ACDI/VOCA
Farmer-to-Farmer Program

Lwoba Farm

Improving Irrigation & Rice Production
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Lwoba Farm:
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List of Acronyms

AIT	Asian Institute of Technology
CAN	Calcium Ammonium Nitrate
DAP	DiAmmonium Phosphate
IRRI	International Rice Research Institute
JICA	Japanese International Cooperative Agency
KATC	Kilimanjaro Agriculture Training Center
LMIS	Lower Moshi Irrigation Scheme
OLPC	One Laptop Per Child

Lwoba Farm:
Improving Irrigation & Rice Production

Executive Summary

At the request of Haji Ahmed Narba, ACDA/VOCA arranged for a four week volunteer consultancy to assist Haji with the irrigation development and improvement of the 1200 ac. Lwoba Farm he owns and the Manafwa Basin Rice Farmers Association, representing the tenants to whom he rents the farm.

While the consultancy centered on the irrigation improvements, the consultant also looked at a broad range of joint interests that would impact on the overall operations of the Farm and other enterprises Haji was interested in getting involved with.

Irrigation System

The irrigation system is basically a run-of-the-river diversion without any improvised diversion weir or storage facility. It operates on free flow system throughout the farm with no attempt to control the water and no structures that would facilitate controlling the water. However, the biggest problem with the irrigation system was the sediment load that was being deposited during the first couple months of the rainy season until the annual crops planted in the upper catchment have grown sufficiently for full canopy closure that can reduce the erosive impact of rains. Thus, the first need for the irrigation system was getting control of the sediment. This will require inserting a sediment trap at the beginning near the diversion to slow the water and allow the sediment to drop out in a convenient place where it can easily be removed.

In addition to the sediment trap, the irrigations system needs a master plan for overall design and operation. This requires some basic decisions on how the system is to operate. Will it be the administratively simple and default free flow as is the current practice in both the farm and neighboring Doha Scheme? The free flow does not allow for overall irrigation efficiency. The alternative is to develop a more comprehensive plan that will require installing check structures and hiring someone to manage these. This will improve the quality of the irrigation, but the system will become more vulnerable to disruptions in the operation by breakdown in control structures or employees hired to manage the system taking an unscheduled day off, etc. As this will put people's livelihood in jeopardy, breakdowns can quickly lead to vandalism of the system and more problems. This master plan would include any reallocation of the basic design including removal of some field canals and the enhanced means to access the field for equipment and removal of produce.

Based on the decisions above, the next step would be designing and installing any control structures such as drop structures, check structures, field canal inlets, field inlets and field drains. Many of these could be simple pipes of specific size.

There is a need to develop a maintenance plan that looks at both the communal vest interest as well as individual vested interest. Thus, instead of the normal having farmers responsible for the canal adjacent to their field but past their inlets, they will be responsible for the canal above their fields between their neighbors inlet and their inlet.

From a legal perspective, there is a need to work with the government to get an entitlement to divert 1.2 m^3/s from the river with the understanding that only 0.4 m^3/s will actually be consumed and 0.8 m^3/s will ultimately be return to the river for downstream use and this will be in an environmentally and economically more advantageous manner.

Farm Operations

The farm is rented to the tenant members of the association on a cash basis at UShs 100,000/ac/yr with the prospects of producing two crops of rice. This is divided into UShs 30,000 for rent and UShs 70,000 for operations, mostly the cost of managing the irrigation system including any capital repairs such as obtaining rock for making the weirs, and other control structures.

For their rent payments, the tenants receive an allocation of from 0.5 ac to 1.5 ac. This is really not sufficient for full time farming. Thus, farmers have to manage additional non-irrigated land outside the farm. Normally these outside lands have to be given priority once the rains come, or the opportunity will be lost. In contrast, the irrigated farm provides more flexibility and thus can be delayed even if it provides a higher return.

There is a need to carefully consider any desire to operate the whole farm in “Estate Mode” following the example observed at KATC in Moshe, Tanzania. It has not proven as effective as promoted in most cases such as the Gizeria Scheme in Sudan.

Rice Production and Processing

For the most part, the actual production of rice should be left to the farmer tenants as they struggle between their in-farm and out-farm gardens. They should be encouraged to start using at least nitrogen fertilizer such as Urea, but avoiding the liquid fertilizers being marketed. They might want to consider shifting to direct seeding, particularly if allocation size increases with any mechanization efforts. Also, approach any in-line transplanting with caution as it takes about 20% extra labor. It is one of those recommendations that are highly promoted by research and extension personnel but with only limited farmer acceptance unless combined with the mechanical hand weeders, IRRI developed many years ago and were demonstrated during the

visit to KATC. If getting involved in processing for local and regional marketing, consider shifting to single pass mills instead of the current double mills.

Rodent Control

Concern was mentioned for rodent control. This can be a major problem in rice for which there are only limited prospects for control. One possibility would be the introduction of mongoose. However, they can eventually become as big a pest as the rats they control.

Mechanization

One of the major concerns recognized during the consultancy that is largely overlooked by the development community is the amount of drudgery in the system that often exceeds the calories that individuals have access to. The result is farmers only have enough energy to work three or four hours a day. Thus, to advance the overall efficiency and returns to the farm, it is necessary to undertake some form of drudgery relief. For farm work this implies mechanization which for rice implies individually owned 2-wheel walking tractors or power tillers, and for upland crops contract access to 4-wheel tractors for basic land preparation. In addition, it might be possible to mechanize the threshing operation and expedite the turnaround time between the two rice crops.

Aquaculture

Haji is interested in committing some 20 ac to fish farming. This was reviewed from perspective of the fish farm visited during a field day, and general background of fish culture. It is a fairly risking undertaking that needs to be done carefully. It also needs to be done in close coordination with the buyer and processors of fresh fish as with fish farming it is necessary to harvest and market a whole pond of some 500 fish at once. For additional information and possible training at the MSc level, it is suggested contacting the Asian Institute of Technology's (AIT) aquaculture program. They have one of the best aimed at smallholder production.

Haji Family Enterprises

With all the activities described above that Haji and his family are interested in, it might be good to look at a small local conglomerate of agro-enterprises whole owned subsidiaries and managed by different adult children. These subsidiaries would be both financially and operationally independent but collaborating with each other on a purely business relationship. Such subsidiaries would include:

- The rice farm
- Irrigation development services
- Mechanization
- Input supplier
- Milling and marketing rice

- Fish Farming

Other activities

Other concerns not directly related to the farm and agro-enterprises would include

- Boy College (Secondary School) and possibility of getting some computer from OLPC program
- Low Head Hydroelectric generators for inserting in the river.

Lwoba Farm
Improving Irrigation & Rice Production

Introduction

The consultancy was done at the request of Haji Ahmad Narba to ACDI/VOCA. Haaji was seeking assistance in managing the irrigation system for his 1200 ac. irrigated rice farm and the 1200 tenant farmers it serves. The consultancy was for four weeks from 24 May to 21 June 2008. It was based in Mbale, Uganda the closest town to the farm. The farm is located some 20 km South west of Mbale and some 220 km from Kampala, the capital. The consultancy was primarily intended to evaluate and recommend improvements in the irrigation system, but expanded to look at several other areas of common concern. These included general rice production and processing, integration of irrigated and rainfed production, mechanization and the urgent need for drudgery relief, aquaculture and general support services. Frequently, the consultancy simply provided a logical framework for what was already being observed on the farm and companion upland cropping areas. The daily activities of the consultancy are included in Appendix A.

Lwoba Irrigation Farm

The Lwoba Irrigation farm is a 1200 ac (500 ha) farm located some 10 km south and 12 km west of Mbale, Uganda. The farm is owned by Haji Ahmed Narba. Haji rents the land to tenants in half acre or one acre allocations for rice production. The farm is irrigated by a run-of-river diversion from the river. The water is then distributed by two main canals serving a multitude of field canals. It is all free flow with no control or drop structures. As the main concern of this consultancy is the irrigation system it will be dealt with shortly.

Rainfall Distribution

Based the closest available data from Eldoret, Kenya, approximately 110 km SE of Mbale, the area receives some 1400 mm of rain annually (Table 1). This is distributed throughout the year with a concentration between March and September, but with the other months still averaging some sufficient rains for limited production, particularly for crops like sweet potatoes and cassava. However, the annual variability (CV%) appears higher than most tropical countries which makes a lot of uncertainty in managing crops, particularly rainfed crops outside the Farm. With the irrigation water available to the Lwoba farm it appears there is sufficient water most years to produce two rice crops. This was noticed by the extensive harvesting activity taking place during the May-June visit with an implied crop establishment in January and February during the period of lowest rainfall.

Table 1. Monthly Variation in Precipitation for Eldoret, Kenya (mm)

Year/Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1987	61	67	72	118	273	150	61	155	20	39	130	3
1988	46	9	36	192	41	146	170	108	134	59	25	16
1989	15	46	121	159	152	101	207	126	110	59	41	116
1990	45	156	66	128	122	220	617		880	21	620	
1991	38		129		490	162		193				160
1992	30		13	178	87	100	180	245	96	128	39	12
1993	63	68		24	111	810	97	97	79	140	40	160
1994			96		10	142	23		25	140	100	50
1995	0	36	850	193	54	67	167	142	60	85	70	23
1996	27	55	180	59	77	145	247		70	9		
1997		0		285	25	152	175		1	157	177	65
1998	231	91	37	74	130	179	321	236	95	101	32	1
1999	38	0	183	109	57	68	192	129	33	197	39	293
2000	5	3	14	39								9
2001	126	2	79	154	77	143	147	234	234	106	65	0
2002	43	30	39	88	182	37	96		2	64		175
2003	3	2	47	238	170	103					8	42
2004		3							96	54		
2005				61							11	
2006		46	106	108	77	64	129	288	113			
Count	15	16	16	17	17	17	15	11	16	15	14	15
Sum	771	614	2068	2207	2135	2789	2829	1953	2048	1359	1397	1125
Ave.	51.40	38.38	129.25	129.82	125.59	164.06	188.60	177.55	128.00	90.60	99.79	75.00
Std. Dev	60.74	43.80	205.61	74.10	111.53	178.69	139.89	67.61	214.09	53.88	163.18	88.02
CV (%)	118.18	114.13	159.08	57.08	88.80	108.92	74.17	38.08	167.26	59.47	163.53	117.36
	Ave. Total Annual Rainfall					**1398**						

Farmers Association

The farmers are nominally organized into a farmers' association, but this may not be the same as US farmer associations as Haji is the chairman and his family members serve in all the official capacities. This is consistent with farmer associations in many developing countries in Africa and other areas, and does provide some organizational structure to manage the farm. It also has political advantages with donors such as ACDI/VOCA that can only provide volunteers to organized groups of farmers or other beneficiaries. There may be a need to enhance the participatory involvement of the farmer/tenants but in a non-binding advisory capacity.

Rent Agreement

The rent agreement with the tenants is cash rent at UShs 100,000 (US$ 62.50)/ac/yr, with the tactical obligation for Haji to assure the irrigation system is always in working order and providing adequate water for rice production. The effort to provide reliable irrigation water has provided Haji with some good basic understanding of hydraulics. The rent is actually fairly nominal. Of this the rent is allocated at UShs 30,000 (US$18.75)/ac/yr for rent and UShs 70,000 (US$ 44.37) for operational cost mostly associated with the irrigation system. In addition, as needed, there can be community days on Wednesdays when the farmer/tenants are expected to assist with community activities, mostly working on the irrigation system such as assisting in building a riprap diversion weir (Fig. 1). Those not participating are subject to fines.

Fig. 1. Farmer/tenants assisting in building a diversion weir.

From a US consultant perspective, this is a very nominal rent particularly if two rice crops a year are possible. However, while there is no need to account for the rent component of this fee as it is basically the owner's salary, it might be appropriate to provide an annual accounting summary on the irrigation component. There is no legal obligation, but it would make good public relations for the tenants to know how this money was used in the continued development and

improvement of the irrigation system, including any money escrowed into a bank account against future repair and maintenance costs. This is because irrigation maintenance costs are not uniform each year and money has to be set aside for periodic major repairs to such things as diversion weir and major control structures. In this case, it is the tenants' money, entrusted to their landlord.

Also, I am not terrible comfortable with the mandatory community days. This is because smallholder farmers are multi-enterprise private entrepreneurs and have other commitments in their in-farm gardens, outside farm gardens or elsewhere, and this has to be appreciated. I would consider making these paid working days by increasing the irrigation fee and then as needed call for work days and hiring the tenants to do the manual work. When possible, these work days need to be during slack periods in the agriculture season activities and not during major crop conversion or establishment periods such as during the visit. As is the custom in other parts of Africa I would include a good lunch meal in the compensation. As we discussed, there could be a serious calorie limitation on the part of the farmers, and a good lunch could be considered as nothing more than a fuel stop needed to assure the energy for the afternoon's work.

I also find the cash rent and level of owner input into the farm management interesting. Usually, cash rent gives the tenant full flexibility in what he does with the land, including selecting what crops to grow. The owner has his money so has little vested interested in what the tenant does to earn the rent. The level of owner management in the farm is more consistent with a share-cropping arrangement where owner and tenant share in the production costs and share in the yield. The three basic sharecropping agreements are actually nearly universal being the same in Fort Collins, Colorado as in Uganda. These relations are 30-70, 50-50, 70-30 depending on who pays or shares in the payment of the inputs. Cereal crops such as rice are the more common sharecropping agreements, while vegetable crops are more often cash rent.

Allocation Size

As we have discussed, a 0.5 or even 1.0 ac (0.2 or 0.4 ha) is not an economically viable garden size for a full time farm enterprise even with the suppressed economy of Uganda. Thus, if you are going to keep the present allocation size the farmer/tenants will have to have additional lands or other economic activities outside the farm in order to make a minimal living. If they are managing additional non irrigated lands outside the farm, these lands will have to be given the highest management priority at the beginning of the intensive rainy season. The reason is that, even if the yield will be lower, there is no flexibility in managing them so that if they delay the rainfed gardens the opportunity will be totally lost. In contrast the irrigation system provides considerable management flexibility and prolongs the cropping season. This priority for rainfed over irrigated has been observed in the small tank systems of Sri Lanka, the small rice irrigation systems of Malawi, and Madibira, Tanzania, as well as with the Lwoba Farm. Typically, depending on the amount of outside land involved, the delay in getting to the irrigated areas can be as much as six to eight weeks. This provides Haji and the farm with a vested interest in

assisting the farmers with their outside cultivation. This could be done by providing a contract tillage service based on 4-wheel tractors such as the Massey-Ferguson 165s or 265s equipped with 3-bottom disc plows.

If you are interested in having tenants working full time in the farm then it will be necessary to increase the allocation size. This might have to get up to 15 ac (6 ha). This would be consistent with the farm size in Thailand, where smallholders have broken out of basic subsistence poverty. However, the increase in allocation size may need to be accompanied with an increase in the basic means for managing the land. That would imply the appropriate mechanization, such as the power tillers. There would also have to be some consideration for those displaced by the expanded allocations, unless it was done with whatever the normal tenant turnover is, but that could be slow process. In expanding the allocation size, it might be desirable to look at the basic layout and consider making the layout into longer narrower parcels each stretching from canal to drain, as will be discussed shortly in the irrigation section,

Mode of Management

The visit to Moshi, Tanzania and the JICA sponsored KATC (Kilimanjaro Agriculture Training Center) and Lower Moshi Irrigation Scheme (LMIS) project develop an interest in what is normally called Estate Mode for managing smallholder farming. That is where Haji and his family basically take over the management of the farm making all the decisions for the individual tenants and forcing them to comply with a preset schedule. While this appears to have some advantages in terms of overall operational efficiency, it has never been well received by the producers. Basically, it simply converts the tenants to laborers on their own land. In this case, it could greatly interfere with any off-farm land management. Also, the preset schedule could and often does exceeds the means the farmers may have available to implement the production schedule. The idea of Estate Management for smallholders has been around for over a hundred years. It was first attempted by the British in Gizeria, outside Khartoum, Sudan and contributed to the ultimate total disaster of that multi-million hectare irrigation scheme designed around cotton.

I would thus suggest that if you are interested, proceed with extreme caution. The basic reason is that the production function of yield vs. time of crop establishment is usually negative, with potential yield declining with delayed planting. Thus, under estate mode management, there will always be some inherent disadvantages to those farmers whose land are established late relative to those establish earlier. Those losing out will be most unhappy and clearly know who is responsible for their lower yield potentials. It will be the scheme management. If the intention is to keep the farm under tenant management, it is better to allow the individual tenants to manage their land independently and accept any inefficiencies occurring. I also visited KATC annually when working in Tanzania and recognize that with the 30 years of JICA assistance the Lower Moshi Irrigation Scheme (LMIS) appears successful with some good six t/ha rice yields. However, I seriously doubt if it will continue once JICA assistance ends and the Japanese depart.

You only have to visit the unofficial irrigation scheme just up-stream from LMIS and involving some of the same farmers, where “Estate Mode” is not practiced.

Of course the alternative would be to take over direct control of farm and manage it as a unit, hiring many of your present tenants and laborers. On international standards, the farm is not all that large. Bolivian and US farmers manage rice farms of this size. To do so would require going to full mechanization and doing the land development that would be required to efficiently handle the tractors and large combines. Also, I am fairly certain there are private estates of this size in Uganda, frequently owned and managed by the muzungus, with full mechanization. I am not certain with the current subsistence management people are not economically equal or better off as estate laborers relative to independent smallholder producers/tenants.

Irrigation System

Basic Design

The irrigation system for the Lwoba Irrigation Farm is a basic self-constructed Run-Of -The-River Diversion without any head works. The system was developed with little professional engineering assistance. During the visit an attempt was made to construct a riprap rock diversion weir head works with stones that had a maximum size small enough to be man-handled by individuals or pairs of individuals. Rather this is sufficient to withstand the high volume flows during a rain surge is questionable. The diversion is also at the nearest point in the stream to the fields and thus is below grade for the first several fields. Plans are made to acquire additional land so a new diversion approximately 500 m up-stream of the current diversion can be built that would convey water on grade for complete gravity distribution.

The water is distributed by a short main canal leading to two secondary canals and on to various field canals, which than served the individual one acre or 0.5 ac allotments. The basic layout is a good rectangular layout with most field canals serving a similar number of acres in a rectangular pattern. This means each field canal needs approximately the same flow and same inlet capacity, which makes improving the system fairly simple. The system also allows for the reuse of any return flow. The field canals are along the contour and can only irrigate the downhill side of the canal, while also serving as collectors for any surface return flows from the previous field canal. How much return flow was redistributed was not assessed. It would vary considerable with the surges in rains and amount of water being diverted into the farm. There had been several attempts to install control and check structures in the main canal, but these did not have sufficient engineering support. Thus, as so often happens, they failed to fully appreciate the total force exerted by flowing water, and all have either been washed out or been eroded around and rendered unusable. The field canals did not contain any check or drop structures to make for effective irrigation reaches nor were there any field inlet control structures other than farmer made bank cuts. Thus the system operated on the default management of free flow throughout.

One of the biggest needs for the irrigation system is get some solid engineering structures designed for the different controls and constructed to a standard that will not wash out and with sufficient head works to prevent eroding out.

Water Requirements

Based on the computation for the Madibira scheme in Southern Tanzania where the estimated water requirement was 2.5 l/ha/sec, the Lwoba farm needs to divert approximately 1 l/ac/sec. In the absence of any more comprehensive climatic and soils data, the Madibira estimate should be reasonable valid since Madibira is only 1000 km South of Mbale, but still well within the tropics and at or near the same to elevation of 1100 m/amsl. Thus the temperatures that determine the evapotranspiration rates should be similar. In Madibira, of the 2.5 l/ha/sec diverted it was estimated that 1/3rd would go to evapotranspiration, 1/3rd would go to deep percolation and 1/3rd would go for conveyance losses. The same should apply to Lwoba. Since the only physical loss of water is via evaporation either from the canals and ponded water surface in the paddies or transpiration through the plant, the actual consumptive use would be only 0.3 l/ac/sec. The rest of the diverted water will eventually be returned to the river for beneficial use downstream, but with a delay in availability that should be beneficial as it would be well after the peak hydrograph of any rainfall surges have passed and the river flow declined. This delay in availability of the surface water should be in the order of a week or less. That which actually becomes deep percolation will enhance the base flow when it eventually returns to the river. This delay could be months and provide enhanced flow during the dry seasons.

The accounting for return flow is somewhat different from the water decrees in the Western US, where the accounting is strictly on the water diverted, with no consideration or credit for any return flows. That has the interesting effect of having the decrees on the South Platte River, in Eastern Colorado greater than twice the annual natural flows. Since the water laws in Uganda are not as strict, the consumptive use should be all that is necessary.

Allowing extra water into the system should make the distribution of sufficient water fairly easy, but will require allowing for fairly rapid drainage of surplus water. Any rainwater would also be surplus and have to be drained from the farm. This may result in some minor flooding but rice, once well established but prior to grain filling, can usually withstand a few days of inundation with little damage. Rice only needs to have its head above water during times of temporary flooding that can last up to four or five days. Once the grain begins to fill flooding will discolor the grain resulting in downgrading the quality.

For the total 1200 ac of the farm the total diversion needs to be 1.2 m^3/s, of which only 0.4 m^3/sec will be used and 0.8 m^3/sec. will ultimately be returned. In addition, any rain received will ultimately have to be drained from the farm and discharged into the river. That is because, as previously mentioned, the only real losses are those from evaporation either as evaporation from the water surface or transpiration from the plants. The rate of evaporative lose is

determined by the climatic conditions, mostly solar radiation, and is independent of any plants parameters. The extra water normally attributed to rice production is really the water that infiltrates and ultimately returns to the river. With paddy rice irrigation that maintains a continuous or near continuous ponded water on the soil surface, the natural water loses will be at both peak evapotranspiration and peak deep percolation so that any extra water diverted with the irrigation system or coming from rain has no choice but to move laterally through the system, out the drains, and back to the river.

The actual peak demand for water is the initial ponding of the paddy for crop establishment. This requires a onetime access to some 20 cm of water per individual field. That water can come from a combination of irrigation water plus rain water. Typically in designing rice irrigation schemes it is estimated that the crop establishment will be completed within the first couple of weeks of operations and thus require extra water. However, more realistic projections are four to six weeks for full crop establishment. With this extended crop establishment the need for individual fields to have access to 20 cm of water can easily be integrated into the overall operation of the system without relying on extra diversions.

Sedimentation

Perhaps the biggest concern in the farm is the amount of sediment coming in with the diverted water and clogging the canal. This then requires extensive cleaning each season. The sediment is the result of the farmers in upper watershed not really having the resources to practice good conservation tillage that will protect their lands. Thus, when the rains begin, they have no practical alternative but to burn off the previous crop residues as it is impossible to incorporate the residues for an entire garden in a timely manner if you only have hoes to work with. The level of sediment in the stream remains high until the upper catchment crops are well established with a closed canopy that will intercept the rain and allow it to fall gently to the ground in a non-splattering, non-erosive manner. This will be approximately one to two months after the rains begin or until approximately the end of June. Until such time as there is sufficient mechanization in the upper catchment to allow for more conservation tillage, sedimentation in the farm's canals as well as the adjacent Doha Scheme will be an annual problem, and there is nothing the people in Lwoba can do to prevent it. This is very similar to the Madibira scheme in Southern Tanzania in which the sediment trap was completely filled (Fig. 2) and the two meter high inlet tunnel was closed to within 50 cm (Fig. 3) each year.

Other rice producing tracks in the Mbale area may appear to be avoiding the problem because they are developed in the natural wetland papyrus swamps, so that as the water enters the area it is natural dispersed at the upper end and the sediment drops prior to getting to the paddy area. A visit to the upper end of these papyrus tracks should show some massive alluvial fans of recent sediment.

The potential sediment load in a water channel, be it the natural river channel or irrigation canal system, is in direct proportion to cube of the water velocity. If you double the water velocity the potential sediment load can increase by eight fold. The solution to removing sediment is to slow the water velocity sufficiently to allow the sediment to drop out in a convenient location. This is basically what a sediment trap is. It is an enlargement of the canal that slows the flow of the water sufficiently to drop the sediment and proceed cleanly through the farm. In the case of Madibira the sediment trap was large enough to retain the water for one hour. For the Lwoba farm, if it is diverting 1.2 m^3/sec of water and the desire is for an hour of retention time, the sediment trap needs to be 4200 m^3. That should be sufficient to settle out all the gravel, sand and silt, leaving only the clay particles in suspension. Clay particles usually flow through a system with little problem or accumulation, and could contribute some non-nitrogen fertility to the farm.

Fig. 2. Sediment Trap in Madibira, Tanzania,as viewed from the discharge weir. The trap filled each season.

The design of a sediment trap to accommodate the Lwoba farm needs to consider how it will be cleaned. If this is to be done mechanically with a locally available excavators on contract, then the width of the trap can be no more than twice the reach of the excavator. Otherwise there will be a ridge of sediment in the middle that will have to be removed by hand, or at least pushed into the reach of the excavator. In Madibira, the project excavator was specially ordered with extra long arms to accommodate the sediment trap shown. I don't think that is reasonable for Lwoba as I would expect the farm to contract for an excavator each year for the few days it is needed, rather than attempt to own and maintain one that will not be extensively used. The only solution would be to compensate by making the sediment trap longer. The example would be if the cross-section of the canal is typically two meters square it would be necessary to expand that to approximately 12 m^2, either with extra width or extra depth. A 12 m^2 cross-section would then have to be over 300 m long to satisfy the 4200 m^3 trap. If is possible to increase the cross-sectional area either by being wider or deeper the length can be reduced proportionally. A

smaller trap could be used, but it would most likely have to be cleaned more frequently and allow larger material through. However, it is recognized that the rate of deposition will decline as the sediment trap is enlarged with progressively less sediment trapped for each increment of increased size. Thus the optimal size may be less than the one hour retention time used in Madibira. This then requires an economic analysis to determine the optimal design relative to costs and available land. Looking at the proximity of the diversion weir to where the secondary canals split, a 300 m sediment trap may not be possible.

Fig. 3. Inlet tunnel at Madibira that would be 3/4th filled with sediment each year

Ideally, the trap should be cleaned during a lull in the rains a couple months into the rainy season when the flow in the river slacks to some degree. That would be when the sediment load should start to decline and remain low for the balance of the rainy season and following dry season. It should than be able to run the rest of the season with little difficulty. However, this will also be when the demand for water might be high and you cannot fully shut down the system. Hopefully an excavator operator can work with the water slowly flowing in the trap.

Another possibility to consider is the overall operations of the farm and take advantage of the farmers giving priority to outside crop establishment and not even operate the system for the first month or six weeks after the rains begin and sediment load is highest, then when the sediment load declines turn the system on. What would happen if the system was closed from during May and June each year? Observation during the visit indicates this would be during the harvest and

transport of the rice from the field, rather than crop establishment. This is just a spur of the minute brainstorming idea but may be worth consideration.

Field Layout and Access

While a detailed schematic diagram of the farm showing all field canals and land allocations was not available, the overall field layout appeared typical, with each farm along a field canal being square or rectangular shaped. This probably makes good sense from the irrigation hydraulic consideration. However, it might not be the most convenient from the overall farm management perspective, as it forces farmers to access their field via their neighbors. A more convenient layout might be to have the fields run in long narrow strips being at the field canal and extending to the drain. In the Philippines a 1 ha field could be 10 m wide and 1000 m long (Fig. 4). This allowed farmers good access without disturbing their neighbors. Something like this might be worth considering for the Lwoba farm.

Fig. 4. Field layout for an Irrigation Scheme in Central Luzon, Philippines with the field running 1000 m from the canal to the drain with field width as small as 10 m. This enhanced the individual access to individual farms.

An important consideration in the field layout is access, particularly if anticipating increased mechanization, via power tillers, portable threshers or other forms of appropriate small scale mechanization. In smallholder irrigation schemes, field access is usually associated with the irrigation system including both canals and drains. This can be critical as noted by the number of farmers or laborers struggling along the field canals with heavy bags of rice, because the canal banks were only wide enough for foot traffic. This is a major source of drudgery to say nothing of the potential for injuring individual's backs and disrupting their employment opportunity for several days up to a month or more that they may not really be afford. Thus is should be important to conveniently use the canal system for access by allowing the construction of two meter wide roads along the drain side of the field canals and bridges to access from the main

canals. This width of road should be suitable to accommodate the small trailers associated with power tillers.

If you consolidate the previously suggested desire for longer narrower fields with the need to improve access, it might be possible to remove every other field canal. The land saved by removing the field canal could then be used for the access road, with no net loss of cultivated area. This will then require some land development to consolidate the enlarged fields into level paddies, but that should be fairly easy with the help of power tillers, etc.

It should be noted that it is typical for smallholder irrigation schemes to have up to 10% of the total land area consumed by canals, drains, and access roads. My guess is Lwobe is well within that estimate.

If access roads are built, the maintenance should follow the same consideration as the maintenance of the field canals. That is to be cognize of both the community vested interest and the individual vested interest. While the community as a whole will appreciate the access roads, individuals want roads to serve their fields, but not cross their fields. Thus, as will be discussed later, the access road maintenance needs to be vested with the farmers behind rather than adjacent to the roads, with the right to obtain materials from adjacent fields or canals as well as smoothing out any sediment removed from the canals or filling in any rodent control holes to assure easy access with whatever mechanization is being used.

Control Structures

After the sedimentation problem, the next issue is the control structures needed to control the water and assure it flows smoothly and uniformly through the system. The control structures required are the diversion weir or head works at the entrance to the system, possible check structures to regulate water entering different field canals, drop structures to make certain the flow remains laminar and not turbulent, inlet structures for each field canal and each field, and field drains. These structures all have to be constructed strong enough to withstand whatever force of water they are subjected to, with sufficient head works to prevent erosion from eddy currents and other conditions. The force of water is something that is often seriously underestimated and may require someone with a detailed understanding of hydraulic structures to design and oversee the initial construction.

Diversion Weir. The diversion weir or head works is the structure placed across the river that facilitates water being diverted into the scheme. In the case of the Lwoba farm, this is a recently constructed riprap (uncemented rocks) weir made of stones no larger than what can be handled by two persons. If these rocks can withstand the full force of high water is questionable. Some may have already washed out on the far end (Fig. 5). More often self-constructed head works will actually be cemented as is shown in this informal head works for a self constructed informal scheme serving some 100 ha across a stream in Tanzania near the Madibira irrigation scheme (Fig. 6). The stream is somewhat smaller than that serving the Lwobe farm.

Fig. 5. Diversion into the farm a week after initial construction showing some possible washout at the far end.

Fig. 6. Diversion weir from informal irrigation scheme in Tanzania bridging a stream of somewhat smaller size than Lwoba.

Another option would be to use wire mesh Gabions to contain the rocks and assist in preventing them from eroding as was used in the Doha scheme to protect a bridge abutment (Fig. 7).

The actual placement of the weir relative to the inlet should be at least several meters downstream. This is for two reasons. One, as water approaches the weir it senses the drop and begins to respond to it several meters before the weir. For example, if there is 30 cm of water going over the weir, the maximum head will be up to 10 m prior to the weir. Thus the diversion needs to be at least 10 m upstream of the weir. Second, the weir will cause some turbulence and

eddy flows in the water that could erode the soil around the weir. It would also be good idea to line the stream banks with riprap the first several meters of the inlet to minimize any erosion.

Fig. 7. Gabions used to hold stone work in support of bridge abutment in Doha Irrigation scheme that appear to have been concreted over.

The sediment trap should be as close to this inlet as possible to be most effective.

Drop Structures: Drop structures are simple structures across a canal that will safely drop the water a short distance. They are used to assure the flow remains non-turbulent, when the gradient exceeds the desired slope. This would typically be a maximum slope of 0.25% or 25 cm/100 m of canal length. Drop structures typical are concrete or concrete and bricks with a rectangular cross section. They then include a small splash plate at the bottom to dissipate the energy of the falling water and prevent erosion at the drop point before the water gently proceeds down the canal. Drop structures can and often are combined with check structures. For the Lwoba such drop structure may be desired along the main canals as well as the field canals depending on the drops involved. A well placed drop structure or two could be helpful in controlling water on the left hand secondary canal as the water flows past the small knoll or land bench. This is an area where the free flow management has difficulty delivering water to a couple field canals. Like all irrigation structures, the drop structures have to be designed sufficiently strong to withstand the maximum pressure of the water backed up behind them, although this should be no more than 50 cm. However, the same design should be effective for both main canals with a similar but smaller design for the field canals. It would be possible to pre-fabricate the structures and drop them in place as needed. The location of the drop structures should be shortly past the last field canal or field inlet they affect. They will then require some adjustments as needed based on observations of the flow rates.

Check Structures: Check structures are structures that regulate the water. They are used to raise or lower the water level to allow only a portion of the farm to receive water at any time. They

normally have some kind of gating devise (Fig. 8). In the Doha scheme these are usually steel gates with wheel to raise and lower them. However, over the years many have fallen in disrepair so the system basically operates as free flow with no effective control structures. A simpler check structure would be simple flash boards that can fit into a grove in the control structure to raise the water and withdrawn to lower the water (Fig 9). Typically, such flash boards are made of 2 x 6 timbers. However, in countries like Uganda this can pose a security problem as unless fully secured to the structure with a lock and cable, they can be easily and are frequently pilfered. This could become a real major problem that could disrupt the operation of the farm with accompanying discontent and conflict, leading to possible vandalism. If flash boards are to be used it might be best to make them of concrete. They are heavier but perhaps more durable and less likely to be pilfered. They will still need a cable and lock to minimize the pilferage potential.

Fig. 8. Check structure with lift gate for controlling water in Doha scheme. This one appears to be permanently open and thus non-functioning.

The use of a simple flash board check structure in a canal implies the canal has two sections. A lower section that will carry the full capacity of the water, but is below any of the field canal outlet structures it serves, and an upper section that when the flash boards are in place will raise the water level so it can flow into the designated canals or fields. The use of flash board or any other check structure implies someone is responsible to insert and remove the flash boards at the appropriate times as designated in a published schedule for the Lwoba Farm. Such check structures should only be on the secondary canal and control several field canals. To place them on the field canals would require additional manpower to adjust them as needed. That would require approximately one person per field canal, instead of one person per secondary canal. It may be possible to have the farmers operate the structures provided that all agreed to adhere to the published scheduled and they all perceived the schedule as equitable.

Fig. 9. A flash board check structure used to control water in rice field in Bolivia. This one is mostly for draining the field after flooding or prior to harvest.

Field Canal Inlet Structure: Another control structure that would be desired is an inlet structure for each field canal. Most of the time field canal inlets are simple PVC pipes of a specific diameter depending on the command area of the field canal. Since all field canals serve similar areas, only one type inlet structure would be needed. They also require some head works for couple meters at both the inlet and outlet side to prevent any erosion and movement of the pipes and allow easy access along the banks. Without such protection, the inlet structures can easily erode and if the canal banks are doubling as access roads quickly reduce the access to the area (Fig. 10). The use of pipes allows uniform amounts of water to enter each field canal fairly independent of the flow in the canal. These pipes would replace the current open channels leading to the field canals. If you do not have the pipes and head works, farmers could easily expand the field canal inlet and take more water than entitled at the expense of the field canals further down the secondary canal. The real problem with the enlarged inlets is the farmers receiving the extra water benefit directly, while the losses are shared among all the remaining field canals and may not be easily recognized.

For the most part you would need a 1.5 to 2 m of 15 cm PVC pipe per field canal. It is critical that they be accurately placed relative to the height above the controlling check or drop structure to assure water enters only when in turn and not during the off cycle, and water is equitable distributed during periods of low flow.

Fig. 10. Google Earth Image of Irrigation Scheme in Iraq showing erosion at canal inlet and how it can hinder the access to the area.

Field inlet Structures: The next control structure would be individual field inlets. These are not usually considered for smallholder schemes but one I would strongly recommend. Normally the field inlet is a simple cut in the canal bank. However, this can allow for some substantial variation in the water each person gets as they can open larger areas or lower the cut to get more water, particularly if there are drop structures in the field canal. While field inlet structures can be numerous, they are fairly simple and cheap. They can usually be constructed out of simple bricks and cement or a simple PVC pipe. Since no access roads are suggested for the irrigation side of the canal, these pipes can be as short as 50 cm. There is little or no pressure on them, but it would be good to have some erosion control for 50 cm on each side of the pipe, and even a notch on the outside to place a brick for plugging the inlet when not needed. They do require a means of plugging them if the farmer desires because of excessive rains or need to drain prior to harvest. I would think the farmers could be billed for the cost of such structures.

Drains: Since you are diverting excessive water and still have rain water coming in to contend with, it is necessary to provide controllable surface drainage. The current layout with one way diverting from the field canal to individual fields, and thus surplus water returning to the lower field canal, it is necessary to have some type of field drains. The most effective would be simple PVC pipes that can be easily blocked or unblocked at the farmers' discretion, depending on the need to retain water or drain water such as after a surge of rain or prior to harvest. It the plans are to mechanize with rice power tillers with the accompanying small trailers, and if the access is to be along the drain side of the field canals, the PVC drain pipe needs to be 2.5 m. and will require some limited amount of erosion protection on the inlet side and free fall to a splash plate, such as

a couple bricks, on the discharge side. This assumes the wheel base on the trailer is 1.5 m. The size of the drain pipes need only be 5 or 10 cm diameter. That should be sufficient to drain a one acre field in one day, which is adequate for rice. Again, you will need a multitude of these drain pipes but again they could be charged to the farmers. They could also be easily plugged with simple brick and some mud.

Operations

The operation of a smallholder irrigation farm is the most dramatic example of the extent smallholders are individual entrepreneurs with little appreciation of any community allegiances. Thus, if not done carefully and dependable, operations can quickly result in conflict and vandalism to the controlling structures. Somehow farmers never seem to feel they have sufficient water.

Once the control structures are in place, the next concern is how to operate the system in a manner that will equitable distribute the available water with minimize conflict and avoid any vandalism. At present, the system is simple free flow throughout the system. That is water enters the farm from the diversion weir and flows freely through the entire system without any attempt to control the flow. This provides a low but continuous supply of water to each field. It normally does not make for good efficient irrigation, particularly for upland crops where each irrigation requires forcing a wetting front across the field. The more water available, the faster the wetting front will move across the field, and less total water will be applied. It is not as critical for paddy rice. This is mostly topping up an already ponded field and smaller flows of water can easily equilibrate across the field. Free flow is also the easiest form of irrigation management and the default management when control structures no longer function as has happened in Doha.

A better method is allow free flow into the two main canals and divide the secondary canals into several equal sections or reaches with each reach serving an equal number of field canals and area. Check structures can then be used to allow water into one reach on each of the two main canals at a time, while excluding water from the other reaches. This will provide a larger supply of water to each farmer when they are irrigating and allow for faster irrigation, but water will not be available all the time. The typical sets times would be six hours, but this leaves a problem of night irrigation and the reluctance of people to be wondering around the farm at night because of snakes and other security concerns. Thus you would need to have two six hour on periods and a 12 hour on period over night each day. That quickly means the total number of reaches cannot be an integral multiple of three, or the same people will benefit for the extra night irrigation each time, when this needs to be rotated among the farmers. Probably 5, 7 or 8 reaches would be best as it would assure people getting water at a minimum of once in three days. The alternative would be 12 hours sets. In this case, you would still need an odd number of reaches so the farmers irrigating at night would alternate. It should also be noted with field canals of two kilometers length, it normally takes a couple hours for the furthest field to start receiving water

and then it will continue to drain into the areas for a couple hours after the water has been shifted to other reaches. The two kilometers length is about as long as you would want a field canal to run, as with the low flows and conveyance loses are considerable.

The schedule needs to be well published in advance and strictly adhered to. Any breakdown will very quickly result in vandalism to the check structures and the system will revert to free flow. It should be noted that when the check structures malfunction for any reason, such as the flash boards are pilfered, or the ditch ride is late making adjustments, individual livelihoods are at risk and they will quickly vandalize the system to get the water they are entitled. It also means the need to hire someone to manage the check structures. This would very much be the equivalent of the Ditch Riders who perform that function for the private ditch companies in the western US. It is important that these Ditch Riders have no vested interest in the farm or at least the secondary canal they are working on to manage the check structures. Hiring someone with vested interest in the secondary canal they are managing either because of renting a parcel or even having a close relative renting a parcel, can bias the management or even give the appearance of biased management and quickly result in conflict and/or vandalism to the check structures. It could also become an opportunity for the "ditch rider" to earn extra informal income by giving extra water to individuals for a small monetary or even in-kind incentive.

Considering how sensitive the improved operations are, it might be worth consideration to just put in the drop structures to enhance the flow of water and plan on operating the system free flow. With the flash board control structures suggested, if they are removed or damaged than the field canals they serve will be left high and dry with no access to water. That will quickly result in informal blockage of the check structure or pure vandalism with reasonable justification since livelihoods are at risk. The decision on how to manage the system with either check structures and ditch riders or free flow has to be made prior to installing any field canal inlet structures as it will impact on the height of these controls.

Maintenance

As already observed, the effective maintenance depends on recognizing both, the collective or communal vested interested and the individual vested interest. The communal vested interest is in having nice clean flowing canals, free of weeds, debris and other obstructions. Individual vested interest as both discussed and noted during the visits to the farm and neighboring Doha scheme can rapidly shift as each farm inlet is passed. That is because the weeds and other obstruction adjacent to an individual field but passed an individual's inlet generate back flow and thus assure them more of the water that reaches their inlet will enter their field (Fig. 11). Likewise, removing the weeds adjacent to their fields but past their inlet allows the water to flow more freely past their inlet and actually reducing the water they received. The weeds farmers are most interested in removing are the ones above their inlet and adjacent to their neighbors fields.

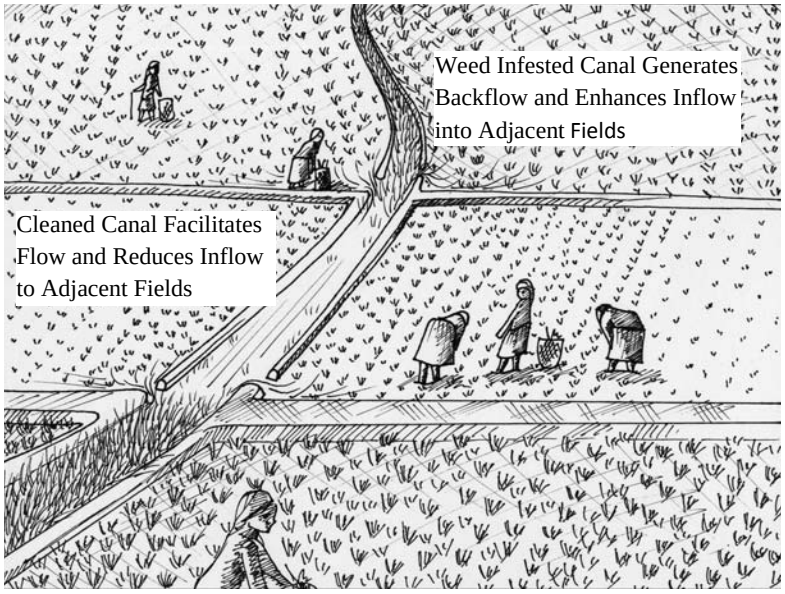

Fig. 11. Illustration of How Weeding Adjacent Irrigation Canals Will Reduce Inflow to Owners Fields While Increase Inflow to Downstream Neighbors (Source: Developing Smallholder Agriculture)

While the common idea is for farmers to maintain the canal adjacent to their fields, this is really not in their individual vested interested as described in the figure above and noted in both the farm and Doha scheme (Figs 12). It is more in their vested interest to maintain the canals adjacent to their up-stream neighbors' fields as noted by farmers complaining about their upstream neighbors not maintaining the section adjacent to their fields while neighbors further downstream make similar complaints against the first farmer. However, to do this will require that the farmers have a clear mandate from the authorities to do so, including the right to obtain material from the adjacent field to prevent overtopping.

Fig. 12. Farmers in Loba partly plugging the field canal to enhance flow to their fields at expense of lower fields.

Thus, the overall recommendation is the farmers within a field canal to jointly take responsibility for the secondary canals from the previous field canal outlet to their outlet and the farmers take individual responsibility for the maintaining the field canal, starting with their upstream neighbors' field inlet and ending at their field inlet.

The community as a whole should take responsibility for maintaining the weir, sediment trap and main canal up to the point where the two secondary canals split off. This would basically be a unique approach to smallholder irrigation maintenance, but one worth considering as it attempts to take into consideration the communal vested interest as well as the shifting individual vested interest. However, it does require a clear mandate from Haji as the owner and ultimate manager of the scheme. An example of an agreement for operating a smallholder irrigation scheme drafted for use in Madibira, Tanzania is shown in Box 1.

Box 1 Operational Proposal for Madibira
The total proposal put forth by the author for organizing the tertiary blocks in Madibira included: **Entitlement**: Every farmer was entitled to an equal share of the water entering the block. Admittedly this is a weak and nebulous statement but all that was really available under the circumstances. **Right to Intervene**: All farmers have the right, either singularly or as a group, to physically intervene above their inlet and adjacent to their neighbors' fields to assure they receive their equitable share. This would include removal of pipes, smearing the canal walls to reduce seepage, adding material to the top of canal banks, removing weeds and sediment from the canal, etc. They would also be entitled obtain any necessary fill material from first 30 cm of field (1 transplanted rice plant) as well as from the bottom of the canal, to assist with raising the canal bank. **Recourse**: Any 10 of the 30 farmers in a tertiary block could partition the management to intervene in the tertiary block management. If so partitioned, every member would be assessed TSh 1000 ($1.50). This would be just to keep frivolous complaints out. It represents less then one day's wage for a project hired casual worker. Once it received a complaint the irrigation management would suspend the leadership of block and appoint a 3-person panel to review the problem. The panel would consist of one member from management, one farmer from another tertiary block and one member from the community at large. Each person would receive TSh 5000 for the effort, with the other TSh going to the project as overhead. The panel would then investigate the complaint, listen to the plaintiffs and defendants, visit the block, check to make certain it was receiving the allotted 75 l/s of infow, and make certain no unnecessary water was being discharged into the drains, etc. The panel would then render a decision that could include fining individuals, dismissing the block chairman and calling for new elections, expelling individuals from the block and scheme, or simple recommending more effective rotations systems, including the use of check structure in the field canals during an individual turn.

Follow-up

To follow-up on these recommendations would require:

1. When necessary, work with the Government of Uganda to establish the right to divert 1.2 m^3/sec. with the understanding that overall consumptive use will be only 0.4 m^3/sec and 0.8 m^3/sec will be return in an environmentally favorable manner as surface runoff with up to a week delay or as subsurface base flow enhancement several months later during the dry season.

2. Develop a detailed schematic diagram of the whole farm at a scale that will show individual parcels as well as all the main and field canals. If possible, this should include 0.5 m contours. This is needed to determine slope and areas where drop structures are needed to assure smooth flow of water. It would be similar in scale and detail as used in Doha.
3. Have some open discussions with tenants to see if they would prefer longer fields with better access. Would they want the system to remain as free flow or on rotation with enhance flows during the designated on period?
4. Spend considerable time on the internet looking at and getting an understanding for the different control structures. Most of this is readily available on the internet via any of the over a100 computers in the various internet cafés in Mbale. This will give Haji or one of his sons a fundamental understanding of the structures available and how they can be used, and prepare them for detailed discussion with any design consultants. Things to look up would be diversion weirs, sediment traps, drop structures, check structures, field canal inlets and field inlets.
5. Using the civil service or university system, identify an civil engineer with an advance degree from outside Uganda and knowledge of irrigation and hydraulics. This person can then become a consultant to determine how to most effectively renovate the system, following the ideas in this report. Sorry but the external advanced degree is needed to assure substantial more hands on field work than normally possible at Ugandan universities with their limited budgets.
6. Once the renovation design is prepared, develop a detailed management plan including cost accounting for charges to the tenants for access to the system.

Rice Production & Processing

In addition to some of the issues mentioned under overall farm management, there are some specific issues regarding general rice management.

Overview

In evaluating and accepting agronomic technology, it might be best to appreciate how crop management technology is developed. In the case of rice production, as with the other major crops, new technology is based on small plot analysis. This does a very good job of determining what the maximum potential of the physical environment as reflected in climate – moisture & temperature, and soil type. That is all, bas!!! Such agronomic research does not take into consideration the drag imposed on the physical environment by the limited resources the producers have to implement the technology and extend it from a small plot to an entire farm allocation or whole farm. This is particularly true of studies in timing and plant population. This is back to the poor farmer with only a hoe to work with. How often did our guide at Doha mention his program got behind schedule and his planting was late with old seedlings? The results are for maximum yield and not the economic optimal yield. The economic optimal is the

level of an input at which the incremental increase in yield is less than the cost of the increment. It is in the farmers best interest to adopt the economical optimal instead of maximum yield. Such find tunings are left to the farmer and are based on changing costs of the inputs and the overall economic situation in the national economy. The best example would be looking at Egypt and Israel. The high prices Israel farmers receive for their produce allow them to invest in drip irrigation, while the low returns the Egyptian farmers receive prevent the Egyptian farmers from taking advantage of drip technology. Ultimately, the individual farmer has to carefully review any technical recommendations and individually fine tune them to his economic situation and the capital and operational resources available to him. This holds true for the Lwoba farm and the individual tenants.

Variety Choice

This is something that might best be left to the individual farmers. There is a tendency, particularly when operating in Estate Mode, to select the variety for the farmers and plant the entire farm to one variety. However, occasionally this can have disasters impact. That happens when the tolerance to a particular pathogen, such as the rice blast fungus, breaks down and the entire farm suffers considerable loss. Several years ago this was the case in Egypt when the entire rice producing area was grown to Giza 131. A new strain of the blast fungus mutated for which Giza 131 was not tolerant and damaged the crop across the entire 1,000,000 ac of rice production in the Nile Delta. It caused the head of the Egyptian breeding program some real serious problems. Within the farm it is usually best to have four or five varieties in use. If resistance breaks down in one variety it will not affect everyone's field. In Madibira we grew five or six varieties each year distributed across the scheme at the preference of the individual farmers. The potential yield difference among improved varieties is usually not that great and shifts between the top varieties each year in an unpredictable manner. That is why multi-year testing is used and usually there are no significant differences between the top four varieties.

As for particularly varieties, I am not in a position to give any advice as we really did not discussed this nor look closely at the varieties that are available. The starting point is the research rice variety improvement program managed by the Ministry of Agriculture Research Division. This is only the starting point and you can expand on that with whatever varieties you encounter from any source. I think you brought some seed from the visit to Moshi and KATC. They are actually independent of the Tanzanian Ministry of Agricultrure and bring in exotic lines through their connection to JICA and then IRRI. Try them and if you like them, go ahead produce them regardless of what the Ministry says. They have no realistic enforcement means if you produce varieties not recommended. In Madibira one of the popular varieties was Zambia. It was not a recognized variety in either Tanzania or Zambia. My best guess is that some unknown individual quietly brought it across the border from Zambia to Tanzania as an improved line. It was tried and liked but they didn't know the proper name, so they called it Zambia. It is a good example of informal extension and distribution even to remote areas.

Anytime someone goes into rice production, they think about growing Basmati. It is the world's premium quality rice variety or group of varieties, because of both it aromatic qualities and elongation potential. The elongation potential is defined as doubling the length of the grain upon cooking making for a very fluffy final product. This is the lesser know grain quality but just as important to those South Asian buyers who are the primary consumers of Basmati. The grains are easily identified because they are both longer and slenderer than other grains. Climatically, basmati rice is produced in the higher latitudes of rice production. This is mostly along the Caspian Sea in Iran and foothills of the Himalayan Mountains of Pakistan and India. Whether it can be produce in Mbale, Uganda is thus questionable. Other than being adapted to cooler climates it has been difficult to develop improved varieties because for many years it was considered an Indica line. However, once DNA analysis was completed, it was shown to be closer related to the Japonica lines. Japonica lines are normally associated with short grains and temperate or subtropical climates. The result is that the available basmati lines are low yielding, which has to be compensated by the higher price. With the long slender shape, the grains tend to break more readily in milling and with the expected elongation requirement any breakage would be a market distraction. My suggestion is not to attempt it, but if you do, do so slowly and cautiously.

Certified Seed

Another production concern often promoted by research/extension personal as well as the seed companies or Ministry seed divisions is the use of certified seed each season. In reality this is impossible as the logistic to supply certified seed for the entire farm on an annual basis is overwhelming to most seed industries in countries like Uganda. Very few farmers actually use certified seed. Since rice is self-pollinated and the genetic qualities do not deteriorate as hybrid seed does, it is not necessary nor worth the extra cost. Most of the time the seed being informally distributed within the village among the farmers is more than adequate, unless you easily see a natural deterioration from either the natural 3% out-crossing as shown by the number of taller off-types in the field, or it gets contaminated with red-rice which is easily identified by the awns protruding from each grain, etc. Most other impurities such as weed seed, stones and chaff can easily be mechanically cleaned. It would actually be a good service to have a couple seed cleaners available to clean retained seed each year. It could be part of the agriculture supply business and work in conjunction with cleaning any in-kind loan repayment. If in-kind payments are received and cleaned, they could be held for the following year's seed supply.

While not needed every year, it is good to have a limited supply of certified seed flowing into the area each year and propagated and distributed each year within the farm. With a multiplication ratio of 50 to one, a kilo of seed will produce 50 kg of seed. The next season, the 50 kg will become 2500 kg. One more season and you would have 135,000 kg well above the 125,000 needed to plant the entire farm. A 50 bag of certified seed can blanket the entire farm in no more than two seasons. This is basically what is being done in Doha.

It might be also worth noting that here in Colorado only 30% of the wheat land is planted to certified seed each year with the rest planted to retained seed.

Crop Establishment

The standard method of rice establishment in the area appears to be transplanting. This is highly labor intensive requiring some 60 person days/ha (25 person days/ac). If you move to larger allotment size the labor supply for transplanting could easily decline. As this happens, you might want to consider direct seeding via broadcasting pre-germinated seed into the puddled fields. This has become the standard in Asia as holdings increased to the present six hectares per farmer with the introduction of power tillers and labor was draw to the cities. In other areas with larger farm size including Italy, Bolivia and the US, direct seeding is the norm with little if any transplanting. When done correctly direct seeding can be just as productive as transplanted. However, it usually has to be accompanied by the use of herbicides to help control the weeds and requires a doubling of the seed requirements. This was common in the area before the Chinese constructed Doha and introduced transplanting.

I also heard mention of in-line transplanting. Be careful as this is highly recommended by research and extension program by rarely widely accepted by producers. The problem is that it takes 20% additional labor for what may be a 10% return (Fig. 13). The real problem is one I usually refer to as quality vs. extent. That is with a finite amount of time and a limited labor supply farmers have a choice of doing a limited area at ideal management or a larger area at a lower level of management. Normally, the standard economic production curve will favor the larger area at the slightly reduced management level. In-line transplanting usually falls in the category as does plant populations.

Fig. 13. In-line transplanting requiring extra persons to man the marking string contributing to the 20% additional time and effort.

Fertilizer Use

The fertility of rice fields is closely related to the change in soil chemistry associated with flooding and the oxidation – reduction of anaerobic chemistry that results (Appendix B). This is an exceptionally adverse environment for Nitrogen, but very advantageous for Phosphorus. The nitrogen gets caught up in what is known as nitrification – denitrification reactions depending on the oxidation reduction state and if the nitrogen is in the ammonium or nitrate form. The result is normally rice will need additional chemical fertilizer particularly Nitrogen. This has to be in the ammonium form and, if possible, incorporated into the soil in the reduced zone a centimeter or more below the surface. The latter is possible for initial applications, prior to sowing or transplanting, by making a final tillage pass after applying the fertilizer, but difficult for top dressing once the rice is established.

Typically urea is the standard for nitrogen fertilization of rice and appears readily available in the market. At 49% Nitrogen, it is the most concentrated solid form of Nitrogen and it is in the desired ammonium form. The recommendations are for 100 kg N/ha which is basically four 50 kg bags of Urea. This would be for a crop with the yield potential of five tons per hectare or more. Less would be required if for some reason the potential yield will be less. For an acre it would be somewhat less than two bags. I would thus recommend you initially plan on one bag urea per acre and if that works increase it a half bag a season until you get the economic optimal – where the value of the increase in yield is less than the cost of the fertilizer. You need to avoid CAN (Calcium Ammonium Nitrate) and ammonium nitrate as both contain nitrate forms of Nitrogen that will do no harm, but simple be lost to the paddy chemistry.

You should not have to worry about Phosphorus as it becomes more available under flooded conditions and is actually mined by rice. You usually don't need to use DAP or other mixed fertilizer unless you start seeing visual signs of nutrient deficiencies, but that should some years from now. However, if you shift to upland crops, phosphorus could become an essential and important fertilizer to use to replace what the rice mined from the soil.

We did observe some Azolla in the paddies. This is a blue green algae that can fix nitrogen similar to legumes like beans and groundnuts. It also tends to die back when shaded or if the fields are drained, and thus the nitrogen fixed can become available to the current rice crop. The amount of nitrogen fixed can amount to 10 to 50 kg N/yr. This is a reasonable amount, but not really sufficient for the potential yields in the farm. The big problem with Azolla is how to maintain enough between seasons when the paddies have to be dried for harvest, to inoculate the fields for the next crop. It requires substantial water surface that is normally not available with the canals and other water courses.

As a note of caution, I saw in the shop across from your office, they were selling some liquid fertilizers with an application of one liter per acre (Fig. 14). I would strongly avoid these as they are more fraud then effective fertilizer. If you are thinking of needing 50 kgs N/ac there is no

way to contain that in a liter bottle. They do contain a very small amount of Nitrogen that will quickly green the crop but nowhere near enough to sustain the crop and it will quickly dissipate. There may be some value if you have a specific micronutrient problem but these are rare, particularly in paddy.

Fig. 14. Samples of liquid fertilizer that most likely are not effective.

As always interest has been expressed in using organic fertilizer. This again needs to be approached carefully. Basically, while there is always enough material for a small demonstration, there is rarely enough for a complete allocation or the complete farm. I once calculated that to use rice residues for a commercial crop it would take the residues from three acres to fertilizer one acre. It would also require extensive time and labor to accumulate it, spread it and incorporate it. That is if you could incorporate it with hoes or even power tillers. Than how would you fertilize the two supply acres. The actual nutrient concentration in residues is very low, perhaps in the range of 1%. Thus given the manual calories needed to utilize it, I very much doubt if they can be recovered by the additional yield. To me it is a non-starter. The best I can offer is to graze the residues with whatever animals will consume it. This will typically convert what is normally burned to something that is normally incorporated.

Plant Protection Chemicals

I am not really in a position to advice you on plant protection chemicals use as the new crop was not advanced enough to observe problems and the crop being harvested was too old for valid observations of any pests. Plant protection chemicals would include insecticides, herbicides and fungicides. In general, insecticides are the most common chemicals used on rice. However, there is a growing tendency to look at insecticides as counter-productive. That is most insecticides not only kill the pest but disproportionally kill the natural enemies of the pest thus intensifying the infestation. Many of the pests parasitic enemies are near microscopic wasps that attack the egg

masses and thus more easily killed by broad spectrum insecticides just on a body weight ratio. The idea is to be patient and allow the natural enemies to develop and bring the pest under control. It can be a little nerve racking being patient while watching the insects consume the crop, but eventually the natural control takes effect. The natural enemies can usually inflect over 90% control on the eggs and larvae.

Rodent Control

Rodent control was mentioned among the visible notice of a multitude of rats scurrying about on virtually every farm visit even during the day. They can be a major problem with rice production for which there are no easy solutions. They are really too numerous and they reproduce too fast to effectively trap, and they are too cautious to bait. IRRI has looked at some interesting fencing with traps embedded in them that can be reviewed at www.irri.org/irrc/Rodents/ecologically.asp. However, other articles indicate fencing is prohibitively expensive and cost can exceed the value of the crop. Others have introduced Mongoose to control the rats. These are rather furious animals that might control the rats but could then become serious pest themselves as they will attack chickens, small goats and other desired animals within a village.

Upland Rice

I noticed in some of the high area not accessible by the irrigation system, the farmers were attempting upland rice. I would not endorse this. Upland rice just takes too much labor and too many weeds to get a good crop. Those areas suggested for upland rice should consider producing other upland crops like maize, vegetables, etc. On some of your deep friable volcanic soils that you can physically work shortly after it rains, I would consider it but they do not occur in the farm.

Environmental Impact of Paddy

You asked about the environmental impact of paddy production. I normally consider the paddies to be more environmental friendly compared to upland crops. That is because the bunds to retain water also virtually eliminated the surface runoff and prevent erosion. It also buffers any storm or rain surge hydrograph so that it is less intense but distributed over a longer period and thus less likely to cause flooding or reduce the severity of any floods that do occur. Short term flooding of less than three days normally does little damage to a well established rice field. On the negative side, methane gas also known as swamp gas is the by-product of anaerobic decomposition. Methane is one of the greenhouse gases and is emitted from paddy fields in small amounts depending on the amount of organic matter in the soils. However, this is most likely considerable less than from the papyrus swamps in the area., which should contain more soil organic matter.

Processing

There appears to be an interest in expanding the rice production enterprise to including milling and other post harvest processing. It is noted that most of the rice is locally milled before being exported from the village for market. This is in contrast to what I experienced in Madibira when the buyer were purchasing un-milled paddy and taking it to other mills. In Madibira, the only milling that was done was for local use.

As I understand the milling process, milled rice, unless well cared for, is more susceptible to weevil infestation. Thus, for long term local storage it is better to retain the rice un-milled. Typically you can hold rice for three generations of weevils or nearly three months without the normal weevil infestation becoming a problem and down grading the market value of the rice. The milling process reduces the weight by some 30% and the bulk by slightly more. In transporting out of the area, you can fit more milled rice on a truck than un-milled rice. Also, the milling process does leave the hulls and bran behind. While hulls can be a problem to dispose of even by burning because of the silica content, the bran has some potential as a feed for chicken, cattle and goats. However, it has to be used quickly as it contains 20% oil that unless cooked will go rancid within 24 hours and cause problems with any animals it is fed to.

The milling operations observed during the visit were surprising as they were a double pass milling. The first pass was mostly a dehulling operation while the second pass through a second machine was polishing. The net result was an acceptable quality of milled rice suitable for local in-country or regional markets, but most likely not suitable for quality demands of the major international markets that demand less than 6% broken.

It is possible to consolidate the two milling processes into single pass machine similar to those I saw in Madibira (Fig. 15). They were capability of milling about 0.5 t/ha with 14% broken as I measure it when in Madibira. I would think these would be more advantageous to the milling effort in the villages near the farm. Single pass mills are promoted on the Internet including costs estimates and availability. Such mills might be worth considering for any expansion of milling capacity within the family enterprises.

Development Oversight: Caloric Energy Balance, Drudgery Relief, & Mechanization

One thing that has been overlooked by the development community for the past 40 years that has hindered the overall effectiveness of the development effort for rural poverty alleviation is the caloric energy balance of impoverished people. How this is related to perceived laziness on the part of the rural population, particularly African men, and how mechanization is the real key to rural poverty alleviation.

Historically, the oversight is based on an accurate observation of delayed crop establishment of up to eight weeks and the assumption this was because the farmers were risk aversive and

deliberating waiting for more assured rains, etc. This was a convenient assumption as it allowed the development professionals to concentrate on technology development and extension without looking at the operational resources, in terms of labor and labor substitutes needed to expand a research demonstration plot to a full 1.5 ha farm. It was and continues to simply assume the labor supply is readily available.

Fig. 15. Single pass rice mill used in Madibira, Tanzania used for milling rice for local use.

Caloric Energy Balance

While everyone is accepting that there is a dietary shortage and the ultimate objective of the development effort is to improve diet as part of the poverty alleviation effort along with improved economic well-being, to the best of my knowledge, no one as every related the available calories in a poverty level diet, to the calories needed to accomplish the intended manual effort envisioned by the well intended development advisors. Typically they will acknowledge that subsistence farmers can only produce enough food for six months. However, they then fail to evaluate how the farmers sustain themselves for the other six months, how that impacts on their following year's crop production, and their ability to implement "technology advances" developed and promoted for their benefit, particularly those that depend on timely planting. Again, as someone mentioned in the field, the alternatives are eat less to make food supplies last longer, but have less energy to do the work when the time comes, or work for another farmer in exchange for an in-kind payment of maize. Both scenarios delay work in their own garden, resulting in prolonged crop establishment and lower potential yields.

Typically to sustain a person for a day requires 2000 to 2500 calories. This is assuming no major physical exertion such as an office worker. To undertake manual labor such as managing an acre or more garden, but not the heavy initial digging for land preparation, requires some 280 calories

per hour or 2800 calories for a full 10 hour agriculture day. Thus, the total caloric requirement is 4800 to 5300. In contrast a person living at or below the internationally accepted poverty level income of a US$/day can only afford about 1800 to 2200 calories even at consumer prices such as in Uganda. Examples of the available calories for different counties prepared by my class are shown in Table 1. This does not balance and it would be physically impossible for people to sustain a full day of agriculture field work. It is very possible and more likely that people loafing around their home or village in the afternoon with plenty of field working urgently needing to be done are more hungry and exhausted, than lazy in need of motivation. As mentioned in the farm discussion, most people only seem able to put in three or four hours of digging a day and it takes a week or more to prepare the half acre or acre fields for paddy production.

Table 1. Estimate Food Cost for Host Country Compared to US, and Estimate of Calories Available to Impoverished Person Relative To Needs

Host Country	Your Daily Food Costs			Host Diet		
	Host	US	Host/US	Calories	% Needed*	Protein (g)
Philippines	5.58	7.23	0.77	2365	43.8	25.3
Nepal	1.28	3.10	0.41	2825	52.3	143
	1.48	4.06	0.36	3764	69.6	160
Thailand**	8.55	7.67	1.11	2482	46.0	137
Afghanistan	3.09	9.74	0.31	3225	59.7	107
Viet Nam				2079	38.5	210
Iraq	8.24	19.78	0.42	3744	69.3	56.8

* Based on estimated need of 5400 calories divided between 2400 for basic maintenance and 280 calories per hour of gardening type activities for a 10 hour agriculture workday.
** Included an estimate of fuel needed for cooking.

Drudgery Relief

In my humble opinion that unfortunately is not shared by most of my development colleagues, drudgery relief is the major key to development and poverty alleviation as well as enhanced yield and return to labor. As mentioned at the town council meeting, I just cannot see how a farmers and their family will ever escape poverty if the only thing they have to work with are hoes.

Drudgery relief comes in many forms. The most common is the mechanization of agriculture activities particularly those with the highest drudgery requirement such as initial land preparation. However, it could also include threshing and combining as well as mechanical pumping of irrigation water.

Drudgery relief can also be indirect. I think the initial drudgery relief in Africa was the introduction of village maize mills that replaced the manual pounding of women preparing maize and other meals. I think pounding has virtually disappeared from the rural African scene, except for possible specialty crops. I doubt if it is missed. While this reduced a major component of domestic drudgery, it also could have substantial economic impact on agriculture production.

This would be in the form of better rested women joining their husbands and families in the gardens the next day, being able to exert more energy to managing the crops, and enhancing the yield or quality.

Another often overlooked drudgery relief activity is domestic water supply. Again this removes the domestic drudgery mostly done by women. If you reduce the time women spend securing the domestic water needs, the more time they have available to assist with crop management or other farm economic enterprises which will enhance yields, etc. My best example comes from my last visit to Uganda in 2005 when I was assigned to Mitiyana. There the water table was some 30 m or more below the surface and women had to venture nearly a kilometer to get water including ascending 100 m with heavy 20 l jerry cans. The minimum water supply for a couple without children would consume 20% of the daylight hours. You have similar dark red soil conditions in the Mbale area, but not at the farm as these red soils are too permeable for paddy rice production. While domestic water supply is well appreciated by the development community, this is mostly for public health reasons and not economic impact. The public health concerns are real and justified, but the enhanced economic opportunity can be just as important

Mechanization

While I consider mechanization to be the key to rural economic development and poverty alleviation, the opinion is not shared by the development colleagues. I am not certain why, but they are actually highly opposed to it. Thus, development micro-credit project will rarely fund mechanization loans. I think they feel it would take away employment opportunities, when in reality it would create them. Meanwhile, they development community prides itself on the success to the "green revolution" for rice production in Asia, while quietly overlooking that this was concurrent and largely dependent on the retirement of the water buffalo in favor of the rice power tiller, also known as the 2-wheel walking tractor. The shift reduced the paddy crop establishment time in half and ultimately lead to substantial spontaneous value chain enterprises such as the combination of poultry and fish farming, we talked about and will return to with the aquaculture discussion. Since the development community was overlooking the contributions of mechanization the shift to power tillers was all self-financed by the individual farmers and community members. How these basically impoverished smallholders afforded their initial power tiller I don't know, but would be very much interested in learning. It had to be more than selling their water buffalo to make the purchase. However, many Asian farmers are on their second or third power tiller and have substantially improved their standard of living with refrigerators, motorcycles, TVs and of course VCRs as well as cell phones. The current emphasis on bringing the "green revolution" to Africa still overlooks the need to mechanize and continues to emphasis new technology and extension with the implication this is to be manually implanted by the farmers with their hoes.

Meanwhile there is a major interest in mechanization at the farm level, including here in Africa. We noted during the Municipal council meeting the cost of contract tillage in Uganda is some

UShs 30,000 (US$18.75)/ acre. Likewise, in Zambia in 2005, the cost was ZK 100,000/hr (US$7.00). This was enough to do about ¼ ha or ½ acres. It should also be noted that on my return to Madibira, Tanzania after five years, there were several recently purchased used tractors in the villages. Again all this is self financed. It is also worth noting that most of the basic land preparation for smallholder communities in Egypt, Pakistan, Afghanistan, and Iraq is done by individually owned tractors contracted to the farmers. Many of the owners had actually given up farming and were only involved in contract tillage service. As such, with the fully irrigated sub-tropical climate in which the annual cropping is divided into mutually exclusive summer and winter seasons, the tractor owner/operators could anticipate some 220 workdays per year strictly for land preparation and excluding any transport services or night work threshing. What the potential work year would be in Uganda with it fully tropical and mix of irrigated and rainfed will have to be worked out. It should be noted that the profit margin and density of tractors is highly dependent on what farmers can afford to pay. This normally limits the profit resulting in more deferred maintenance then preventative maintenance and only a limited number of tractors being in an area to make certain the tractors have sufficient opportunity to meet their expenses.

Upland Mechanization: When evaluating mechanization for smallholder it is best to divide the situation into upland operations and paddy rice operations as the two tend to be totally different. Upland mechanization tends to center around 4-wheel tractors. The most popular are approximately 65 hp, with the Massey-Ferguson 165 and 265 by far the most popular tractors. They are usually equipped with 3 disc plows or a set of chisel plows. They are also usually equipped with trailers that can be used for hauling goods as well as providing bus service between village and gardens. Their most popular agriculture use is for land preparation and they rarely get involved in other field activities, simply because the demand for land preparation is so great they do not have time to go back and do any planting or weeding. The second field task is usually threshing which can often be done at night via a stationary belt drive (Fig. 16). The third is commercial hauling particularly sand and gravel for road maintenance.

Fig. 16. Farmers Threshing Wheat with Stationary Tractor with Belt Drive

Four wheel tractors are considerable less efficient in working with smallholders because it takes considerable time getting between fields and there is a 20% efficient loss in working fields of less than one acre because of excessive time in turning and backing into corner, etc. The overall operations could be only four acres per day, compared to 20 ac/day for large farms and large fields.

Regarding the Lwoba farm the availability of tractors for contract tillage only has an indirect effect. That would be mostly recognizing if farmers are managing lands outside the farm and have to give these lands priority because they are rainfed, anything that can expedite their outside activities will quickly impact on when they can begin working inside the farm.

Smallholder Paddy Rice Mechanization: Instead of 4-wheel tractors available under contract, paddy mechanization centers individually owned 2-wheel walking tractors or power tillers. This is because of mechanical problems with the 4-wheel tractors particularly with mud getting into the front bearing and quickly wearing them out. In Bolivia, they estimated working in paddy field the bearing had to replace annually instead of every three years at a cost of some US$ 2000 per change.

In contrast, the paddy power tiller has completely mechanized the rice cultivation of Asia. This reduced the time it took for basic rice establishment by 50%. The typical power tiller set comes with 10 – 12 Hp single cylinder Diesel Engines, rotovators for tilling and puddling the soil in one operation, small trailer for transporting good and equipment to and from the field, and pump attachment for assisting with irrigation as needed. They also have standard plow and harvesters available, but I am not certain how important they are.

They are available in Kampala for some UShs 6,000,000. One is being used in the Doha Scheme (Fig. 17). The power tillers are equipped with steel wheels for traction in the mud. These wheels are not suitable for road use and have to be ferried back and forth from the field to home in the trailer. It should be noted that the Chinese power tillers have problems in shifting from the small trailer to the rotovator. It seems installing the trailer hitch requires removing the PTO (power take off) that operates the rotovator. In making the conversion you lose the PTO oil. Since you have ferry the steel wheels to the field in the trailer and shift to the rotovator in the field the loss of the oil can be a major concern. Thus it might be best to look at Japanese manufactured 2-wheel tractors, or see a major redesign in the trailer hitch. You might want to contact JICA to see what Japanese power tillers are or could become available.

Examples of power tiller use are shown in Figures 18 – 20. I was also very impressed when I returned to Madibira, Tanzania in 2005, the farmers had purchased some 50 power tillers. This was all post donor funding, and thus had to be self-financed (Fig. 21). It should also be noted that power tillers, like all machinery, have to be individually owned and not jointly owned by a farmers association or even a small group of producers. Too much conflict arises with joint ownership and the equipment quickly falls into disrepair.

Fig. 17. Power tiller with steel wheels and trailer available in Doha.

Fig. 18. IRRI Power Tiller Use for Paddy Preparation (Not really the best example)

Fig. 19. Power Tiller being used for low lift pumping water

Fig. 20. Power tiller with trailer used for family transport.

Fig 21. Self-finance power tiller, 1 of 50 in Madivira being used to transport rice from field to home.

The other area where mechanization becomes important in paddy production is harvesting and threshing. This is particularly important if a second crop is to be quickly established. If not, and the farmers have whole dry season to wait, the urgency of threshing is reduced and mechanical threshing may not be worth the cost. The threshing equipment most suitable for smallholder with the allocation size in the Lwoba farm might be the IRRI portable axle-flow thresher (Fig. 22). It is designed for two people to manually carry to the field over the bunds and along the canal banks. If I recall, it can thresh a ton of rice an hour. The mechanism is to insert the whole rice plant at one end, the plant will make a couple revolutions down the axle and the straw will be discharged at the far end with the grain filtering down through the screen and collected below. In my opinion, this provides a faster and cleaner threshing compared with some of the current rice threshers observed in Kampala where the operator is expected to hold the rice heads

over the exposed rasp bar while it is being threshed and withdraws the straw when finished. In addition, I would think they are safer as the rasp bar is internal to the machine and not exposed so it is less likely for someone to get their hands and arms caught and seriously hurt. Please be aware that farm machinery can be very dangerous. In the US, farm machinery injuries are one of the most common sources of industrial injuries and fatalities. These axle-flow threshers have an additional advantage to speed of threshing in that they normally are cleaner and increase the recovery of rice by 5 to 10% over hand threshing, and eliminate gleaners coming in after threshing to pick up the left over grain (Fig. 23). The blue prints for local fabrication for this portable threshers, and it large trailer based model are freely available from IRRI by email request to irri@cgiar.org or their website www.irri.org. If you obtain the blueprints and have some fabricated, make certain you follow or exceed all the specifications. The last one I saw in Iloilo, Philippines had been used to it full projected service life in one season and looked beaten apart.

Fig. 22. IRRI portable rice thresher

Fig. 23. Gleaner recovering the left over grains after manual threshing.

On a somewhat larger scale, that is becoming progressively more popular is small combines (Fig. 24) capable of working within a one rai ($1/6^{th}$ ha = ½ ac), the size of the smallest allotments in Lwoba. They can completely harvest a rai in about one hour. That would include cutting, threshing and bagging. These tend to be under contract and have allowed fully irrigated Thai farmers to increase their production from two crops per year to five rice crops in two years.

Fig. 24. Small combine used for harvesting rice in Thailand

If in the future you take over full management of the farm with the current tenants become mostly hired workers, you can consider the mechanization for large rice production such as Italy or Bolivia. This now moves to 4-wheel tractors with steel wheels (Fig. 25). They still may need to be equipped with rotovator attachments (Fig. 26). You could also consider using the normal four meter wide combines (Fig 27).

Fig. 25. Four wheel tractor with steel wheels for paddy operations.

Fig. 26 Rotovator attachment for 4 wheel tractor

Fig. 27. Normal 4 meter wide head combine.

Pumps

When you discuss irrigation and fish culture, there is often a need to include pumps. Of course pumps come in many sizes that you can select from and many are reasonable available in Mbale or in Kampala. Any pumps that you would require would be low lift pumps that can lift relatively large volumes of water two or at most three meters. The low lift pumps I like are the Liester-Pietter pumps out of India. They are single cylinder diesel engines with a centrifugal pump directly attached (Fig. 28). They also usually come with a small wheeled wagon that can

be pulled to the field and returned back to the house when completed. These pumps have completely taken over for the animal drawn sakia or water wheel in Egypt where the water is delivered below ground and the farmers have to lift it to their fields. The Liester-Pietter pumps can usually deliver up to 50 l/sec. However, with the diesel engine, they are fairly heavy so it is very difficult to hand carry them to and from the field. The alternative I saw extensively in Zambia was the small five horsepower petrol engine like we saw in the shop the other day. This, however, would be limited to irrigating no more than an acre of upland crops after rice. It would not be useful for the fish pond as you need somewhere in the order of 20 l/s continuously or higher if you are going to pump intermittently.

Fig. 28. Typical small scale diesel irrigation pump. This one Japanese manufacture used in Bolivia on rice.

Treadle pumps are often the pump of choice by the developing community and mentioned in my terms of reference, but I have some reservations about them (Fig. 29). Being man operated, they can only generate about 1/10 hp. With that they can lift water no more than two meters and irrigate no more than 0.25 ha (0.5 ac.). As we have discussed before I am concerned with the calorie energy balance as they would require considerable amount of calories in the diet to operate. I would expect a treadle pump would require more than the 280 cal/hr needed for basic gardening, and be more consistent with heavy crop establishment needs. When I looked at them in-depth during a consultancy to Zambia most farmers who had received them had quickly graduated to small portable petrol pumps (Fig. 30) as we noted in the shop downtown. Also, I was concerned when I learned that virtually all treadle pumps are distributed via NGOs, with very few actually sold on the open market. If it was really a desired technology the open market sales would be considerable more extensive. I am equally amused that you can get a $100 treadle pump on credit through an NGO but have to self-finance a motor pump at considerable more expense. I understand this is consistent with your concerns with treadle pumps.

Fig. 29. Treadle pump pumping water from dambo to an adjacent small vegetable plot in Zambia

Fig. 30. Small petrol pump frequently replacing treadle pumps in Zambia.

Aquaculture: Fish Farming

Aquaculture is not my specialty and my knowledge is more observational than academic. My limited knowledge is mostly based on the three years I worked for the Asian Institute of Technology (AIT) outside Bangkok, Thailand. AIT has one of the strongest Aquaculture programs I know of, particularly relative to smallholder agriculture as found in most economically developing countries such as Uganda. For this reason the AIT aquaculture program would be more relevant then programs at more prestigious institutions in Europe or North America. The Agriculture System program I was assigned to was working very closely with the aquaculture program and I was able to make some field trips with the aquaculture program.

I do appreciate that as capture fish reserves decline both fresh and salt, fish farming has provided a progressively greater percent of the fish supply worldwide. In the US, most of the shrimp, salmon, catfish, tilapia, etc., are from fish farms, both domestic and imported from Asia and South America. I also appreciate that fish are some of the most effective feed converters and thus the cheapest form of protein in most developing countries. However, I do believe that fish farming is more labor intensive and more risky than you might appreciate at present, but will shortly find out as you proceed. You might proceed with some caution. I think the visit to the fish farm was most enlightening but the guide was mostly being promotional and may have avoided some of the problems that they have to overcome on a daily basis. I don't recall any discussions of marketing and profitability nor on some of the risks involved such as a purely accidental upstream insecticide spillage that overnight kills most of the fish.

In Thailand there has been a major emphasis promoted by the Royal Family for including fish ponds in rice producing areas, either as independent ponds or integrated into the rice paddies. The fish ponds have been reasonable successful. However, when I interviewed some farmers in Northeast Thailand, they related their ability and interest in fish culture to first converting the rice production from water buffalo to power tillers. Once the rice production was under control, they had the additional resources, including time, to diversify into fish culture. Thus, be careful there may be some subtle economic pre-conditions that have to be met if you are expecting some of your farmers to rent both rice land and fish ponds without first getting some of the rice production mechanized. They may not have the resources to do both.

As I have mentioned, there is a move to also integrate the aquaculture with other activities the most dramatic is poultry production both broiler and layers suspended over the fish pond with the waste from the poultry becoming feed for the fish particularly catfish (Fig. 31). These operations appear somewhat larger ponds than what we observed at the fish farm. The Asian ponds were on the scale of the last pond observed under construction.

Fig. 31. Example of combination of fish farming and poultry production in Thailand.

They also combine fish farming with irrigation of the surrounding area for high value fruits and vegetable during the dry season (Fig. 32). However, this requires fairly deep ponds of 3 m. This will allow one meter for the fish, one meter for evaporation and one meter for irrigation.

Fig. 32. A Fish pond also being used for irrigation of fruits and vegetables during the dry season in Thailand.

Typical depth of ponds not used for supplemental irrigation is two meters. The fish require about one meter, and the second meter is a reserve to make certain the water will last through any dry periods or even an entire six month dry season. With the rainfall distribution in Mbale that has only limited totally dry months, this depth may not all be necessary. Depth in excess of three meters can cause problems as you can get thermal clines set up with different layer of water at different temperatures. It is possible to have some of the depth as part of breams that are actually above the land surface. Some of the excavated material can be used to build these

breams and may be desirable to protect against flooding that would allow all the fish to escape into the stream. Also, if you are occasionally taking water from the river to fill the ponds, it should be a separate supply from the irrigation system as if the rice irrigation is being rotated and you pump from the farm supply, you will be reducing someone's water and they will not be happy. Another concern is you may need to consider a means of aerating the ponds. This could be by continuously pumping some fresh water into the ponds with some degree of splash, or some type of splashing devise that would agitate the water. If there are continuous breezes in the area this could be done with small windmills. I am not certain timing the daily feeding to have the fish aerate the water while feeding as demonstrated in the fish farm visit is something to fully rely upon. Finally, you might wish to make a sexual adjustment to assure all the fish are males. That assures that there is no breeding in the ponds and a mixture of generations develop. As I understand it, this is actually a very simple process of injecting a chemical into the water just after hatching when the sex is still not fully developed. I forget what the chemical is but it is not an expensive one.

One of the operational aspects of fish and boiler poultry production is that, as I understand it, most of it was under contract farming. That is the buyer contracted with the farmer in advance of actually starting production for delivery on a specific day. This could be critical for highly perishable fish and to a lesser extent for poultry. That is because if you try and harvest and market at your convenience you could easily flood the market. Small quantities of capture fish or broilers can usually be fairly easily absorbed by the market, but to harvest a whole pond of 500 400 g fish can easily flood the market and the processors need some advanced planning to accommodate this level of input, particularly on a regular basis. Also, a 20 ac fish farm would have some 80 individual ponds of 500 or so fish. This could easily result in marketing some 2000 fish of 400 g each most weeks. Since fish are far more perishable then rice or even chickens, the production and marketing may need considerable coordination with the buyers and may require consolidated management rather the rental management as I understand you are considering. You might want to have some in-depth discussions with potential processors before going too far into the production. If you go into poultry production on top of the ponds, the same could hold true.

You also need to look very closely at your feed supply and make certain it is adequate, reliable, and a steady price to meet your contracted buyer price. If you are marketing some two tons of fish each week, you may need a highly reliable supply of four tons per week quality feed. You have several rice mills in the area that are producing rice bran or a combination of rice bran and ground rice hulls. You can try this, but it needs to be very fresh as rice bran has about 20% oil that will quickly go rancid if not used quickly or fixed by cooking. A dairy farming friend was concerned when his feed concentrate contained rice bran. The cows would get diarrhea. I don't know how that might affect fish production. With catfish that are basically scavengers consuming dead materials, it might not be a problem.

There is also interest in combining rice and fish production within a rice paddy. While there is technology available that has been heavily promoted, particularly in Thailand and other parts of Asia, it has not been widely accepted by farmers at the same level as fish ponds. Thus proceed with extreme caution. There may be some serious operational problems not mentioned in the promotional material. The technology most often promoted is basically digging a trench of at least a meter depth and a meter wide along one side of the paddy for the fish to shelter in when the rice is harvested and during the dry season as was illustrated in Doha (Fig. 33). These trenches are too deep for rice and I think subject to continual slumping of mud from the rice production area into the trenches further eroding the area available to rice, and reducing the depth of the fish reserve. This will consume at least a linear meter or two meters of paddy production that will now be too deep for rice production and lost. Once the fish are introduced the use of insecticides and other crop protection chemical has to be banned or they will kill the fish. I am very hesitant to encourage you to undertake this enterprise except on a highly experimental basis.

Fig. 33. Trench in rice paddy for sheltering fish during the harvest and fallow period in combining rice and fish.

This has about exhausted my technical and observational knowledge on fresh water aquaculture. To follow up on this I would encourage you to see if one of your children could get a scholarship for an MSc degree at the AIT. They will provide English language MSc degrees in 20 months including an opportunity to return home to do thesis research on you program. As I mentioned above, they have the most practical program available aimed at developing countries. To obtain such a scholarship I would first contact DANIDA the Danish assistance program. They have been heavy sponsors of AIT and its Aquaculture – Agriculture Systems program. Alternatives would be DIFD the British aid program. They have also been heavy supporters of AIT aquaculture program, underwriting several faculty salaries and development support. The other donor to consider is SIDA the Swiss assistance agency. As you mentioned, these agencies tend

to offer scholarships mostly to civil servants as part of civil service capacity development programs, that tend to overlook the extent the civil services are financially stalled, and don't have enough operational budget to fully take advantage of the training. Thus, you will have to emphasis that you are an operational private sector organization and thus it would be part of enhancing the capacity of the private sector. You need to emphasis you are representing a major fish farming farmers association and upon return you will work with assist the entire association and not just the family enterprise. I will have to mention that is basically a long shot, but worth taking.

Haji Family Agro-Enterprises Limited of Mbale, Uganda

As I have pleasantly enjoyed my working with Haji and family, and their desire to put together an extensive agro-industry conglomerate based on the rice farm and potential fish ponds, it occurred to me that what is really needed is a group of agro-enterprises that work independently but collaboratively. The idea is based that if you look closely at commercial agriculture it really consists of two groups of people. They are the producers and the support service providers. The relationship between them is symbiotic with each very much dependent on the other. This is in contrast to the general concept but forth without any supporting data that service providers are exploitive of the producers. In a pure brainstorm concept I can envision the following fully independent subsidiaries of the family enterprises, each perhaps headed by one of the Haji's adult children. These subsidiaries would be operationally and financially independent so they would be free and encouraged to work with other producers and service providers, but have the other subsidiaries as their primary clients. The different subsidiaries are:

Rice Farm

The central feature of the agro-enterprises would be the rice farm as the primary source of production. The person in charge of the farm would manage the rental agreements, handle any turnover in tenants, and oversee the obligations to provide reliable irrigation water and equipment access, and resolve any disputes over water or other issues. If in the future the farm is reorganized for consolidated management, then the person would become the production manager.

Irrigation Development

The irrigation development subsidiary will most likely be the most technical challenging. It will require a good working knowledge of hydraulics and structures, and may require the individual involved to seek additional civil engineering education. This is necessary to make certain the water flow remains non-erosive or laminar (non-critical) instead of an erosive or turbulent (critical) flow and any structures withstand the force of water, which is often badly underestimated as noted by the problems with previous control structures in the farm canals. The task assigned will be to initially redesign, rehabilitate and construct the different irrigation canal and control structure including the diversion, weir, sediment trap, and other control structures in

accordance with the overall operational master plan. Once this is done, he will be contracted to maintain the system including cleaning the sediment trap and two main canals, but not the field canals. He would also be responsible for maintaining the access roads as they are normally adjacent to the canals and maintained as part of the normal canal maintenance. The biggest problem could be disposing of any silt removed from the sediment trap or from the canals. This would not be a full time effort so when not working on the farm he would be expected to contract for different irrigation or road construction work in the area, including with the government.

In order to do this he would have to invest in considerable construction equipment such as excavators, front loaders, graders, and rollers. This would all be needed for the irrigation work, but could equally be used for road construction.

Input Supply & Marketing

This subsidiary would deal with the production supplies the farmers need. This would include seed, fertilizer, crop protection chemicals, and the small scale manual equipment needed to operate a farm. That would include hoes, backpack sprayers, and perhaps small pumps. This would be very similar to the input supply shop in Mbale mostly operated by the Asians. While it would be aimed primarily at rice, it would deal with the full range of inputs the farmers might such as vegetable and maize seeds, etc., so it can serve the farm tenants in both their farm gardens and outside gardens as well as non-tenant farmers. Complete one stop shopping for inputs.

The input supply could become involved in informal production credits as I understand is a common practice and using common conditions which can sound exorbitant, but may reflect the actual cost of servicing informal production loans, including in-kind repayments that may need to be rewinnowed while discarding considerable material that effectively lowers the quoted interest and the cost of monetizing the in-kind payment back to cash.

The input and marketing subsidiary could also become involved in marketing including operating one or two mills. If you are receiving in-kind loan repayment, marketing is the next logical involvement. In this case, I would consider a mechanical grain cleaner so the in-kind payments can be quickly processed in front of the barrowers so they know how much is being rejected. This would require some additional go-down facilities.

Finally, as the marketed rice is mostly milled rice, this subsidiary could easily expand into the milling business, or incorporate the existing milling business. This if the volume is large enough this could be set up as an additional independent subsidiary.

Mechanization

The mechanization subsidiary would provide equipment to the community either via direct ownership or by contract. It could contain three divisions:

Dealership: One division would be the dealership that would be selling reconditioned 4-wheel tractors and rice power tillers for sale to members of the community or the greater Mbale area. This would be a straight forward buying wholesale from Kampala or directly importing, marking up the value and reselling on the open market. A quick internet search indicated you could get some used Massey-Ferguson 165s for $5000 out of US or UK, but would have to have them packed and shipped. It is expected that used tractors could be obtained, imported, reconditioned and sold for around US$ 12,000.

Repair Services: The second division would be supply spare parts and doing any repair work that would be needed and the farmers or operators cannot do themselves. This could include assisting the dealership with reconditioning any used tractors acquired and needing reconditioning prior to being offered for sale. This would require maintaining a fairly complete stock of spare parts and well as a complete machine shop for doing the repairs.

Contract Services: Contract services are the division in which you own, operate, and maintain the equipment for contracting to producers. The contract should include providing the driver and to make certain the equipment does not get abused and you have some heavy leverage on any abusive use. The equipment would be mostly the larger 4-wheel tractors used for upland cultivation. For the benefit of the farm you would, when possible, concentrate the services in the upland fields of the farm tenants. This will expedite their upland cultivation so they can more rapidly start their work in the farm. You might try leasing power tillers, but they have always tended to be individually owned instead of contracted. You can consider providing these services to farm tenants on credit under normal informal credit terms.

Fish Farming

The last subsidiary would be the fish farming enterprise. Since this is the one I know least about I can only mention it as one of the family subsidiaries. Responsible person would operate all the fish ponds and support facilities either directly or coordinate any tenant agreements.

Subsidiary Interactions

I think it is important that all the different subsidiaries be completely independent both financially and operationally. They are expected to collaborate with each other and when possible provide the support services to the Rice Farm and Fish Pond production units, but this has to be on a purely competitive business relationship, and not one of internal family favoritism. Each subsidiary is free to contract with outside producers when they have extra material or have

a better business arrangement. It is expected that the rice farm and fish pond enterprises will generate enough initial business to make the support service subsidiaries financially successful.

The Haji Family Agro-Enterprises Ltd. as discussed above is presently pure brainstorming. It thus needs some very careful business planning to come into existence. This would include a comprehensive evaluation of the economic and logistic consideration and time flow graph for bring each subsidiary on-line. It will require some considerable capital or extension of bank credit. There are good prospects that if the planning is not done completely, the credit could be overextended and the concept collapse. I fear overall business planning is a weak component in the current family effort and needs to be strengthened.

Other Issues

Computers

One of Haji interests is with a boys' secondary school near his village en route to the farm. After noting the number of Internet cafes in Mbale that provide a total of over 100 computers connected to the Internet, the idea of supplementing the schools limited resources for educational material of the school with material from the Internet was reflected upon. This would actually be reasonable. The Internet charges were actually fairly reasonable with as little as UShs 25/min (US$ 0.015) or approximately US$ 1/hr. However, to get the school boy interested in using the Internet, it is necessary to first get them familiar with computers and the mundane task of typing. A task often considered for the girls only. Thus the idea was suggested to contact One Laptop Per Child (OLPC), the NGO out of Boston that is trying to provide a laptop for every child in the developing world. These computers are available for a little as $200 each fully complete with comprehensive set Lexus based software. Lexus represents a completely different operating system from the Microsoft systems used on most computers. However, I understand the programs are sufficiently similar for individuals to quickly learn the Lexus programs. One of my follow-up issues to see if sponsors can be found to finance up to 200 such computer provided they are divided between the boys school and a corresponding girls school.

Low Head Generators

Mention was made of evaluating some low head generators that could be inserted in the stream and generate some power for the farm and surrounding villages. This is worth looking at and can be evaluated on the Internet including the costs for different units. However, it will require a short term consultant to fully evaluate the economic potential and develop a business plan to harvest and distribute the power.

Summary and Recommendations

Overall Recommendations

1. During the consultancy, considerable discussions were held regarding various agro-business enterprises that Haji Narba and his family were interested in undertaking. These all need a very comprehensive evaluation as to their commercial viability including risks, profits, etc. This must recognize some of the restriction imposed by the overall agriculture economy of Uganda as it might differ from the world economy and regional economy. What might be profitable in more developed countries where returns to agriculture produces are considerable higher than in Uganda may not be profitable in Uganda, with more limited returns to agriculture products. With two sons having business degrees, this would be a good task for them to undertake.

2. Within Mbale, there are over 100 computers connected to the Internet through the various Internet cafes. Since the Internet can provide substantial supplemental information on a complete line of subjects and since one of Haji's sons has a degree in computer science, the possibility of getting considerable additional information on the full range of family interests from the Internet should be looked at in depth.

Irrigation Recommendations

1. The first recommendation for the irrigation system is to develop a detailed layout plan showing all the canals and fields. If possible, this should include 0.5 m contours so that the need for drop structures can easily be determined.

2. Work with the Government as necessary to establish an entitlement to divert 1.2 m^3/s of water to the irrigation farm but returning 0.8 m^3 in an environmentally more desirable time. In addition divert, 20 l/s for the proposed fish farm.

3. Evaluate the overall master plan for the design and operation of the irrigations system. Will it be the default free flow or a more regulated flow with the extra management component including hiring ditch riders and extra vulnerability to breakdowns that is required? Also, will the system be shut down temporarily during periods of high sediment loads in the river? This should include maintenance responsibility as well as any adjustments in allocation size and access road.

4. Develop a means of getting more advisor input from the tenants into the overall master plan. This only has to be advisory and as the final decision has to remain with Haji as owner.

5. Determine the basic design for all control structures, including drop structures, check structures if desired, field canal inlets, farm inlets and drains. Also, determine where any drop or check structures should be placed.

6. Proceed with the development of the diversion weir and sediment trap.

Rice Production and Processing

1. Be extremely careful in the use of "estate mode" operations for the entire farm, in which the management tries to control all aspects of production, and the tenants are basically laborers on their allocation. This has been tried for over 100 years and rarely been successful without continuous facilitation.

2. Take a close look at how much certified seed is needed relative to what can be retained and distributed within the farm and surrounding rice areas.

3. Encourage farmers to use some fertilizer such as Urea, but avoiding any of the liquid fertilizers being marketed in the area.

4. Consider shifting to direct seeded rice particularly if allocation size is allowed to increase.

5. Be careful in promoting in-line transplanting to make certain it is fully justified with the amount of labor available.

6. For processing, look at getting some single pass mills instead of the double milling as is currently being done.

Mechanization

1. Take a close look at the prospects for mechanizing the rice production as well as the upland crops tenants are also involved with.

2. Suggestions are the rice mechanization should be based on individually owned power tillers also know as hand tractors.

3. The upland areas should concentrate on contract access to 4-wheel tractors such as the Massey-Ferguson 165 or 265.

4. Consideration should be given to acquiring some reconditioned used tractors for this purpose.

5. Also, consider mechanizing the harvesting and threshing component particularly if it will expedite the establishment of a second rice crop. The IRRI portable thresher may be ideal for this.

6. Look at other means for drudgery relief in the farm and surrounding communities from which the farm tenants are drawn.

Aquaculture

1. Move with caution in developing the aquaculture program, it might be more risky than promoted.

2. Contract with the buyers and processor for advanced deliveries, as it would be difficult to market an entire pond of fish without some advance preparation.

3. As the program develops, consider the combination of poultry production suspended over the fish ponds and is commonly done in Asia.

4. Be very cautious in trying to combine fish production within the rice fields. This has been promoted far more than actually accepted.

5. Obtain a separate decree from the government to divert 20 l/s of water for the fish ponds and have the diversion of that water independent of the irrigation water for the rice.

Agro-Enterprise Conglomerate

1. Develop a detail business plan for each of the agro-enterprises under consideration to see how feasible they are and a logical order for developing them.

School Computers

1. Work with the headmaster of the school to continue promoting interest in getting some computer for the school and what arrangements can be made of students to purchase at a nominal fee the computer coming from *One Laptop Per Child*, if this can be arranged.

2. This will require identifying a second secondary school. This being a girls school, to maintain the gender balance expected from any participating donors.

Low Head Hydroelectric Generators

1. Check the Internet for the potential of obtaining and installing low head generators in the river to provide limited power to the community.

2. Also, develop a business plan to charge for that power if it is developed.

Follow-up From US

Used Tractor

Working with a mechanical engineering colleague of mine here in Fort Collins and another associate, Paul Sugg, who is President and CEO of **AppTech Development International, Inc.,** a for profit NGO working on mechanization in Uganda, to evaluate the prospects for obtaining, reconditioning, and local sale of used tractors. It is hoped that these tractors could be marketed to individual within smallholder communities for between US$ 12,000 and 15,000.

Computers

Work with One Laptop Per Child and charitable service organizations in Colorado or elsewhere in the US to see if it is possible to get 200 computer for nominal resale to the students in Mbale with half the computer distributed to a boy school and half to a girls school.

Appendix

Appendix 1: Daily Activity Log During Visit

Appendix 2: Management of Paddy Soils

Appendix 1

Lwoba Irrigation Farm Ltd.
ACDI/VOCA Assignment 441153 B
24 May to 22 June 2008

Daily Activities

24 May	Saturday. Departed Fort Collins, 09:00am for Denver International Airport, Checked baggage to London, to be claimed and rechecked
25 May	Sunday, Tried to claim baggage in London, but lost. Proceeded to Kampala arriving at 11:30 pm. Proceeded to Fairway Hotel
26 May	Monday. Remained in Kampala to recover lost baggage, successfully recovered at 5:30 pm. Used the extra day to check availability of motor pumps, treadle pumps, and power tillers, etc. All appear reasonable available in Kampala.
27 May	Tuesday. Traveled to Mbala and met with host for consultancy, checked into Sunrise Inn for duration.
28 May	Wednesday. Initial visit to Lwoba Irrigation Farm, enjoy some welcoming ceremony and made brief initial field visit, including construction of rock diversion across the river.
29 May	Thursday. Heavy rain overnight made field visit difficult, thus remained in Mbale and had in-depth interview with Abudallah, the host son on the overall operation of the farm.
30 May	Friday. Made second field visit to the farm to look at other half of area and some of the adjacent government projects. Also, noted the rock weir constructed on Wednesday seems to have held with the heavy rains.
31 May	Saturday. Host arranged to join a farmer association field tour to a fish farm and fruit farm, return at 8:00 pm.
1 June	Sunday. rest day.
2 June	Monday. Mechanical problems with vehicle prevented farm visit so remained in hotel outlining report made trip to town to see agriculture supplies available.
3 June	Tuesday. National Holiday for Martyrs' days continued working from hotel.
4 June	Wednesday. Political day for meeting district official in the district of Lwoba farm, interesting discussion on need for tractors to expedite land preparation and crop establishment, returned to hotel by local taxi van.

5 June	Thursday. Returned for farm via local commercial transportation to look at plans for aquaculture program, took detailed look at irrigation distribution, return to hotel via commercial mini bus.
6 June	Friday. Islamic Sabbath, tourist visit to Sipa Falls, vehicle got stuck needed hour to extract.
7 June	Saturday. Remained in hotel working on report, and visit to Ancient Rock Painting
8 June	Sunday. Rest day at Hotel working on report
9 June	Monday. National Holiday, reviewed material with Haji and Son
10 June	Tuesday. Visited School to make arrangements for student assembly address for Wednesday, and visit farm to look at levees and flood protection
11 June	Wednesday. Worked on reports in morning and meet with students in afternoon
12 June	Thursday. Worked on reports and meet with town consul etc. in Mbale.
13 June	Friday. Islamic Prayer day, remained in Hotel working on report
14 June	Saturday. Remained in hotel working on report
15 June	Sunday. Meet with client and family to review agro-business prospects
16 June	Monday. Visited Doha irrigation scheme next to Lwoba Farm
17 June	Tuesday. worked on report and had farewell dinner with host.
18 June	Wednesday. Remained at hotel working on report and meeting with host.
19 June	Thursday. Returned to Kampala
20 June	Friday. Debriefing in Kampala
21 June	Saturday. Morning checking out, afternoon visiting with friend, evening departed for USA
22 June	Sunday. Travelled to USA arriving 10:00 pm

End of activities

APPENDIX 2

Excerpt from:
Developing Smallholder Agriculture: A Global Perspective
Chapter 9
Pivotal Practicalities of Smallholder Farming

PADDY SOILS

Another situation when basic soil chemistry becomes skewed is the submerged conditions of paddy cultivation. Under these conditions the soil microbes rapidly consume all the oxygen and soils become chemically reduced. The initial reduction will take place in about 24 hours after ponding and proceeds as long as the soil remains ponded with successive reduction of the progressive harder materials to reduce. The extent of reduction is dependent on the duration of the ponding, amount of organic matter, and the temperature. As a biochemical process, it is a slow reaction taking days or weeks to reach equilibrium. The reduced conditions change the availability of various nutrients, particularly, Nitrogen, Phosphorus and Zinc.

The oxidation-reduction process results in three layers forming in the soil; the ponded water, the very thin oxidized layer, and the reduced layer. The oxidized layer can be as a thin as two or three millimeters and is normally reddish in color. As such it is sometime confused with fresh sediment coming in with the water. The reduced layer is always gray. The color again reflects the pigmentation of iron minerals in the soil in which the oxidized forms of iron are red or yellow, while the reduced forms are gray.

Nitrogen Efficiency

The oxidized and reduced layer heavily interact with nitrogen fertilizer as under oxidized conditions ammonium fertilizer will nitrify to the nitrate form, which will then leach into the reduced layer. In the reduced layer nitrate nitrogen will be denitrified and lost as NO_2 or N_2 gas. This makes the paddy environment very inefficient for nitrogen fertilizer and necessitates the use of ammonium fertilizers like urea or ammonium sulfate, and avoiding the use of nitrate fertilizers such as calcium nitrate and even ammonium nitrate.

Typical recovery of fertilizer Nitrogen in rice is approximately 50% of the applied Nitrogen. It is also desirably for the Nitrogen fertilizer to be placed into the reduced layer, if at all possible. For basal applications this is reasonably possible by applying the fertilizer just prior to the last land preparation tillage activity, which is normally puddling, and allowing the tillage operation to incorporate the fertilizer. However, this can be difficult for top dressing applications normally planned for panicle initiation, with near full canopy through which broadcast granular fertilizer must filter through the canopy to reach the ponded water and then sink to the oxidized soil surface. It will then have to dissolve and diffuse into the reduced layer to become available to the roots. All this must take place before it can be nitrified.

Phosphorus Availability

Phosphorus availability actually improves in the paddy environment as it is normally retained in association with iron, which becomes reduced and more soluble under paddy conditions. Phosphate fertilizer is thus rarely required. However, if the paddy land is converted to upland crops, phosphorus needs to be applied sufficiently to replace all that was mined while under paddy.

Zinc Availability

The reduced condition also adversely affects the availability of Zinc. Under reduced conditions the oxide forms of Zinc are reduced to the less soluble sulfide form, making Zinc the second most important nutrient management concern after Nitrogen. The problem becomes more severe in calcareous soils or other soils with a pH of above seven, where the normal oxidized forms of Zinc become less available. There are numerous ways to increase the Zinc, including dipping seedling in a Zinc oxide (ZnO) slurry, direct soil applications with Zinc sulfate ($ZnSO_4$) and foliar sprays. It can also be made more available by simply draining the soil, and allowing it to reoxidize for a couple days in the middle of the season. Since oxidation is an inorganic reaction, it will take place quite rapidly, hours rather than days. Thus, in areas where the common water management practice is for a brief mid-season draining of the soil, making Zinc more available is most likely the reason.

The other nutrients are less affected by the reduced conditions of the paddy environment and can be expected to follow normal soil chemical and soil fertility conditions regarding availability and soil management needs.