-muds, or closing the NSWs and clearances of the Abu XX carry head-tail dimensions. These different dimensions result in:

- ❖ Inequity in water distribution between farmers, since the benefit might be only for a few or one individual farmer;
- ❖ Conflict between upstream-downstream farmers at each level;
- ❖ Additional workload to those farmers at the downstream end: some farmers leave the built sudd-mud, or the closed NSWs, or open nakoosi FOPs as it is after finishing their irrigation. So the downstream farmers need to check where the problem is and remove it by themselves, which gives them extra work;
- ❖ It affects the minor system as a whole; especially the nakoosi from the minor section which was built beyond the designed capacity of the minor, which results in canal damage. The NSWs breakages and disappeared FOPs have brought negative impacts on the whole system performance.

Socioeconomic differentiations in strategies (wealth and poor)
The socio-economic differentiation of the strategies creates water distribution differences between farmers. For example, in case of low water supply in Tuweir minor, rich farmers can buy a pump which helps to irrigate their crops directly from the other minor or major. But poor farmers cannot afford it; they have to wait for the remaining water from their minor. Again rich farmers usually have their own farm, while poor farmers are sharecroppers, renters or labourers.

The farmers' strategies have also impacts on siltation. The impacts can be seen in two ways. On one hand the strategies affect the silt distribution among FOPs and Abu VI. For example, when one makes a sudd-mud across the minor canal or Abu XX channels, the probability of high silt entrance into that opened upstream FOPs or Abu VI courses become high. Because purposely sudd-mud increases water level to those upstream parts of the sudd-mud, then the increased discharge can wash much silt into its way. In addition, the concern of different farmers on de-silting is different because of their particular coping strategies. For example those farmers who have a pump, could not have as much as concern for maintaining their canal on time as other farmers, because, they can access water using the pump directly from the minor. On the other hand, as proved in the Tuweir minor, the downstream farmers have more concern for canal maintenance than upstream users, to the extent they would like to cover the fuel cost of the excavator machine (see chapter 3). So these situations can affect sedimentation negatively as well as positively (downstream farmers motivation on de-silting the minor can be seen as positive). Hydraulic property relation is also another factor that affects maintenance situation in the Tuweir minor, a nakoosi number having been constructed in Tuweir minor can be concrete examples. Since the original tenant was requesting permission for the nakoosi presently his son is being involved in its maintenance (footing the bill, supplying labour and replacing the FOP gate) is very instructive for the scheme, it shows how maintenance levels in the scheme could be improved by hydraulic relationship.

8.7 Influence of water distribution and sedimentation on crop choice and yields

As already stated above in the Tuweir minor, there are water distribution and siltation problems. On the other hand obviously different crops have different water demands. Their resistance to water shortage is also different. Vegetables and cotton need more irrigation water than groundnuts or sorghum. Cotton is the most valuable cash crop in the area, but sorghum is not a cash crop (it is cultivated mostly for home consumption). However, the Tuweir minor farmers prefer to grow sorghum rather than vegetables or cotton. The yield of sorghum and other crops have been decreasing from year to year. This is because the water distribution and siltation problem in the minor is also increasing.

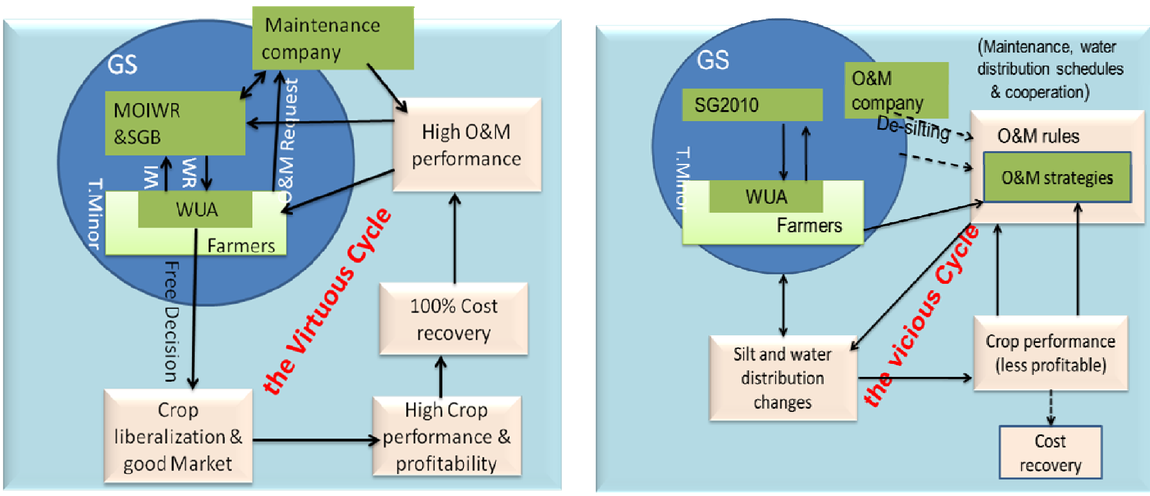
Therefore as the above points confirmed, farmers along the Tuweir minor of the Gezira Scheme have been practicing different O&M strategies. Indeed these strategies are related to, and shaped by, the increased sedimentation rates and management (O&M) changes in the Scheme. It can be seen that, because of increasing rate of sedimentation and water distribution changes, the scheme management has been incapable to address all the necessary O&M needs in the Scheme. Hence, the Scheme suffers from a low O&M performance. Therefore, an option was made by the Sudan Government on management changes throughout the scheme (virtuous cycle). However, the changes have not made improvement on the O&M situation in the Scheme (vicious cycle). While at the same time, these changes impacted on the crop performance in the scheme as stated in chapter 6. So, farmers could not see their crops to die totally, they are using their effort to cope with the changes. For instance, farmers divert water from downstream Abu XX (nakoosi) to irrigate their higher levelled part at a tail of their hawasha due to sediment load. Also, the strategy leaving the village to town or city to find a job option is related to the changes.

This research found out that, the practical irrigation life of farmers in Tuweir minor, i.e. farmers day to day struggle to keep their livelihood against the existing problems in the scheme. It is also realised that farmers might not express their argument orally (directly), but they can express practically. For instance, at least in Tuweir minor it was evident that some farmers participated in WUAs election. But those who participated have not implemented the WUAs concept. So, this depicts that farmers do not hesitate to do what they believe in or not to do what they do not trust in. The situation of cotton farming and using credit are also related to this reality. As the WUAs head in Tuweir minor explained, there is credit service through WUAs to farmers but farmers have not borrowed yet. Because they do not have trust how they would turn the money back. The same is true for cotton growing, indeed the input demand of cotton is high but why most rich farmers could not grow it is still questionable. Indeed the degree of farmers’ persistence might differ from farmers to farmers. Therefore, management bodies (decision makers) need to think in depth how they can make a decision that farmers understand and trust in. Otherwise whatever improved technology is introduced to farmers, they might not accept it.

However, further research is needed on the following topics:

- How do farmers strategies affect siltation, only some points are highlighted, so it needs further study
- How can farmers' strategies be improved/avoided/substituted to avoid its negative impacts and to keep the positive one on the irrigation system.
- What are the real missions of the Private (security) companies in the Scheme, what are their impacts on the Scheme
- What are the impacts of the changes in the scheme from 2010 on irrigation management
- What effects that have occurred in the Scheme can be ascribed to the management changes that took place in 2010
- What are the past water management facts in the scheme (in more detail than World Bank and Eldaw's reports)
- Sedimentation rate within the Scheme rather than the Blue Nile

Generally the following figures show the interaction of each factor in Tuweir minor.



(a) The Virtuous Cycle **(b) The Vicious Cycle 1**

Figure 8.1: O&M determine crop choice

N.B. Figure 8.1 (a) is the virtuous cycle which is intended O&M success in the Scheme through the Gezira Act, 2005. It shows that with farmers freedom of crop choice (crop liberalization), and good market, farmers could grow high profitable crops. The crops could also be performed well since the established WUAs can manage their minor in good way. They can request to the Scheme management bodies (MOIWR and SGB) for O&M, and private maintenance based on their demand. Then farmers can also cover their O&M charges fully. Hence there can be highly performed O&M activities in the scheme. However, as Figure (b) the vicious cycle indicates the Scheme has entered a different cycle from was thought by the Act. Rather the siltation and water distribution changes are determining farmers what they can grow, it is aggravated since there is no working O&M rules. Therefore, farmers are manipulating their own strategies to keep their crops from dying. Since the crops profitability is low and they are not motivated by the change they could not cover O&M costs.

8.8 Recommendations

As mentioned already, at the time of 2005 Gezira Act i.e. when IMT era began, it was intended that the crop liberalization and market would improve and determine O&M performances of the scheme, as well as farmers' livelihood. However, what has happened in the scheme is the performance of O&M are the most important factors which has been determining what farmers can do to keep their livelihood. Therefore, this session pops up with some suggestions which help to change the vicious cycle that the Gezira scheme has faced into a virtuous cycle.

The existing water distribution should be improved. This can be achieved if hydraulic property is created by each farmer. However, since the performance of the irrigation infrastructures in the scheme has been deteriorated; first the Sudan Government should rehabilitate the infrastructure based on research with farmers' full participation. This includes replacement of old and non-functional irrigation structures (gates, weirs, FOPs, canal cross-section), maintenance of broken structures; removing the piles of sediments at the canal banks and maintenance of roads, and where necessary construction of new roads.

The rehabilitation can be done by both MOI and private companies. The MOI primarily lead the work, and the private companies which are famous in canal maintenance, structure installation can be hired to facilitate the work. Before starting the rehabilitation, surveys of the irrigation system and if necessary researches by MOI; consultancy or experience sharing from known successful countries is important. The government may get funds from like the World Bank or other supportive funders may be also some local private companies. Participating farmers to contribute for the rehabilitation cost would be also important to create hydraulic property.

Regarding maintenance: farmers can find a maintenance company by themselves, and farmers can deal the cost with the companies. But the government should control the quality of the companies to keep the quality of the work; the amount of silt/weed removed should be first measured by whoever is going to maintain the canal. Those who do not have a good track record in irrigation infrastructure maintenance; they should be controlled from being a contractor in the scheme by the government.

To control, the sediment entrance to each minor canal, controlling the amount of discharge to release to each minor during the peak sedimentation period of August should be reduced. One solution can be specially adjusting the planting date of many crops to minimum of water need during this month.

Critical review of some core assumptions of the GS2010 scheme management

It may be questioned whether all the Gezira scheme personnel and management bodies aware about the theoretical story of the scheme with its current reality? For example, the huge amount of Abu VI, reported from the last decade which still state that the design field layout of 9 Abu VI rather than the present 45 Abu VI. Second, is it likely that the maximum discharge, the canal capacity to carry it, the designed cross section etc. have stayed the same with the huge amounts of sediment load story in the scheme at present?

In addition, the results of the 1988-1989 silt report by HRS with collaboration of Wallingford are outdated. But still the silt entering proportion to different levels of the irrigation system is referred to, though obviously the sediment entering rate into the irrigation network can be influenced by water discharge and operation of the specific canal, time of sampling. The proportions of the silt entering into each 'reach' of a canal is obviously also affected by the discharge situation of the levels, if there is always maximum discharge at the head then the amount of silt settling in it will decrease, if minimum discharge is recorded the reverse will occur. For example we thought 33% of the sediment load entering into Sennar will settle in the minors but when the minor canals are excavated randomly, there is a disturbance in this distribution. As a result high sediment concentration can enter and increase the reported proportion into the field. So that the sediment proportion entering into each level shall be reported in different situations and conditions, it cannot be just one single figure.

Furthermore, the amounts of silt that are expected to be settled at each level in the scheme, depends not only on the specific area situation from the incoming sediment, from the upper catchment area of the Blue Nile. Because it is known that there is also canal bank erosion in the scheme, and excavation disturbances, throughout the growing season especially since recent years.

I observed that, at the minor canal sometimes the water flow is high, creating a kind of turbulent flow, but sometimes there is totally zero flow. So it is difficult to take representative sediment samples in the canal unless one can measure the discharge at that time and derive an equation of discharge vs. sediment vs. time vs. point of sampling.

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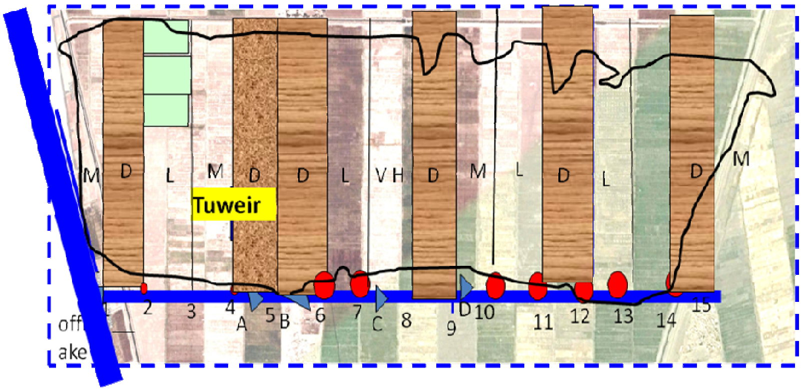
Annex

Round trip water distribution observations Samples

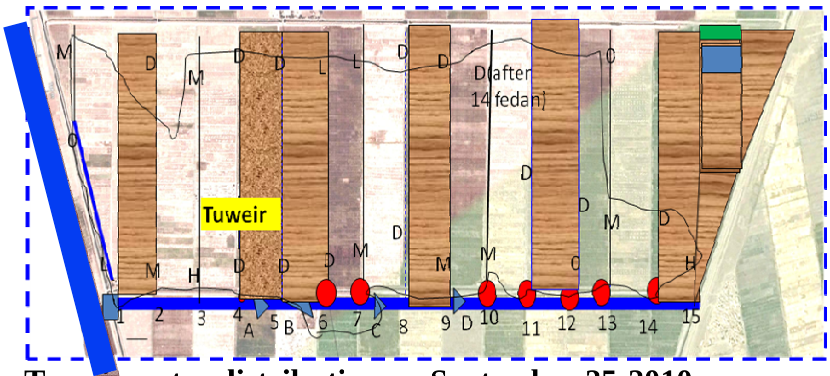
Abu xx flow Estimation

1. High (H) =80-120 L/s
2. Medium(M) =40-80L/s
3. Low(L)= 10-40L/s
4. Zero(0)=0-10L/s
5. Dry (D)

Correction of errors=plus or minus 30%



Tuweir water distribution on September 3-2010



Tuweir water distribution on September 25-2010

Legend

=Minor off take

=Night storage weirs(NSWs)

=Field outlet Pipes(FOPs)

= Round trip/walking rout

= fallowed lands