## Rotational Method in Farmer Managed Irrigation Systems Tanzania. "The need to re-examine the validity of its use"

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# Abstract

*Most of the traditional farmer-managed irrigation systems (FMIS) in Tanzania have their water delivery schedule based on Demand. Rotational schedules have been introduced to the newly upgraded FMIS which came into operation in the late 1980's such as Majengo irrigation scheme in the Usangu Plains in Mbeya region and Lower Moshi irrigation scheme in Kilimanjaro region. This Study which was conducted in two cropping seasons (1991/92 and 1992/93) concentrated on a Rotational schedule introduced in Majengo and its results compared to Ipatagwa a neighbouring traditional irrigation scheme located in the same Usangu Plains. The results showed that although the water delivery schedule in Majengo was designed to operate on Rotation and likewise the water conveyance systems were constructed to meet the water delivery objective, the water users resorted to their old system of irrigation. An in depth performance evaluation over the two seasons showed that Majengo scheme performed better than Ipatagwa scheme, but it is concluded that this was not due to improved water distribution and control. Rather, the high performance of the irrigation systems shown in Majengo over that of Ipatagwa was mainly due to bigger water capture because of a bigger intake and canal structures. Other parameters such as crop variety and fertilizer application had little or no effect. The rotational schedule envisaged in Majengo was not practised simply because the farmers lacked irrigation water management technology and there is a possibility that the irrigation system may not be sustainable. Given that rotational schedule needs some expertise which our farmers do not have, more careful consideration must be given during the design phase to the manageability of alternative methods of water control. If it is inevitable that rotation has to be practised, then it should be between tertiaries rather than between secondaries as was the case in Majengo until such time that farmers are acquainted with the kind of irrigation water management.*


# INTRODUCTION

In Tanzania, FMIS have existed in some parts of the country for more than a century while some are still evolving (FAO, 1987; Tarimo, 1994). Most of the FMIS have their water delivery schedule based on Demand. In general, water delivery schedules can be flexible as with demand or rigid such as Rotation schedules (Replogle, 1987).

According to Merriam, 1987, Demand schedules are completely controlled by the farmer with some practical compromise between the water users and supplier as to the maximum flow rate. They need no communication system. Rotation schedules require no communication system as the various conditions of frequency; rate and duration are predetermined and remain the same throughout the cropping season.

The rigid conditions imposed by rotation system remove most irrigation management decisions from the water user's control and force inefficient water use, cause labour difficulties (night operations and long work hours) and often limit the selection of adoptable crops (Merriam, 1987). Apart from sugarcane, tea and coffee estates, most of the FMIS in Tanzania grow paddy crop. The first two FMIS to be upgraded with assistance from Government namely Lower Moshi in

Kilimanjaro region and Majengo in the Usangu Plains in Mbeya region were all for paddy production (FAO 1987).

The executing agents of these schemes developed them based on rotation system without consultation to the farmers. As usual, the belief from the professionals is that the average farmer has insufficient influence or education to test development proposals against his own goals. Once the professionals were convinced that the modern ideas and techniques they brought with them offer the only solution to the irrigation problem, the water users may have to accept the innovations, even if they have no direct bearing on the realities of their situation. Frequently, these innovations do not evolve from questions asked by the traditional farmer, but rather from those asked by Government Officials high up in the system.

It is against this background that the two schemes were developed. The authors of this paper made a two year study (19991/92 and 1992/93) in Majengo scheme and among many things they were interested in; the rotational system practised in Majengo was one of them.

Based on the Case Study, this paper tries to explore whether it is now ripe for Tanzania to introduce rotational irrigation method to our small farmers or not. This is because most of the small-scale irrigation farmers are still evolving and their main irrigation method is based on having irrigation water whenever they need.

## MATERIALS AND METHODS

**The Study Area**Majengo traditional scheme was fully rehabilitated by UVIP while Ipatagwa was still a traditional scheme at the time of the study. The study took two years covering two cropping seasons of 1991/92 and 1992/93.

## INSTRUMENTAION AND DATA COLLECTION

Discharge measurements into Majengo scheme were conducted on daily basis for the two cropping seasons. The flow measurements were taken along the canals at different stations as shown in Fig. 1. Seepage and percolation losses in the paddy fields were measured using a wooden sloping gauge similar to one developed by International Rice Research Institute in the Philippines.

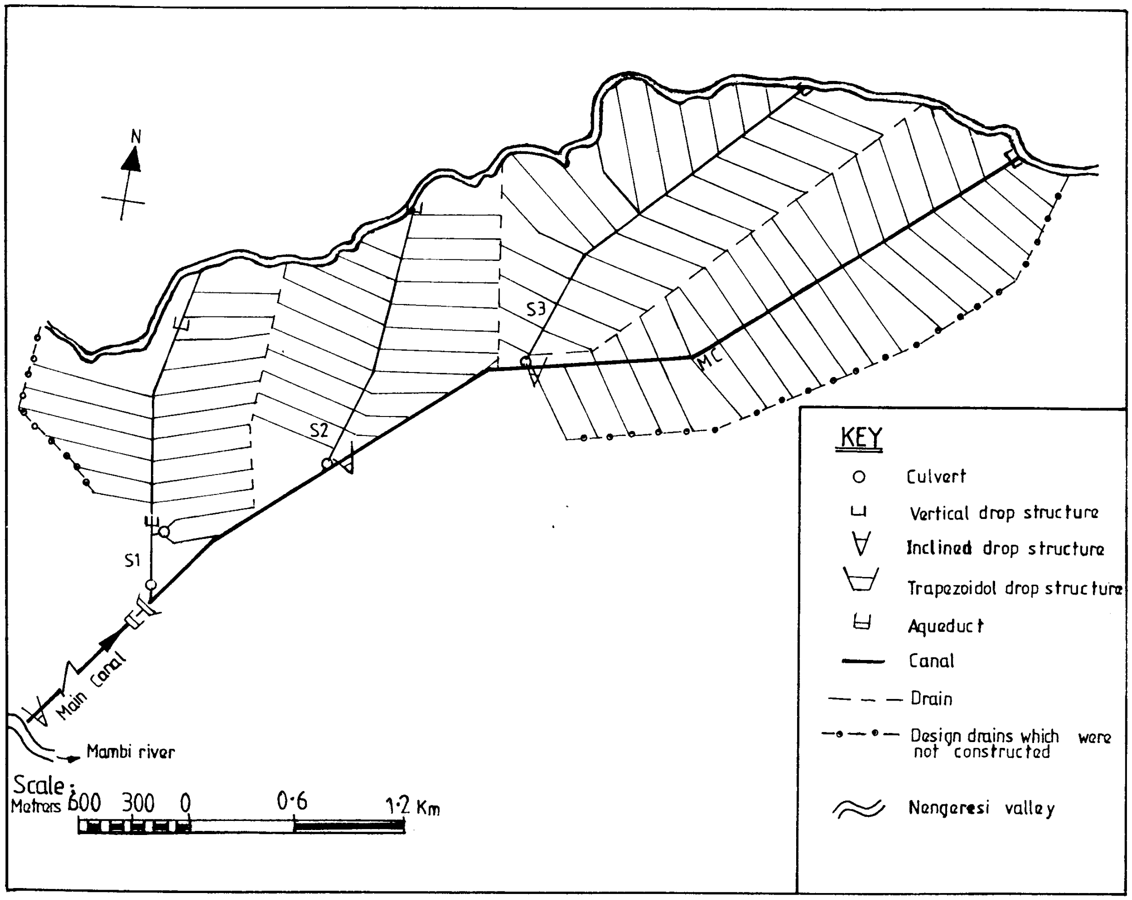



**Figure 1: Canal layout of the improved Majengo scheme**

Meteorological data which includes rainfall, temperature, humidity, wind speed, pan evaporation and sunshine hours was collected from a meteorological station at UVIP's headquarters from January 1985 to June 1993. The data was used to compute the crop consumptive use.

With the above information, daily relative water supply (RWS) was calculated for the whole of the cropping season. Equation 1 which was suggested by Sakthivadivel *et. al.* (1993) was used to calculate the daily RWS.

For crop growth period,

$$RWS = (I + R)/(ET_c + S\&P) \quad (1)$$

Where;

| | | |
|---|---|---|
| RWS | = | Relative water supply |
| I | = | Irrigation water delivery (mm) |
| R | = | Effective rainfall(mm) |
| S&P | = | Seepage and Percolation (mm) |
| $ET_c$ | = | Crop evapotranspiration (mm) |

Majengo scheme has 470 farmers out which 157 or (33%) were sampled for crop yield data collection. The sampling was biased towards head, middle and tail. The crop yield data was collected by counting the number of bags harvested by each of the sampled farmers and multiply by 70 kg to get the weight. The factor of 70 kg was found to be the average weight of a bag of paddy (Tarimo, 1994). The same data was collected from Ipatagwa scheme South of the TAZARA railway.

The sampled farmers were asked two basic questions regarding the irrigation water supply. The first one relates to their judgement in-terms of flow rates, time of planting and dependability of the irrigation water and the second one relates to the importance of the three factors. They were requested to answer the questions in the form of very good to very bad. Using fuzzy set theory, farmers utility of irrigation water was calculated from the answers of individual sampled farmer.

## RESULTS AND DISCUSSION

The performance assessment of the irrigation systems of both schemes is shown Table 1. From Table 1, RWS shows that the supply was adequate in Majengo but just or less than adequate in Ipatagwa. This is because when a value of RWS equals to 1 at the field means the supply matches the requirement exactly and is called the critical RWS value. It has been observed that a RWS approximating 2.0 monitoring and control of the secondary channels and limited communication between the system managers and the farmers would still permit relatively high yields of paddy crop. For RWS of 2.5 or greater systems with minimum operational control at the main system distribution level would be adequate to ensure that water will not be a limiting factor in crop production (Sakthivadivel et al., 1993).

**Table 1: Performance Assessment of Majengo and Ipatagwa Irrigation schemes**

| Season | Location | Mean RWS | CV(RWS) | Farmers' Utility | Yield Ton/ha | Yield Kg/$m^3$ of water |
|---|---|---|---|---|---|---|
| 1991/92 | Majengo<br>Ipatagwa | 1.64<br>0.94 | 0.60<br>0.78 | 0.63<br>0.64 | 2.5<br>2.1 | 0.150<br>- |
| 1992/93 | Majengo<br>Ipatagwa | 1.69<br>1.00 | 0.69<br>0.96 | 0.68<br>0.70 | 2.5<br>1.6 | 0.121<br>0.146 |

The coefficient of variation of relative water supply CV (RWS) indicates the degree of dependability of water delivery and as its value approaches zero the RWS becomes more uniform over time, indicating a more dependable delivery (Molden and Gates, 1990). The CV (RWS) of both Majengo and Ipatagwa for the two seasons were high i.e. above 0.60 which indicates that the water supply was not dependable. It has got to be understood that dependability does not indicate whether the canal has low or high delivery. All what it says is that one can depend on the delivery of a given supply over a given period of time.

Farmers utility of irrigation water which is a measure of water users' own perception of irrigation system's performance. Both schemes indicated that the utility was more or less high in both seasons. This is because a utility value of 1 means the supply is very good while a utility value of zero means the supply is very bad (EL-Awad, 1991). For both schemes the utility was found to be between 0.63 and 70.

In both schemes, water utilization efficiency varied between 0.121 and 0.150 kg/m$^3$ as shown in Table 1. These are very low water utilization efficiencies because water utilization efficiency for harvested yield of paddy containing 15% to 20% moisture is 0.7 to 1.1 kg/m$^3$ (Doorenbos and Kassam, 1986). This shows that the availability of more irrigation water does not necessary mean high crop yield per unit volume of water used if the water is not properly managed. For example, Majengo scheme had less irrigation water that was captured in 1991/92 season than in 1992/93 as shown in Fig 2 but the yield per cubic meter of water that was supplied was more in 1991/92 season than 1992/93 season as shown in Table 1. Also, the irrigation water that was supplied to Ipatagwa in 1992/93 season was less than in Majengo in the same season but Ipatagwa had a higher yield per cubic meter of water that was supplied than Majengo. And apart from RWS and the crop yield of Majengo which were higher than those of Ipatagwa, the rest of the irrigation system's indicators did not show much difference (Tarimo,1994). Thus, given the current water supply with good irrigation water management the crop yield in both schemes could be increased.

The RWS was higher in Majengo than Ipatagwa not because of the irrigation system's management but because the irrigation water supply was bigger due to bigger intake and canal capacities as shown by the design parameter of Majengo scheme's canal system in Table 2 and the canal dimensions of the selected portion of the Ipatagwa traditional scheme in Table 3.

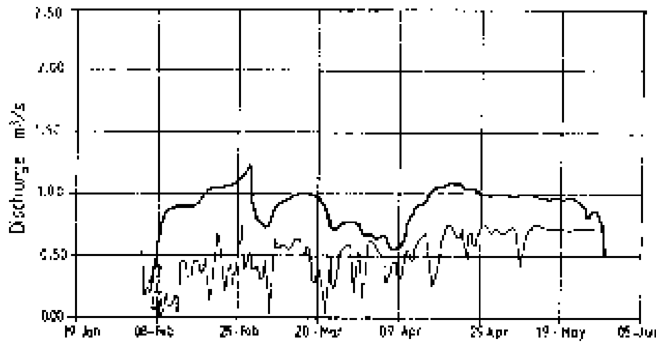
**Table 2: Design parameters of Majengo scheme's canal system**

| Canal's Name | Design Capacity m$^3$/s) | Long. Slope (m/m) | Side Slope (1 : z) | Manning's Roughness Coefficient (m$^{1/3}$/s) | Flow Depth (m) | Bed Width m) | Free Board (m) |
|---|---|---|---|---|---|---|---|
| Main | 2.000 | $10^{-3}$ | 1 : 1.5 | 0.035 | 1.00 | 1.5 | 0.50 |
| Secondary | 0.700 | $10^{-3}$ | 1 : 1.5 | 0.035 | 0.63 | 0.7 | 0.57 |
| Tertiary | 0.080 to 0.125 | $2x10^{-4}$ | 1 : 1.0 | 0.035 | 0.50 | 0.3 | 0.30 |

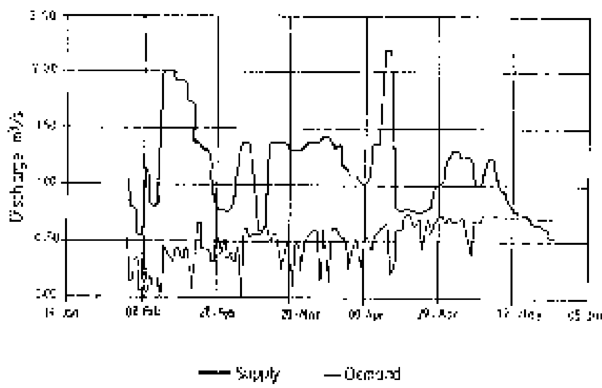
The design of the secondary and the new main canals using conventional design criteria in Majengo resulted in canal depths from the bank level to the lead level of about 1.2 m to 1.5 m

**Table 3: Canal dimensions of the selected portion of Ipatagwa scheme**

| Canal's Name | Mean Top Width (m) | Mean Depth from the Ground Surface to the Bed level. Left (m) | Centre (m) | Right (m) | Mean Long. Slope (m/m) |
|---|---|---|---|---|---|
| Lead Canal | 2.2 | 0.61 | 0.98 | 0.58 | 0.0047 |
| $M_1$ | 1.6 | 0.75 | 1.15 | 0.70 | 0.0029 |
| $M_2$ | 1.5 | 0.32 | 0.89 | 0.31 | 0.0033 |
| $M_3$ | 1.0 | 1.14 | 1.42 | 0.16 | 0.0045 |
| $M_4$ | 1.2 | 0.85 | 1.21 | 0.85 | 0.0057 |
| $M_5$ | 1.8 | 0.85 | 1.41 | 0.86 | 0.0066 |




Supply and demand curve for Majengo scheme for 1991/92




Supply and demand curves for Majengo scheme for 1992/93

Supply and demand curve for Majengo scheme for 1992/93

respectively as shown in Table 2. These canal depths, means that the length of the side slopes for the secondary and the main canals to be 2.7 and 2.2 m respectively as the side lopes were 1:1.5 and a top width of 6 m and 4.3 m respectively. Therefore the canals were bigger in size than those of Ipatagwa shown in Table 3.

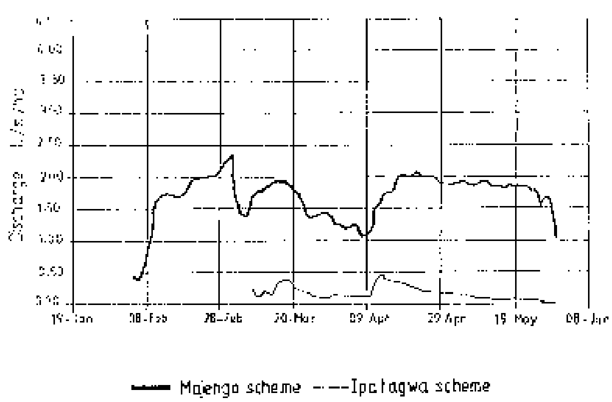
**Figure 2: Irrigation water supply for Majengo scheme**

Also, the daily irrigation water supply in L/s/ha into Majengo scheme and into the portion that was under this Study in Ipatagwa were plotted against time in days for the two seasons as shown in Figure 3. In 1992/93 seasons, Ipatagwa had a higher supply in the second week of February and after that Majengo had virtually a higher supply for the rest of the period with an exception of a few occasions in the first two weeks of March. Unfortunately, in 1991/92 season the flow measurements in Ipatagwa begun late but for the same period that the measurements were taken, Majengo had between 0.5 L/s/ha and 1 L/s/ha more water than Ipatagwa. For the same period, sometimes the range was even higher in 1992/93 season as shown in Figure 3. Therefore, on average, Majengo scheme had more irrigation water supply than Ipatagwa for all the two seasons. This explains why RWS was higher in Majengo than Ipatagwa i.e. simply it has more water capture than Ipatagwa.

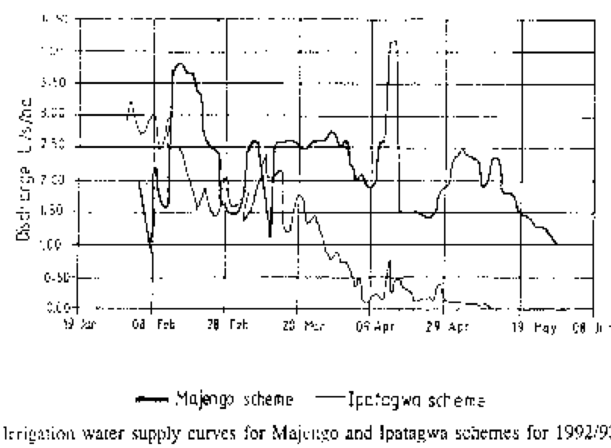
In terms of crop yield, Majengo had higher yield than Ipatagwa as shown in Table 1. An increase in irrigation water supply may have contributed to the increase in crop yield. This is because crop variety, fertilizer application and utility of irrigation water appeared to have little or no effect on yield (Tarimo, 1994).

Irrigation system's performance indicators show clearly that there is no different in performance between the improved Majengo irrigation systems and those of Ipatagwa traditional Irrigation system except for bigger irrigation water capture.

The water users of Usangu Plains did not have the tradition of water allocation and distribution (Tarimo, 1994). Therefore improvement of traditional schemes should minimize the use of rotational system as a way of water allocation and distribution. If rotation is found to be necessary it should be practised between tertiaries that share one secondary canal rather than between secondary canals. It is easier for farmers to negotiate for irrigation water at periods of scarcity among themselves between tertiary canals. Rotation between tertiaries commanded by one secondary canal will also reduce the capacities of the secondary canals and will reduce the danger of the bank slipping because of rapid filling and emptying as they will have continues flow of water (Wang and Hagan, 1981.)




Irrigation water supply curves for Magengo and Ipatagwa schemes for 1991/92




Irrigation water supply curves for Magengo and Ipatagwa schemes for 1992/93

**Figure 3: Daily irrigation water supply in L/s/ha of Majengo and Ipatagwa schemes**

The water allocation and distribution in Majengo was designed to operate on rotation at secondary canal level. The design capacities of the main and secondary canals and the topography dictated the size of the water control structures at the diversion points. The four secondary canals commanded areas of different sizes ranging from 88 ha to 200 ha. The diversion into these canals was made with culverts with the same maximum capacity of 0.7 $m^3/s$ under the assumption that they would be operated in rotation (van Vuren, 1987).

Given that rotation system was not being followed and there was no flow measuring devices at these points so that the flow could be regulated the top most secondary canal with a command area of 88 ha received more water than its area required (Tarimo, 1994). Similarly, the tertiary turnouts had steel plate gates which were supposed to be closed when irrigation water was not needed. It was observed that the gates were constantly opened over the cropping seasons. According to van Vuren 1987, the tertiaries were designed and constructed to have the same maximum capacity of 0.125 $m^3$/s. Since their turnout gates were constantly opened some of them received more irrigation water than they needed as the tertiaries commanded different sizes of land blocks (van Vuren, 1987).

Further more the farmers in Majengo still believed in their old system of irrigation practice as already explained. This means that the water control structures should have been delivering a constant water supply at both the diversion and off take point in proportion to the areas they commanded rather than having a rotational system of irrigation which was not being practiced.

A rotation irrigation system works well only if the amount of water entering into canal systems is known something which requires flow measuring devices. In the case of Majengo the intake was of run-of-the- river type therefore, the flow into the main canal depended on the river flows and it did not have flow measuring devices. In such a situation probably simple proportioning water division devices would have distributed the irrigation water more effectively.

On the other hand the water users in the Usangu Plains did not have the experience of a formal or informal water users organization for management of the irrigation systems. The schemes were young informal irrigation developments which are still evolving and had not attained a sustainable, irrigation systems management (Hall, 1989. Tarimo, 1994). In Tanzania, it is probably only the Sonjo Clusters in Arusha Region or the Chagga and North Pare traditional schemes in Kilimanjaro region which have been in existence for over 150 years and which have fully matured organisational systems for managing the irrigation. The rest of the traditional schemes may be more or less of the same category as those found in the Usangu Plains.

Unfortunately for Majengo the water users were not even involved in the process of the schemes development and hence even the weak association that existed before improvement was destroyed. Thus the executing agency found it difficult to hand-over the completed scheme because the water users did not have an organization that was ready to take (Tarimo, 1994). Hence the good performance of the irrigation system in Majengo in terms of water capture may be short-lived due to lack of an effective water user's organization lack of water management skills on one part of the formers and lack of technical skills and capability to repair the complex water control structure (Tarimo, 1994).

Therefore, Majengo schemes irrigation systems may not be sustainable and farmers will probably resort to constructing their own system as the present improved systems collapse.

Also, Lower Moshi FMIS was designed to operate on rotation among the secondaries both in the rain season and dry season due to scarcity of irrigation water from the rivers namely Njoro and Rau rivers. A research going on in Lower Moshi found out that since 1988 the designed rotation system is not being practiced. Instead, the executing agency in consultation with the water users decided to irrigate continuously one block in each village per irrigation season leaving the rest of the blocks fallow. The scheme covers five villages namely; Upper Mabogini (8 blocks), Lower Mabogini (10 blocks), Rau ya Kati (5 blocks), Oria (8 blocks) and Chekereni (14 blocks). Although the irrigation blocks are not of the size equity in water distribution may exist among villages as some have more blocks the others in terms size or in numbers or both and this can create some conflict. Since there are strict rules that a block should not receive irrigation water continuously for two or three consecutive seasons, some influential water users may end having their blocks through-out the year.

## CONCLUSION

Most of the small scale Traditional Farmer- Management Irrigation systems were recent developments with young and informal water users association which were still involving, As was the case of Ipatagwa and Majengo their water allocation and distribution method is on demand. Therefore, it is being suggested that water allocation and distribution should be designed in such a way that it is more or less similar to existed method of water distribution.

If a water rotation if to be practised then it is recommended that it is conducted between the tertiary canals and not between secondaries. Further proportioning water division devices should be used at the turnouts to distribute the irrigation water instead of steel gates which farmers mismanage.

Finally in the process of the development of the water distribution method and the water control structures to be used for water distribution, the water users should be fully involved.

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