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CONTENTS

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Assessment of smallholder irrigation perfomance; management of conveyance and distribution infrastructure (at Murara and Nyamatanda North East Zimbabwe)

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A study was carried out on two smallholder surface irrigation schemes; Murara in Mutoko District and Nyamatanda in Mudzi District, north east Zimbabwe, between 1999 and 2001. The objective was to investigate possible causes of poor performance, emphasis on water management along the conveyance and distribution infrastructure. The methodologies used included a socio-economic survey questionnaire, an inventory of the existing infrastructure and assessment of its hydraulic suitability, monitoring of the irrigation process and practices, and calibrating the infrastructure for easy use by the farmers. Results showed that the farmers have an appreciation of the irrigation process and the flow in the canals was adequate for irrigation with water duty of at least 8.2 l/s/ha in an eight hour day, for both irrigation schemes against a demand of two l/s/ha. Between the two schemes an average of 60 percent of the canal slopes are outside the recommended 1:300 to 1:2 000 limits that seriously affects water management. It was also observed that both irrigation schemes have distribution and regulation structures that lack water-measuring mechanisms and the water control mechanism is poorly defined, resulting in poor water management. Evidence of poor water management was observed in poor crop yields, use of lost water for fish farming at Murara Irrigation Scheme and loss of about two ha of irrigated fields at Nyamatanda Irrigation Scheme due to waterlogging. Our general recommendations are to rehabilitate the irrigation infrastructure that does not meet design specifications, improve on water management through proper use, repair and maintenance of the infrastructure and generally to educate the farmers to take responsibility for their schemes.

Keywords: Smallholder irrigation, water management, surface irrigation, irrigation performance, infrastructure.

Introduction

Most smallholder irrigation projects in Zimbabwe have been developed in drought prone areas where crop harvest from rainfed dryland agriculture is not guaranteed. Where water is available, it has been Government policy to develop smallholder irrigation projects to ensure food security and avoid drought handouts. Most smallholder irrigation schemes are technically and financially viable when they are initially designed. However, in practice, surface irrigation schemes are not performing as expected where, for instance, the design efficiencies are 70 percent versus operational efficiencies of around 35 percent (Savva, *et al.*, 1994). The main constraints could be poor design, poor water management or lack of adequate inputs. Despite having enough water and inputs the yields have not improved in both old and new schemes where the expected yields are around six to seven t/ha versus the actual average of two to three t/ha (Agritex, 1991; Fao, 2000). It was observed that the irrigation application efficiencies for smallholder irrigation in Zimbabwe are poor in the ranges of 20 to 30 percent (Senzanje *et al.*, 2000; Zirebwa, 1997; Makadho, 1994 and Nyakudya, 1995).

The infrastructure that was investigated was designed according to Agricultural Technical and Extension Services (AGRITEX) standards (Savva, *et al.*, 1994). According to the design report, the maximum tertiary canal gradient should be 1:500. Drop structures should be of 0.15 m when the command exceeds 0.40 m above the ground (Hoevenaars and Brouwer, 1992). The canal side slope should be 60^o and the bed width/water depth (b/d) ratios should range between one and two. The canals conveying less than 0.5 m^3/s should have a fixed water depth of 0.3 m, a bed width of 0.25 m and a freeboard of at least 0.05 m with a roughness coefficient of 0.015 for the wooden finish concrete lined canals (Koegelenberg, 1997). The flow velocity should be between 0.7 m/s and 1.5 m/s (Chadwick and Morfett, 1994). The above parameters have to be satisfied if the infrastructure is to be efficient. Suitable infrastructure is very important in the proper conveyance and distribution of water in surface irrigation systems. When water deliveries are untimely due to poor design, crop yields tend to decline due to either crop stress or over-irrigation. It was indicated that an overriding concern in developing efficient and effective surface irrigation systems is the operation of the irrigation project itself. Thus management of the collection, storage and conveyance systems in a project is a critical factor in the performance of a surface irrigation system at farm level. It is argued that ignoring this linkage is the cause of poor production and poverty of the agricultural sector (Walker, 1989).

This study was designed to investigate water management, focussing on water conveyance, control and distribution. The main objective of the study was to establish whether the management of the infrastructure significantly affected the distribution and conveyance of irrigation water.

The specific objectives were:

- To investigate and verify the existence of appropriate conveyance and distribution irrigation infrastructures.

- To assess the suitability of these structures in their function of conveyance, distributing and measuring water.
- To calibrate the existing structures so that they can effectively be used for distribution and measurement of desired volumes of water in line with irrigation scheduling.

Materials and Methods

The study was carried out on two smallholder surface irrigation schemes. To obtain an insight into how the scheme's infrastructure was being managed a socio-economic survey was administered, an inventory of the infrastructure was taken, hydraulic parameters were measured and calibration of the system was made. In both schemes, water is conveyed and distributed by lined canals and gated diversion structures are used to distribute and control the water. The farmers in both schemes grew maize, tomatoes, groundnuts, butternuts, cucumbers, onions and potatoes. In terms of the irrigation practice the two sites were run differently as outlined below:

Site 1 (Nyamatanda Irrigation Scheme)
Site one had 24 hectares of irrigated land of which 22 were operational. Hundred and fourteen irrigators operated the scheme with each plot holder having a single plot whose sizes ranged from 0.18 ha to 0.2 ha. The irrigators were divided into six groups of 19 plot holders each. Usually, the irrigation schedule was such that each group irrigated once a week for about eight hours per day. During very hot periods two groups irrigated their crops per day so that every farmer irrigated crops twice a week. Each farmer used a maximum of three siphons of diameter 50 mm.

Site 2 (Murara Irrigation Scheme)
There are 36 plot holders on 18 ha of irrigated land. The scheme is divided into 10 blocks with each plot holder having 0.05 ha on each of the 10 blocks. The plot holders are divided into three groups A, B and C, each with 12 people. They irrigate the 10 blocks successively and the scheduling is such that two groups are irrigating at any given moment while the third group is not working. Plot holders in group A on the first block will be in group B on the next block and in group C on the third block and so on. The farmers have metal check plates with rubber linings on the rim (to make a tight seal) to stop the water but most of them are worn out so they can only stop the water partially. The farmers, therefore, use soil taken from the plots, stones and straw to seal the check plates and to stop the water. The farmers have dug fishponds at the end of almost each block to make use of the run-off water. The investigation on the two sites was carried out systematically as outlined below.

Socio-economic survey
Firstly a socio-economic survey questionnaire covering the critical aspects of water management was administered to 20 randomly selected irrigators at each of the

selected sites. The aim was to find out whether the irrigators had the resources and the technical know-how to effectively practice irrigated agriculture. The questions were directed to establish whether farmers knew the types of structures and their functions, the farmers' appreciation of the irrigation aspects, the irrigation scheduling practiced, water application procedures, the farmers' perception of the adequacy of water and the problems faced by the farmers in the use of any of the structures.

Inventory of infrastructure

An inventory of the numbers, types and sizes of structures was taken. These structures were then grouped into categories that perform the same function; that is canals, distribution, control and measuring structures. Samples of infrastructure to be studied were then randomly selected. Canal hydraulic characteristics were measured and recorded. The characteristics measured included sizes, longitudinal slope and available command. These were compared with the design specifications.

Water flow

To establish how water flows in the canals, current meter and float methods were used to measure the velocity of flow. A fairly straight uniform and clear stretch of the canal 10 to 20 times the water surface width was selected, away from areas of turbulence (such as immediately downstream of a gate or a drop structure). The one point current meter method, because of depth limitations, was used to measure the velocity at 0.6 of the stream depth. If the measurements differed by ±10 percent then measurements at that point were repeated until a representative average was obtained (Bos, 1989). A check on the discharge was provided by a rough estimate made by a simple float (tomato) measurement (Hoevenaars and Brouwer, 1992). Water levels were monitored at start and end of flow measurement period by placing a peg at the water's edge at the start. Significant variation in water level during the flow measurement period would adversely affect the accuracy of the discharge value obtained.

Finally it was necessary to establish and mark on the infrastructure the critical scheme management water levels. Gated diversion structures were used for this exercise. The depth of water in the canal was marked so that each water level in a canal would correspond to a specific canal flow rate. The depths of flow were then marked on all similar structures around the scheme. The extension workers participated during the calibration exercises and were supposed to pass on the acquired knowledge to all other irrigators. The farmers were consulted on a number of issues such as the gate openings they found to give them adequate volumes of irrigation water without losses through overtopping and the ideal number of siphons to be used. This approach was found to work well in terms of making the research work more adaptable to practices.

Table 1: Socio-economic survey and measured/observed results for two irrigation Schemes in north east Zimbabwe.

Parameter investigated	Measured/ Observed results	SURVEY RESULTS Murara Irrigation Scheme	Nyamatanda Irrigation Scheme
Gender distribution			
Female (%)	70	70	70
Male (%)	50	50	50
Age distribution			
0-29 (%)		50	15
30-59 (%)		45	55
60+ (%)		5	20
Literacy level			
Up to Grade 7 (%)		50	75
'O' level (%)		50	25
Water control (%)	50	100	75
Water conveyance canals & structures (%)	100	55	30
Sufficient water (%)	100	100	85
Overtopping and leakage (%)	60	30	70
Lateness in coming to the field (%)	85	15	15
Appreciation of the irrigation process. (%)	45	100	100

Results

Information on the general layout and the irrigation practices was extracted from the socio-economic survey and observations by the researchers (Table 1). About half of the interviewed farmers at both schemes showed an appreciation of the existence of various irrigation infrastructures. Observations also showed that infrastructure was available for use by the farmers (Tables 3a and 3b). However some of it did not meet the design requirements (Table 2).

The inventory that was carried out showed that there were lined canals that conveyed water from the dams' 250 mm outlet steel pipes to the fields. Analysis showed that 100 percent of the farmers at Murara and 85 percent at Nyamatanda expressed satisfaction with the amount of water they were getting. This was confirmed by flow measurement results that indicated that the water duty was over eight l/s/ha, more than four times the recommended rates. The farmers on both schemes cited water leakage and overtopping as the major management problems.

Leakages were observed to be frequent along the conveyance and distribution infrastructure at both schemes especially at the inverted siphon at Murara Irrigation Scheme. Leakage through the gates was also noted at the distribution boxes.

Overtopping in the distribution canals was mainly observed at Nyamatanda Irrigation Scheme. For instance, the farmer nearest the last diversion structure at Nyamatanda Irrigation Scheme had to completely block the flowing water in order to get some command resulting in overtopping the plots just before that distribution box. The other 18 group members only irrigated after the problem plot had been irrigated.

The other management problem was lateness in coming to the fields to irrigate. It was observed that only 15 percent of the farmers were in the field at the time water got to the field, resulting in unnecessary water losses.

Table 2: Comparison of the actual and design infrastructure parameters for irrigation schemes North East of Zimbabwe.

Structure	Design Parameter	Irrigation Scheme	
Canal	**Slope**	**Murara**	**Nyamatanda**
	1:300 to 1:2000 (design)	33 %	43 %
	> 1:300	47 %	42 %
	<1:2000	2 %	1 %
	Anti-slope	18 %	14 %
	Command		
	0.15 m to 0.3 m (design)	26 %	14 %
	<0.15 m	0 %	81 %
	>0.3 m	74 %	5 %
	Dimensions		
	Bed width 0.25 m; depth 0.35 m; side slope 1:0.57 (design)	40 %	40 %
	Outside the design limits	60 %	60 %
Distribution boxes	1 m x 1 m (Gated)	100 %	100 %

It was observed that the degree of nonconformity to Agritex design standards varied for different investigated parameters and between the two sites (Table 2). Sixty seven percent of the canal sections at Murara Irrigation Scheme and 57 percent at Nyamatanda Irrigation Scheme were outside the standard design range with respect to longitudinal slope making the scheme management task difficult. The distribution of canals that have different slopes at Murara Irrigation Scheme and Nyamatanda Irrigation Scheme are as illustrated (Figures 1 and 2). As a result stagnant water, that posed health hazards, and sand deposition was observed at sections that had very gentle to anti slopes. The problem was more prevalent at Nyamatanda Irrigation Scheme where sand had to be removed from anti slope sections each time before irrigation. Seventy four percent of the measured points at

Murara Irrigation Scheme and 86 percent at Nyamatanda Irrigation Scheme had command values outside the design range. Sixty percent of the measured points for canal characteristics at both schemes did not conform to the design standard values (Table 2). So the infrastructure was available but much of it did not conform to the design specifications.

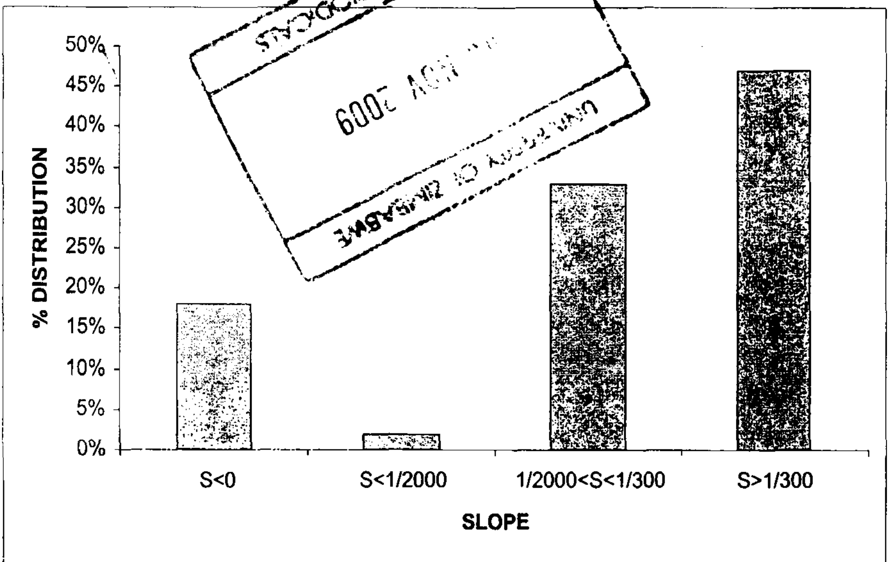

Figure 1: Variation of canal slopes, Murara Irrigation Scheme, north east Zimbabwe.

s = slope.

To calibrate the irrigation schemes, the critical water levels (upper and lower limits) were recorded (Table 3). Although the main canal at Murara Irrigation Scheme was designed to carry 60 l/s it could only convey a maximum of 40 l/s because of design limitations at the inverted siphon. At Nyamatanda Irrigation Scheme 60 l/s was the maximum flow to be conveyed to whichever group of 19 members that was irrigating (Table 3). Effectiveness of control of water using gates at distribution structures was dependent on the canal slopes. It was observed that where canal off-takes with different bed slopes emanated from the same distribution, structure control of water was difficult as the gates had to be adjusted differently.

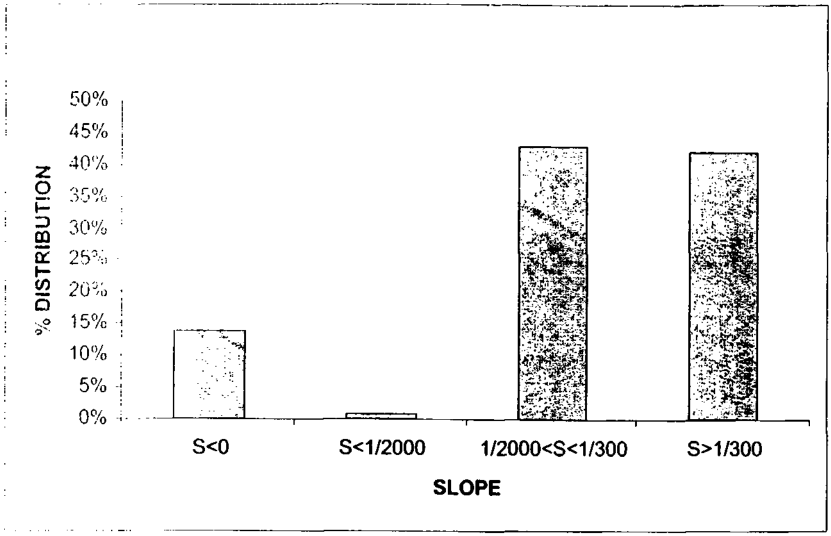

Figure 2: **Variation of canal slopes, Nyamatanda Irrigation Scheme, north east Zimbabwe.**

s = slope.

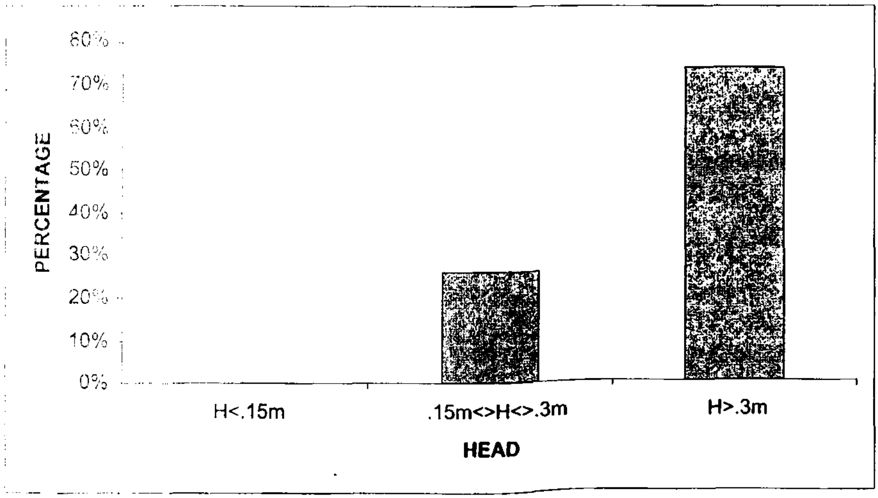

Figure 2a: **Variation of head, Murara Irrigation Scheme, north east Zimbabwe.**

H = command.

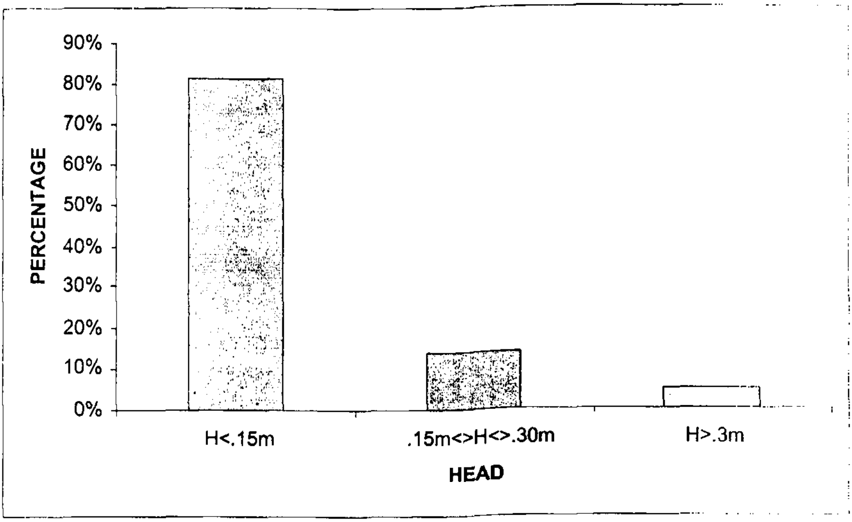

Figure 2b: Variation of head, Nyamatanda Irrigation Scheme, north east Zimbabwe.

H = command.

Table 3: Critical canal water levels during irrigation for two schemes in north east Zimbabwe.

Canal	Critical water Level	MURARA Depth	MURARA Discharge	NYAMATANDA Depth	NYAMATANDA Discharge
Conveyance canal	Max	0.14 m	40 l/s	0.22 m	60 l/s
	Min	0.14 m	40 l/s	nd_1	nd_1
Main canal	Max	0.16 m	29 l/s	0.22 m	60 l/s
	Min	0.12 m	20 l/s	nd_1	nd_1
Canals 1 / 2	Max	0.155 m	30 l/s	0.18 m	50 l/s
	Min	0.12 m	20 l/s	nd_1	nd_1
Canal 3	Max	0.13 m	27 l/s	0.18 m	50 l/s
	Min	0.10 m	18 l/s	nd_1	nd_1
Canal 4	Max	0.15 m	27 l/s	nd	nd
	Min	0.12 m	18 l/s	nd_1	nd_1
Canal 5	Max	0.15 m	29 l/s	nd	nd
	Min	0.11 m	17 l/s	nd_1	nd_1
Canal 6	Max	0.16 m	29 l/s	nd	nd
	Min	0.115 m	17 l/s	nd_1	nd_1

nd = not determined because there are no corresponding canal sections.
nd_1 = not determined because they used one water level without any adjustment because of design constraints.

Table 3a: Inventory of available infrastructure at Murara Irrigation Scheme.

Structure	Length/number	Type	Size
Conveyance canal	1342 m	Rectangular	50 cm wide x 30 cm deep
Main canal	416 m	Trapezoidal	B = 25 cm, T = 65 cm, L = 40 cm
Field canal	10	Trapezoidal	B = 25 cm, T = 65 cm, L = 40 cm
Diversion box	7	Rectangular	1 m x 1 m
Gate	16	Rectangular	25 cm x 40.8 cm
Check plate	2	Trapezoidal	B = 25 cm, T = 65 cm, L = 40 cm

B is the bottom width, T is the top width and L is the side length.

Table 3b: Inventory of available infrastructure at Nyamatanda Irrigation Scheme.

Structure	Length/number	Type	Size
Conveyance canal	1098 m	Trapezoidal	B = 25 cm, T = 65 cm, L = 40 cm
Main canal	1070 m	Trapezoidal	B = 25 cm, T = 65 cm, L = 40 cm
Field canal	11	Trapezoidal	B = 25 cm, T = 65 cm, L = 40 cm
Diversion box	11	Rectangular	1 m x 1 m
Gate	8	Rectangular	40.5 cm x 38 cm
Gate	6	Rectangular	25.8 cm x 37 cm
Gate	8	Rectangular	26 cm x 43 cm

B is the bottom width, T is the top width and, L is the side length.

At Nyamatanda Irrigation Scheme the farmers control water partially using stones, soil from the plots, sacks filled with sand, straw or a combination of these so as to get enough head, while at the same time allowing some to pass for use by those downstream of the canal. As a result, sand got deposited in the canals so that the farmers had to remove it every other day. Another problem was that of water piracy. At Murara Irrigation Scheme four dryland farmers outside the scheme irrigate their gardens by making holes on the sides of the conveyance canal and blocking them when they were not irrigating. At Nyamatanda Irrigation Scheme one farmer outside the scheme irrigates his plot that is approximately equal in size to those found in the scheme.

Discussion

The objective of the study was to investigate and establish whether the management of the infrastructure affected the distribution and conveyance of irrigation water. The water losses in the process of irrigation have normally been expressed as an "efficiency concept", that is a ratio between the water effectively utilized and the water actually received for the purpose, the difference between them being the losses (Makadho, 1985). The following aspects were considered.

Farmer perception

For the infrastructure to perform its intended function, the irrigators have to both appreciate their functions and be in a position to use them. It was observed that the irrigators knew what was expected of them in terms of managing their plots and they confirmed it from the survey results (Table 1), but in practice they did not strictly adhere to proper procedures (Walker, 1989). For instance about 85 percent of the farmers came to the field at least an hour late, after the irrigation water reached the field and 100 percent of the farmers at both irrigation schemes knew that they were supposed to use two check plates, but none did that. The farmers had the necessary skills to effectively utilize the irrigation infrastructure but the infrastructure was sometimes letting them down as outlined below.

Canal hydraulic parameters

It was observed that the canal sections were not conforming to design standards, which affected the conveyance and distribution efficiencies of the irrigation schemes (Table 2). Values outside the recommended canal slope range of 1:300 to 1:2 000 result in either unacceptably high velocity of flow or silt deposition respectively. High velocities made it difficult for farmers to minimize water losses, resulting in farmers at Murara Irrigation Scheme, for instance, resorting to using the lost water for fish farming. Also there is a perennial stream after Nyamatanda Irrigation Scheme resulting from the water lost from the irrigation scheme. Slopes gentler than 1:2 000 caused silt deposition and overtopping which made it difficult to manage the irrigation schemes, since the farmers, especially at Nyamatanda Irrigation Scheme, had to desilt the canals every time they irrigated. Those who did not desilt the canals had overtopping problems.

Generally, command is not a problem when conveying and distributing water. However, if the conveyance and distribution canals do not have enough command this will directly affect the management of water during application. The recommended head is between 0.15 m and 0.3 m (Table 2). Any value higher than 0.3 m leads to high water velocities when coming out of the siphons. At Murara Irrigation Scheme 74 percent of the canals had command greater than 0.3 m and this resulted in soil getting eroded from the canal embankments (Figure 2a). Although the farmers used stover and plastics at siphon outlets they intensified the problem of soil erosion and siltation of canals by removing more soil from the fields in order to make better seals when blocking the water in the canals.

At Nyamatanda Irrigation Scheme the management problem was different in that 81 percent of the canals had command less than 0.15 m (Figure 2b). At such points, the head was insufficient for siphoning the water into the fields resulting in farmers conveying water to the desired plot by unlined canals after having diverted water upstream and letting it run parallel to the lined sections. What made the situation worse was that as the soils are sandy this resulted in deep percolation losses. As a result about two ha of the irrigated land in the low-lying area was lost to water logging.

Structures hydraulic parameters

It was observed that when the canals emanating from the structure have different longitudinal slopes distribution of water becomes tricky. An example was the first distribution structure at Murara Irrigation Scheme where, when water was to be distributed equally, one gate had to be at hole 10 and the other at hole 3 translating to one gate being opened three times more than the other. This makes water management difficult since there are no measuring mechanisms. At Murara Irrigation Scheme the design capacity of the conveyance canals was a water depth of 0.25 m in the canal but due to poor design of the siphon along that canal the maximum depth was 0.14 m. Irrigators were aware of what was expected of them to manage and control water in the canals but they did not practice the use of double check plates due to their shortage. At both schemes a single check and sand bags or any other suitable material were used and this resulted in significant losses of water to the extent that at Murara Irrigation Scheme the water lost was being used for fish farming.

Infrastructure maintenance

In addition to the problems highlighted above, the irrigators did not maintain the conveyance and distribution infrastructure. Grasses, leaves and twigs clogged the conveyance canals. Farmers were expected to do the maintenance work but results showed that farmers expected the Government or donors to provide the funds for the maintenance of the schemes (FAO, 2000). Along the conveyance canal the other management problem at both schemes was water piracy. Even if the water bailiff opened the outlet so that enough water to serve the whole group of irrigators was discharged, insufficient water got to the scheme because some of it was being stolen along the way in the conveyance system.

Conclusions and Recommendations

It was observed that both sites had the infrastructure that adequately conveyed and distributed water to the field although the hydraulic parameters were not conforming to the design specifications. This could be attributed to lack of strict supervision during construction. It is recommended that those parts of the scheme with anti slope canal panels be removed and those fields with poor command are re-leveled to enable irrigators to manage their water better. It is also recommended that farmers should make use of the calibrations on the existing structures in estimating the volumes of water they are using and use the double check plate system for controlling water when irrigating. Irrigators at both irrigation schemes expected the Government to do the general maintenance work at irrigation schemes like repairing leaks and replacing siphons and check plates. Irrigators need to be educated to understand that maintenance of the schemes is their responsibility. Also bylaws should be put in place that will force all irrigators to participate in maintenance and also minimize the level of water piracy.

In conclusion, some of the possible causes of poor water management could be attributed to poorly constructed infrastructure; poor water management by irrigators; lack of appreciation by irrigators that there is need to carry out maintenance on the scheme and unclearly defined irrigation scheduling. Thus the general recommendations are to rehabilitate the irrigation infrastructure that does not meet design specifications, improve on water management through proper infrastructure use, carry out proper repair and maintenance of the infrastructure and to generally educating the farmers that the irrigation scheme is their responsibility.

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