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Raising Irrigation Productivity And Releasing Water for Intersectoral Needs

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RIPARWIN
Raising Irrigation Productivity And Releasing Water for Intersectoral Needs
river basin management research in Tanzania

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IRRIGATION EFFICIENCY AND PRODUCTIVITY MANUAL

TOOLS FOR IRRIGATION PROFESSIONALS AND PRACTIONERS

Part Two

Means and mechanisms for increasing efficiency and productivity

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(With contributions from workshop participants)

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1 Introduction to this manual

This 'Part Two' Manual of the Workshop on Irrigation Efficiency and Productivity describes technical, institutional and programmatic ways in which irrigation efficiency and productivity can be raised, with special reference to rice growing in Usangu in the Southern Highlands of Tanzania. In many ways, these principles and interventions apply to rice irrigation in the rest of Tanzania and East Africa, and in some respects to non-rice crops.

Section 2 goes through all the technical means for saving water while maintaining or raising productivity.

Section 3 presents information on the institutional and programmatic support necessary for the technical solutions to be implemented.

Section 4 provides a brief look at performance management by setting targets – a common method that water users can use to focus on activities and practices to raise standards.

Section 5 briefly shows that farmers are already active in developing initiatives and bye-laws that save water and manage conflict.

Section 6 is an example of how raising irrigation productivity can provide an opportunity to reduce intake flow, while still extending the benefits of water to more families. This case study uses the NAFCO farms in Usangu to demonstrate the change in productivity if their design and management were reviewed and altered.

Appendix A is a list of questions that can be used in interviewing users about water management, and can be used in research or compiling a base-line study.

Separately, the River Basin Game Manual is being circulated to participants. This game is believed to be an important facilitating tool for generating meaningful discussions amongst farmers and support agency personnel regarding technical and institutional means to raise productivity.

2 Technical measures to improve irrigation efficiency and productivity

"saving irrigation water, securing upstream rice production and providing downstream flows"

2.1 Introduction

This section provides advice on ways that water may be saved on irrigation systems in the Usangu Plains without affecting rice yields. This raises irrigation efficiency and importantly productivity, (e.g. measured in kg/m^3) because less water is used (lowering the denominator in the ratio), but also because better water management can increase crop growth (raising the numerator in the ratio). This document does not discuss ways in which yields may be raised by using crop husbandry practices such applying farm chemicals. Although this affects water productivity, this omission is because the non-water factors controlling yields are separated from water management from the perspective of this manual and training course.

The manual applies to surface irrigation of rice watered through bunded small basins, or plots, called vijaruba in Tanzania. The system boundary being discussed here is the total irrigation command area of one river intake. (Note borehole irrigation is absent in Usangu). Water abstracted through this intake, unless it is returned to the river by drainage, or groundwater movement represents a net loss from the river's point of view. Thus the improvement of irrigation efficiency either allows less water to be taken from the river, or the enhanced management allows the existing water to be shared and extended more widely, increasing productivity by increasing the command area, or by ensuring timely movement of water through and around different parts of the irrigation system. As such all of the ideas here represent real ways of improving either efficiency or productivity or both.

These suggested improvements could become the basis of negotiated bylaws drawn up by relevant institutions (RBWO, WUA's). The suggestions are drawn from accepted irrigation texts and observations in Usangu made by the RIPARWIN team. It should be said that during the wet season the standard of irrigation within most traditional systems is generally good given the economy of the area involved, the zero financial value of water and the competitive pressures involved in livelihoods, farming, land, water, cropping and marketing. However, there is room for further efficiency improvements particularly in: the dry season (where water is more used for small domestic purposes); the start and end of the wet season (where water is use in a casual way that is relatively unproductive); and during the wet season in areas of irrigation systems where there is poor water control possibly due to marked social and technical differentiation within the system (e.g. Kimani-Mbuyuni-Mabadaga systems).

2.2 The three ways that irrigation water usage may be reduced

The total amount of water used on irrigation systems may be reduced in three ways:

1. By reducing the water supplied to a system by reducing the amount of water abstracted through the intake, and then cascading this reduced supply through the system to encourage reduced demand;
2. By reducing the water demand of the system, and then operating or modifying the intake accordingly;
3. By improving the return of excess drainage water from the irrigation system back to the river system.

The first method is supply management (driving water saving from the top down), while the second and third methods involve demand management (promoting water saving within the system). It is likely that all three should work together. These are described in the following sections.

Table 2. Framework for increasing productivity of irrigation water in Usangu, Tanzania

A. Total supply increased. A special case of increasing production but not productivity is the storage and delivery of more water to boost total command area under cultivation.				
B. Raise crop response/growth. Here, productivity is increased by attending to factors that boost crop growth and response to inputs (e.g. fertilisers)				
C. Reduce gross demand of water	1. Reduce intake capacity to system, then cascade reduced supply to reduce within system gross demand.			
	2. Reduce within-system demand then reduce intake capacity	i) Reduce duration of irrigation need	1. Season length of rice variety (many varieties are 150 day, some basmati types 120 days) 2. Field wetting up at the beginning of the season – some irrigators utilise 30 days, others 7 days, tailenders use 2 days. 3. Field drying-off before the end of the season is possible but often not practiced. (Two other factors Double cropping of rice and Mixed or unclean rice seed).	
		ii) Reduce total command area (also defined as area irrigated by not transplanted/ planted)	4. Designed command area reduction. 5. Purchase of water by other users might reduce command area or specific demand 6. Improved bylaws and monitoring of land tenure. 7. Tightening up areas watered but not planted. 8. Closing down partially abandoned areas totally. 9. Reducing area of late planted rice cropping. 10. Reducing area of dry season non-rice crops. 11. Reducing area of high catchment dry season irrigated crops.	
		iii) Reduce specific water demand (also defined as the unit demand, or hydromodule)	a) Beginning of wet season	12. Start of field preparation not early, but delayed 13. Reduce amount wetting up field (presaturation: NAFCO accept 300 mm, smallholders 150 mm) 14. Careful design and location of rice nurseries so close to water supply (might entail manually moving the plants to where transplanting is occurring, as is seen in Usangu). 15. Longer duration of rice nurseries. 16. Canal supply of water to downstream nurseries rather than by vijaruba 17. Vijaruba (plot) sizing – smaller when land is steeper or changes more quickly in slope 18. Banding or zoning the transplanting of rice so all vijaruba in one area irrigated simultaneously.
			b) Mid wet season	19. Responding to rainfall (improved intakes allow irrigators to reduce inflows during floods). 20. Controlling depth of standing water layer (between 5-10 cm). 21. Cycling water between areas (applying wet/ dry cycles which can raise yields and save water) 22. Leveling vijaruba and fields so water depths are uniform 23. Adding vijaruba in NAFCO fields to improve water control & depth 24. Strong, clear bunds with defined cuts to manage water flows 25. Leveling land so hollows and high points are minimised.
			d) End of wet season	26. Restrictions on late-transplanted rice which yields very poorly. 27. Method of conveyance of water (using canals not fields) 28. Use of clean seed (allows uniform ripening and earlier cessation of irrigation)
			e) During dry season	29. Location of non-rice crops close to intake. 30. Scheduling dry season crop irrigation (deficit irrigation). 31. Source of domestic and livestock water (to reduce surface abstraction for same). 32. Reducing accidental irrigation into harvested plots (commonly found in NAFCO fields) 33. Using buckets rather than surface diversions (effectively this is reducing the intake volume)
	3. Return unused water to the drains to exit system (if likely to pass to a sink, and not used productively)			
	4. Crop diversification within command area – farmer do explore alternative crops that use less water than rice.			

Vijaruba = plural of jaruba, which is the small plot or basin used to irrigate rice in smallholder systems.

2.3 Reducing the water supply

The intake gate on the river can be partially closed to throttle back the flow supplied to the system. This partial closure would be agreed between the irrigators and RBWO officers, and if done for the peak demand season would need a re-negotiated water right. This could be achieved via ‘institutional’ means whereby decisions over gate adjustments are made (e.g. the gate opening is agreed to be set below that of the maximum), assisted by 'technical' means, where the maximum abstractable flow is physically re-designed (either via a new welded plate, concrete obstruction or new gate altogether). If water management were improved within the command area, then a reduction in the intake would not necessarily affect productivity. (See NAFCO irrigation management transfer case study in this manual for the explanation of this).

In addition to, or as an alternative to, the flow-based method, the reduction of the water supply could be managed on a time-based means. This would involve a schedule of opening and closing the offtake on different days of the week in order to pass compensation flows downstream, and to share water between a series of intakes.

1.1 Reducing the water demand

Reducing the water demand of an irrigation system occurs in three ways:

1. Reducing the duration of irrigation need
2. Reducing the total command area, and
3. Reducing the specific water demand per command area

These reduce water demand because of the following equation:

Water demand = time x command area x specific demand
Or, cubic metres volume = number of days x ha x l/sec/ha x 86.4

In some ways, the three variables are inter-related, for example a shorter duration of irrigation supply can also compact the area irrigated.

Once the total water demand has been reduced, the intake can be closed as described above. The boxes below show how these may be achieved.

1.1.1 Reducing the duration of irrigation need

There are three ways of reducing the duration of irrigation need:

Season length of rice variety. Often discussed, but difficult to impose because of consumer and farmer tastes, the 150-160 day season Kilombero and Subramati varieties of rice could be replaced with a shorter season variety, such as 140 day IR54 and Kartin types. During the 1999/2000 season, the 120-day Basmati variety has been successfully grown in the Hassan Mulla and Kapunga farms. This shorter season also has good aromatic properties and a price premium of Tsh 1200 per kg. (However, the concern here is that two Basmati crops could be grown during November to July which extends the growing season again).

Field wetting up at the beginning of the season. Farmers in smallholder areas show care for water by ensuring that they have transplanted only 7 days after first letting water into their dry vijaruba. These contrast with some farmers who take 10-12 days, and the NAFCO operators who allow fields to be wetted up for over a month before transplanting. Shortening this practice shows real benefit, and might be easily introduced. Some NAFCO fields are wetted and prepared during July to September, well before the optimum transplanting date. This greatly increases the non-useful losses of water via evaporation.

Field drying-off at the end of the season. From a crop biology point of view, irrigation can be withheld from rice from about 3 to 4 weeks before harvest, yet farmers in Usangu often harvest rice that is still is in standing water. The problem here is to persuade farmers to pass on this non-required water to downstream cultivators, or allow it to by-pass their fields. Another factor is the lie and slope of the land affects this movement of water to flow to downstream farmers. **The reason water can be withheld is because of reduced water need during ripening, sufficient storage of water in the soil, and cooler temperatures with lower evaporation.**

Two other factors affect this duration of irrigation need:

1. Double cropping of rice. Early planting (leading to 'season creep') favours double cropping of rice. Farmers who manage to transplant by mid December are able to harvest by April, this allows a successful ratoon crop to re-grow providing about 0.4 tonne/ha of rice without additional planting. This second crop can be harvested in early to mid July. This practice uses irrigation which clearly is of very low productivity (probably 0.06 kg/m^3 water)

2. Mixed or unclean rice seed. A mixed seed results in different varieties being planted in the same field. Because some plants take much longer to mature, irrigation is supplied to the field even though many of the plants no longer need water. This reduces the productivity of water.

1.1.2 Reducing the command area under irrigation

There are several ideas that affect land use patterns – most of them closely relate to reducing the intake aperture as well.

Designed command area reduction. The formal command area could be cut by a re-negotiation of the area during a transitional stage of irrigation management transferral to farmers. For example, Kapunga Rice Farm could be cut from 3000 ha to 2000 ha. This presents the best opportunity to reduce the core irrigated area in the Usangu Plains.

Land purchase. Probably not applicable in the Usangu area, here the government or third party buys up commandable land that is then taken out of production.

Water purchase. This might soon apply in Tanzania if transferable water rights are encouraged (they are in the new Water Act), here the government or third party (e.g. TANESCO) pays upstream users to use less water, in effect buying their water. Farmers make a rational economic decision – is it better to be paid a given price immediately or to labour in their fields to cultivate rice to be sold at an unknown price? Once this decision is made commandable land is then taken out of (or into) production.

Improved bylaws and policing of land tenure. Village and irrigation committees decide on a restricted core area of irrigation, which only in a wet year could be exceeded. In another example, already seen in Usangu, local users believe that a land rent would restrict command areas from growing too much. Each farmer would be encouraged to grow only about 2 acres. This is another example of using pricing to affect land use patterns and water abstraction.

Tightening up of areas that are watered but not planted. There may be parts of the system where water spills and ponds that are then not cultivated. This point applies to large areas (e.g. non-cultivated fields on NAFCO farms) or to marginal areas, (e.g. the edges of cultivated land). In each case, the reasons for these spills should be investigated. Likewise, areas slightly out of command may be watered occasionally when higher levels of water become available but are not generally planted up.

Closing down partially abandoned areas totally. Ideally, rice should be planted within a contiguous area if possible. Conveying water to a small cropped area within a larger abandoned area, the latter itself taking up water, can be wasteful.

Reducing the incidence and command area of late planted rice cropping. Bylaws may be required to control transplanting of late season rice that then establishes a water demand during the dry season.

Reducing the command area of dry season non-rice crops. Bylaws may be required to constrain the growth in area of dry season crops, particularly if they require irrigating rather than using ground moisture. Also important will be the need to zone dry season crops so that they are irrigated together and are close to the intake or existing canals.

Reducing the command area of high catchment dry season irrigated crops. The small water volumes that occur in the dry season are best kept for highly valuable domestic and ecological functions. Bylaws may be required to constrain the growth in area of dry season crops found in the high catchment, particularly if they require irrigating rather than using ground moisture. Given the cooler temperatures, more rainfall and lower evaporation, many crops grow well with rainfall and residual moisture.

1.1.3 Reducing the specific demand

Reducing the specific demand means reducing the 'per hectare' demand for water, and ensuring that most water is evapotranspirated through useful crop growth rather than through weeds, or via evaporation from bare land.

Implicit in this option is the need to distribute water more equitably. This ensures a wider spread of water and its productive benefits. This equity of water distribution is important because of the *productivity function* of water. The amount of crop growth (productivity) alters as the amount of water is increased. A small amount of water may not help the crop at all, whereas more water increases growth, but too much water does not add growth and may in fact harm the crop. This is often the tragedy behind top and tailend farmers on irrigation systems - the former have to much water, a certain proportion of which they do not need, while the tailend farmers need more water, a proportion of which they urgently need - if only to secure an adequate crop.

The options below describe some possible ways in which water may be saved.

- Reducing water demand at the beginning of the wet season
- Reducing water demand during the main wet season
- Reducing water demand at the end of the wet season
- Reducing water demand during the dry season

Reducing water demand at the beginning of the season

This early transplanting period is mainly from 1st September to the 31st December, but also applies to rice that continues to be transplanted during January to March. The objective is to save water where and when possible but to maintain production.

Start of field preparation. Rice cultivation in Usangu appears to show 'season creep'; earlier and earlier transplanting to September and October. Farmers do this to catch higher prices of early harvested rice, but are subject to infestation by pests (yields of very early rice are only approximately 1.5-2.4 t/ha). If possible, irrigation of fields for transplanting for the new season should begin at an agreed date, preferably early November. RBWO could monitor offtakes carefully until control is handed over to the irrigators at the beginning of the agreed start date. Small quantities of water would be allowed to start nurseries during late September and October.

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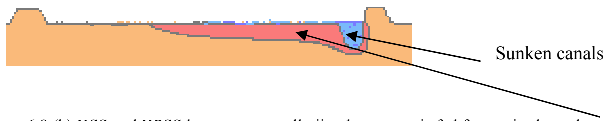
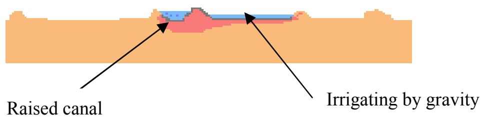
Wetting up the field. (See diagram below). Rice irrigation requires a pre-saturation dose of water to wet up the soil before a standing layer can be created. However the amount of water required depends on the method of watering which in turn depends on the design of the field or field canal. In the NAFCO farms, the relevant part of the design referred to is the tertiary canal that runs alongside the boundary of each field. This tertiary canal is sunken below the level of the field. The sunken canals are not found in the smallholder systems where canals are placed on top of the soil. The sunken nature of the NAFCO canals (trenches) means that water has to be raised to the top of the canal to start to flow across the field but when filled up, this water level is not above the level of the field surface, *it is at* the level of the field. This means that there is no head difference between the canal water and the field water. This in turn means the water moving across the field encounters proportionally very high friction losses. This means water moves very slowly across the field which in turn means that water seeps more into the field. The test of this design is that when the fields are wetted up, they take about 300 mm in the soil profile to become saturated. Some NAFCO fields receive two irrigations taking 600 mm before any rice has been grown (a full crop of rice can be grown on about 750-900 mm).

Continued
This contrasts with the smallholder systems, the canal water level is probably 5 – 15 cms above the level of the field. This allows water to move quickly across the field sealing the surface of the soil quickly – a well-known way of saving water. (And when plot to plot irrigation takes place in the smallholder systems, water can surge from one plot to another which wets up the next plot quite quickly). Under this system, the fields accept about 100 to 130 mm.

KIF has large fields and sunken tertiary canal, capillary irrigation (more water for pre saturation and longer time)



6.8 (b) KSS and KPSS have many small vijaruba - water is fed from raised canals and irrigating by free gravity (less water for pre saturation)



Design and location of rice nurseries. If possible, these should be small, contained areas with clear bunded boundaries that trap water carefully. Where possible they should be close to canals where water can be conveyed to them with minimum loss. If possible, they should be grouped together into a single area. This contrasts with the extensive and ill-defined nurseries of NAFCO.

Duration of rice nurseries. If possible, rice should grow in nurseries for as long as possible due to reduction in cropped area from this concentrated growing.

Conveyance of water to downstream nurseries. Conveyance should be via canals and furrows within vijaruba rather than by using field-to-field irrigation which increases the area of evaporation dramatically. If nurseries are planted downstream, it may be possible to use natural hollows and wet areas where water has seeped. (Note: Furrows within vijaruba allow passage of water without wetting up of the whole plot)

Vijaruba (plot) sizing. Vijaruba should be sized in a way that promotes reasonably rapid advance and completion of watering. The ability to build up a head of water in a neighbouring plot before opening the water supply to the new plot promotes a quick advance rate, and ultimately a reduced dose of irrigation. This contrasts with the large NAFCO fields that do not allow a comparatively quick water advance, and therefore leads to high seepage losses. The reason water advances so slowly in NAFCO fields is probably due to uneven land levelling.

Banding or zoning the transplanting of rice. Contiguous rice promotes higher efficiency. For example, water from lateral seepage can soften soil ready for land preparation, and control of water from one plot to another for rice at the same growing stage is easier. Farmers at the Kapunga Smallholder System drew up new bylaws in response to water shortages in 1999 stipulating that planting should be more concentrated in space and time. This minimises the mixed ‘mosaic’ that leads to a patchwork of cropped and bare fields in close proximity both evaporating water. It is interesting to note that livelihood drivers partly explain this mosaic, farmers are absent from their fields to work on other farms or jobs to get money.

Reducing water demand during the main rainy season

Responding to rainfall. It appears that farmers rarely shut down the main intake when sufficient rain does fall, though this would keep water in the river. Perhaps, in a period of a week, the number of days when the offtake is opened could be reduced from 7 days to 4 to 5 days, for those weeks when heavy rainfall occurred.

Controlling the depth of the standing water layer. Farmers state that the optimum depth of water is "ankle high" (about 12-18 cm), while rice agronomists believe 7-10 cm of water is sufficient. However, some farmers complain that others use too much water - up to 22 cm of water. A decrease in 3 cm of standing water over 500 hectares would provide an extra 40 hectares of land with water for its presaturation and standing water layer requirement. For discussion, a target depth of 12 cm is suggested.

Cycling water. In dryer tail-end areas, farmers have been seen to cycle water to spread water thinly but also to protect rice from drying out. Clearly this strategy maximises returns to water but is not practised in upstream areas. Although unlikely to be adopted, it remains a possibility for farmers to consider. *(There is some evidence that alternative wet and dry cycles in rice cultivation increases yields because of nutrient flushes that occur with each cycle. Research in Asia demonstrates this).*

Levelling fields. Mostly applicable to NAFCO fields, level gradients promote uniform depths of standing water and in doing so lower the average depth ponded, thereby saving water. Level fields in smallholder irrigation systems are more or less guaranteed by the use of small vijaruba, which vary in size depending on the general slope of the land. Without vijaruba, machinery is needed levelling to high standards.

Vijaruba in NAFCO fields. The NAFCO fields are sometimes divided up into small vijaruba by renting farmers. It is good to promote this and allow them to be similar to vijaruba in the traditional systems. Increasing the competition for water within the NAFCO fields means that the amount supplied to them can be decreased. At the same time not using the sunken tertiary canal reduces the amount of water that is used without affecting crop growth.

Bund definition. Strong compacted bunds help manage water by reducing unwanted seepage between vijaruba. A good bund helps with field definition uniformity. Cuts in the bund allow passage of water without erosion.

Levelling land. Allow and encourage farmers to equalise levels between vijaruba by moving soil from higher plots to lower plots. Although this may not be popular, this saves water in flooded lower-lying plots, and brings higher land into production.

Reducing water demand at the end of the season

Restrictions on late-transplanted rice. Another example of 'season creep', the transplanting of rice in tailend areas now as late as May establishes a much longer season - but yields are low due to cool temperatures. It may be possible to introduce a bylaw that halts transplanting after a stipulated date that is decided each year depending on rainfall and riverflow conditions.

Method of conveyance of water. As described previously, plot-to-plot irrigation rather than canal or furrow-within-plot irrigation can greatly increase water demand. The addition of extra canals leading to tailend farmers can help deliver the water they need without watering upstream vijaruba.

Use of clean seed. Mentioned above, farmers using mixed seed of different varieties experience differential ripening within single fields at the end of the season. This requires water to be kept in the fields for longer to irrigate the slower ripening variety.

Reducing water demand during the dry season (for non-rice crops)

Location of non-rice crops. Planting dry season crops in places where they would use residual water from domestic/late rice supply rather than requiring water to be delivered to them. Placing crops at the top end of the irrigation system, near intakes and main canals to reduce seepage losses.

Scheduling dry season crop irrigation. Non-rice crops do not need continuous supply of water, but instead water can be rotated from field to field. It is possible to save water by irrigating later than when the crop first shows signs of stress; this is called 'deficit irrigation'.

Source of domestic and livestock water. Using piped or *borehole* water for domestic supplies rather than conveying surface water to villages reduces the gross water demand.

Reducing accidental irrigation. Fields in NAFCO farms are occasionally irrigated by accident or on purpose for non-irrigation purposes. Duck hunters and fishermen release water into fields to capture their prey. It is usually some time until this water is stopped and it is not very productive. Locking of gates, and negotiation with these water users may reduce this water use.

Using buckets rather than surface diversions. In parts of the Mkoji catchment, farmers have introduced a bye-law during the dry season which only allows water to be abstracted using buckets. This reduces waste from the use of furrow water.

2.4 Returning water to the river systems

Installing and maintaining drains. A network of drains leading from tail-end areas to the rivers returns water that otherwise might pass to a sink (pond, spread and evaporate). However often drains function as canals to extend the area of irrigation. This is an acceptable method of increasing the productivity of water that might otherwise evaporate. A variety of institutional arrangements would be needed to secure the long-term success of drains, particularly to ensure weeding and earth clearing. Clearly, the current layout, efficacy, maintenance, and contribution to return flows of existing drains would need to be explored before recommending a scaling-up of further drains. Also, farmers' perceptions of existing and future drains should be investigated.

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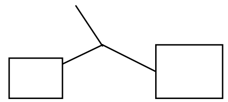
2.5 Infrastructural ways in which water management is improved

The management decisions to save water described in the previous sections are underlain by institutional processes (e.g. the formation of irrigation committees) and the physical-technological means to assist in allocation of water. The former is addressed in section 1.6, whilst the latter is discussed below.

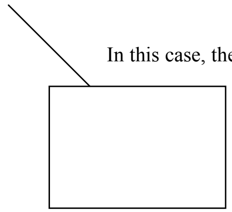
1.1.1 Dividing water to supply a set area – establishing farmer cells.

In this section, and the ones below, the advantages of canals are explained. A hierarchical network of canals enables the division of water. Dividing water enhances control by creating smaller areas over which farmers can compete and negotiate water. This creates smaller semi-independent farmer cells. A smaller number of farmers in each cell simplifies discussions in order to share the available water. The smaller area also enables farmers to identify those who hold onto water for too long depriving others of their fair share.

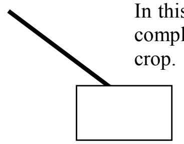


1.1.2 Ratio of flow to area

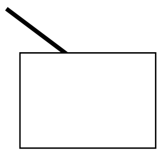
When two canals split from a main canal, the design of the division controls the amount of water supplied to the two respective command areas. This apportionment can ensure that the amount of water correctly matches the area that the canal serves. However, as the following diagrams show design errors can arise. The need therefore is for a design that ensures a correct match of flow to area.



In this case, the water is too little for the area served (or the area is too big) and so irrigation takes a longer time, or planting is stretched out, or fields become dry as farmers try to move water around. Production is reduced or water is required for longer to compensate for effect of drier fields.



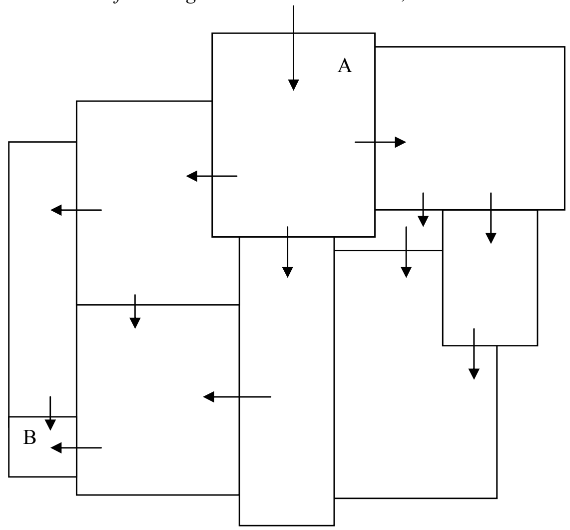
In this case, the supply is too large for the area served, so irrigation is quickly completed. If water is not moved elsewhere, water builds up and drowns the crop. Alternatively, the excess flows into the bush or to drainage lines. If water is moved out of this sub-area to another then this requires cycling of water, with the attendant risk that it will not return at some future point in time.



Here the water supply is just right for the area served, farmers can spread the water evenly among their fields, and the flow can continuously supply these fields. There is no need for cycling water outside of the area supplied, and farmers are more likely to perceive fewer supply problems.

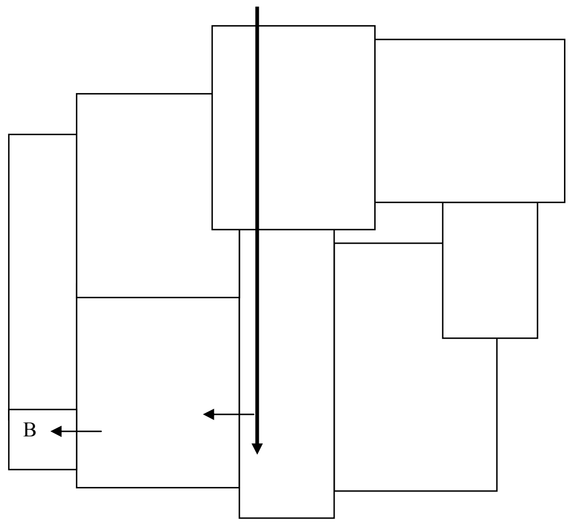
Correct ratio of density of canals to field to field irrigation. More canals means a higher proportion of water is distributed using channels rather than by field to field irrigation. The latter increases losses via evaporation and seepage because it spreads water over a larger area.

Field to field irrigation: water enters here, and cascades through the system



In the case above, the absence of canals means that to get water from point A to point B, farmers irrigate three fields and use more water. This contrasts with the case below where even one canal means that only one other field gets wet to supply water to field B.

Canal irrigation: channels supply water through the system



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In the case above, the left hand side has only one canal supplying an area, while the right hand side has 5 canals with 4 division points to enable distribution to given command areas. The greater the number of canals, the more control there is over where and when water can be put, particularly at the end of the rice season when only a few fields need irrigation. A greater density of these 'arterial supply routes' might also reduce inequity of supply between top and tailend farmers. A rather haphazard arrangement of many minor canals and drainage lines might be equally effective in achieving this distribution than relying on a more formal, modern layout.

Note that if these canals split at simple division boxes, they do not add to the need for human adjustment.

2.5.1 Adding intakes

In some cases, an additional intake will provide a new set of secondary canals, often further down an irrigated area, and so increase control of where and when water can be conveyed. This solution might, for example, be appropriate for Kimani where previously several offtakes found strung along the river were rolled up into the existing larger modernised offtake. This appears to have accentuated the top-tail differences in water distribution.

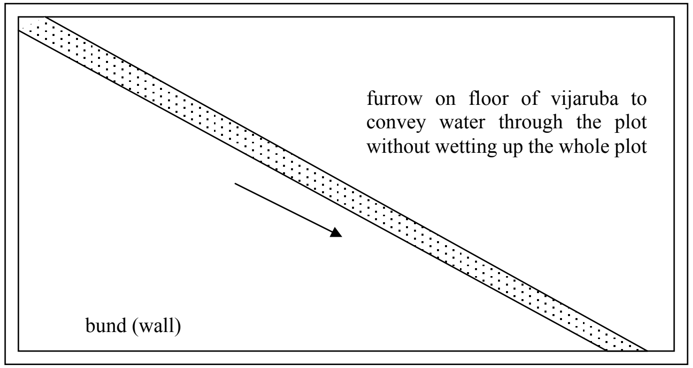
2.5.2 Choice of division type - transparency

The choice of division type affects transparency of division. Division of a flow includes a division point and each division point has a number of characteristics:

- Symmetry of division layout; if canals are similar in size, base height and width then this aides transparency. If the flows are different, then only the width should alter in proportion with the flow;
- direction of division; if canals lead off from the division point in a similar direction then the flows between them can be compared easily;
- symmetry of shape of canals; ideally, canals should be similar in shape to enable comparison (e.g. all parabolic, or all trapezoidal;
- symmetry of 'orifice'; again, the ideal situation is to have the orifices similar in design; either all flume type, or all weir type or all undershot orifice type;
- degree of manipulation required – no manipulation, or simple staged manipulation of the turnout is best, with preferably only on-off stages, or on, mid, off stages. Many stages and continuously variable turnouts require careful adjustment.

2.5.3 Furrows in vijaruba

If field to field irrigation is the desirable option, as it will be in most cases, one way in which water can be moved through fields without wetting the whole plot is by installing a small furrow or corrugation within it. Some are well defined and operate correctly while others do not convey water without spilling. These can be seen in plots that supply tailend areas.



1.1.3 Other water management decisions

1. Removing bottlenecks (silt and weeds) can ensure the correct flow to the area served. Most farmers in the Usangu appear to be aware of the needs to maintain and clean their canals. This principle also applies to drains if the latter are being used as canals to reuse water.
2. Re-building, cleaning, reshaping and raising canal walls to reduce seepage and spillage which creates temporary swamps or unnecessarily deep water in neighbouring rice fields.
3. Supplying smaller isolated nurseries from small wells and boreholes rather than keep long canals open during September/October period.

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3 Institutional and policy dimensions

3.1 Introduction

Related to the management and physical issues discussed in the previous section, are a number of related institutional questions.

- Could a more sophisticated approach to water rights based on proportional rights, which are staged and throttled during the dry season, be formulated?
- How might rights to, access to and re-allocation of land affect how much land is irrigated and therefore the amount of water used?
- Could a change in water rights provide new opportunities for bringing in conditions attached to the use of water? In other words, could water rights be subject to the formation of bylaws that promote the better use of water?
- In addition, how might the water right fee be used to leverage agreement on water allocation between tailend and top-end farmers?
- How might farmers gain confidence in their beliefs regarding security of water supply and distribution? When farmers believe water is uncertain in supply (even in top-end areas), they 'hold onto' water whenever possible, for example having deeper than necessary water layers and irrigating up to the harvest date. Yet strangely, discussions with farmers show that they are consistently observing their rice growing under a variety of field and watering conditions and understand that rice does equally well - or only marginally less well - with less water. Building on this knowledge to gain improved co-ordination and confidence over supply is an important institutional objective.
- How might an appreciation of the need to keep water in rivers (below an intake) help the environment and minimise conflicts? What educational tools can be used to persuade users to keep water in the rivers?

3.2 Devices to generate new allocation patterns

A recap of the main devices to effect a re-allocation of water is as follows:
1. Command and control (e.g. formal water rights)
2. Pricing incentives (charging for or pricing water, markets, tradable water rights)
3. Community natural resource mange, common property management

In addition to these, education, technical infrastructure and accounting for natural distribution of water assist or desist in achieving goals of redistribution. Furthermore, these can be applied at different levels of scale (within one sector or system, between sectors, at the subcatchment or river basin scale).

3.3 Organisations to foster institutional change

It is generally agreed that water user associations constituted from farmers, leaders, other water users (and sometimes other staff) are the favoured organisation to take decisions on water management. WUA’s can – and should - operate at a number of levels to effect good water management from field to basin. A table showing common groupings, functions and membership is given below. Two middle levels usually have legal status (irrigation system WUA and the proposed Apex body sub-catchment level WUA). The lowest level tends to be an informal grouping of farmers around secondary or tertiary canals. The highest level provides institutional space at the basin level of users to be well represented in water management decisions.

Table showing different levels of water associations and committees

Level of group	Function	Membership
1. Tertiary level farmer groups (generally not a legal WUA)	Water rotation and canal cleaning	Farmers
2. Irrigation system level (WUA)	Intake repair, conveyance canal cleaning and maintenance, physical changes, voting on leadership and constitutional changes, water rotation between secondary systems, conflict resolution	Farmers, leaders, elders, other water users, and possible staff from NGO's, Ward, District etc.
3. Apex Body (subcatchment water user assocation)	Conflict resolution in catchment, rotation of water, adjustments in supply, representation at higher level meetings, constitutional changes	Representatives from all sectors (agriculture, livestock, domestic, fisheries), and from all parts of the catchment (high, middle, low)
4. Basin committee (not legally a WUA)	Basin-wide sectoral decision-making, information provision, conflict resolution	Representatives from all sectors, national, ministerial & NGO representation.

Globally, there are some common functions duties and responsibilities of WUA's, these are as follows: **(not necessarily relevant for Tanzania)**

1. Prepare plans on the improvement and maintenance of irrigation systems, water supplies and export, and implement them.
2. Plan and implement the rehabilitation of irrigation systems and drainage network in irrigated areas to reduce water loss and increase effectiveness.
3. Work out a schedule of water delivery with the aim even distribution of the water to irrigated areas.
4. Solve emerging water problems amongst the water users on the basis of mutual understanding and cooperation.
5. Collect membership fees, which will be used to cover all expenditures related to WUA.
6. Make contact with non-member farms, located in the area of the Association and provide with water according to their requests, and collect corresponding payment based on provided services.
7. Identify and prevent the Association members' violations of byelaws on water and land practices, and also non-member land users. If necessary, fine members on identification of consequences and reimburse the damages to aggrieved parties.
8. Provide training and assistance to water users on effective water usage and skills on new irrigation technologies.
9. Keep independent finance records and conduct a finance audit annually.
10. Prepare annual reports.

3.4 Capacity-building and social learning

The ability and willingness of organisations to make changes in the way they manage water, people and resources, is affected by exposure to information and knowledge via educational and training opportunities. Workshops, user-to-user visits, training days, role-playing are examples of devices used to build capacity to reflect on current practices and plan future changes. PRA and interviews with farmers in Usangu show a high level of demand for such knowledge, but this needs to build on what they already know, and meet true gaps and needs. Such 'skills training' can be provided by a variety

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of organisations, but should arise from careful discussions between WUA's, other water users, NGO's and support level agencies.

3.5 Programmes and strategies to improve water management

In general, a strategy or programme is required to implement improvements. It is likely that the most successful progress will occur via

1. The establishment of water user associations at three levels (tertiary, system, subcatchment)
2. The revival and creation of local & customary bye-laws at the three levels.
3. The creation of partnerships (for service delivery) with other support agencies (e.g. RBWO).

These three steps might be generated as follows:

1. Convene higher-level meeting of support agencies (District, RBWO, Zonal irrigation) to discuss the implementation of the strategy and means of supporting smallholders.
2. Facilitate (e.g. via the River Basin Game) users in sub-catchments to agree technical and institutional changes to managing water; expressed as forming water user associations and apex bodies, and then reviving or creating byelaws and other customary agreements.
3. Via creation of a catchment management committee, encourage higher-level agencies to enter into a service delivery of various provisions:
   - Respond to WUA requests without dismissing any ideas or solutions they might have.
   - Discuss ways of interfacing customary and statutory water laws particularly for the management of water during dry and drought periods.
   - Bring in other experts if required to provide training and problem-solving skills.
   - Promote user-to-user visits so different sub-catchments learn from each other.
   - Continue to cycle of social learning, skills training, irrigation discussions and support.
   - Allow feedback on service delivery by WUA's.

It is highly likely that new solutions and changes will proceed quite slowly and in stages. The water management practices that WUA's might implement are listed below in two groups, the first group includes those ideas that are likely to succeed in saving water, while the second list includes those that are either expensive, or are less practicable for one reason and another. It should be stated here though, that inclusion of a point in the first group does not mean that it can be easily introduced!

WUA priorities – interventions for the short term? High benefit to cost ratio in terms of effective saving of water.

- ceasing irrigation 3-4 weeks before expected harvesting date
- restricting the area of dry season non-rice cropping under irrigation
- reducing the depth of water in rice fields from 18 cm to 12 cm.
- using short season varieties for late-transplanted rice
- shortening the time taken to prepare fields and transplant rice
- locating nurseries in upstream areas
- nurseries, agreeing a start date of nurseries and irrigation (e.g. not before 1st November)
- banning of late transplanting after an agreed date negotiated each year depending on climate and river flows
- effectively banning (through early cessation of irrigation, and no second irrigation after harvesting) secondary re-growth of ratooning rice
- encouraging the use of furrows in vijaruba to convey and control water to tailend areas
- utilising smaller vijaruba where possible
- zoning priority land and identifying land not to be cultivated unless it is very wet
- agreeing the closure of the main intake for an agreed period during the dry season
- moving out of abandoned land

- encouraging contiguous cultivation and discouraging late leasing of plots in both upstream and downstream areas
- reducing intake flows during heavy rainfall periods
- installing boreholes to reduce losses via canal distribution of domestic water (this also improves quality of drinking water)

Longer term WUA priorities? Low benefit to cost ratio, or likely to be unpopular (in order of decreasing degree of success)

- reducing peak abstraction flow rate and therefore decreasing overall irrigated command area
- examining options for time-based method of reducing intake flows
- adjusting flows down different offtaking canals by using well-designed division points
- installing secondary and tertiary canals where possible, particularly to take water to tail-end farmers
- using division points and canals to group farmers into smaller negotiating units within which they could either carefully divide or cycle the available water supply
- requirement for digging drains to convey water back to the river channels where practicable

Above all, these bylaws are needed for periods when, from the point of view of most of Usangu farmers, the value of water is dropping; this is at the beginning of and during the dry season. In addition, these bylaws could be drawn up subject to the process of a new proportional water right application.

3.6 Conclusions

Improving water productivity needs a variety of factors to work together, otherwise farmers will not rationally make those investments in water management. Conditions that promote water management are not always known, but some of them are given below:

- Livelihoods become more geared towards irrigation so that absenteeism from meetings and group or timely irrigation work is reduced.
- Clear, agreed and predictable land tenure / land rental agreements
- Well-resourced extension & engineering services that are able to respond quickly and meaningfully to water management questions
- A participatory approach by extension & engineering services
- Ensuring a suitable density of farmers which raises inter-farmer competition for water and intensifies agriculture
- Meaningful dialogue with RBWO and other agencies so that bye-laws (and water rights and fees) are explored and supported.
- Communication of intended actions to farmers within canal command areas
- Clear and understandable policy by village, district and national governments that links together.
- Support toward farmer groups and meetings to discuss and implement changes
- Water use is connected to crop husbandry - fertilisers, FYM, markets, credit, storage.

3.7 Policy recommendations

The workshop participants discussed and agreed recommendations for policy-makers. These are included in and circulated with the workshop proceedings.

4 Thinking about water management targets

The following table gives some examples of thinking about the improvement of irrigation activities and performance. It is a basic planning tool that allows water users to compare existing performance with a potential target. The list is simply an example, and is not complete. Each water user association with support from extension officers, RBWO or Zonal irrigation officers, would then generate its own list of priority activities for improving.

Comparing current and targets indicators

Item	Current figure	Improved target?
Technical		
Total area irrigated (rice)	150	150
Water duty - cumecs	0.20	0.150
Dry season water duty		
Average Yield (t/ha)		3.5 t/ha
Start date of nurseries	1st September	1st October
Start date of field transplanting		15th November
Duration between first field watering and transplanting of rice (days)		6 days
Depth of water in field (cm)		10 cm
Last date of harvesting		1st July
Ceasing of irrigation before harvest (days or weeks)		2 weeks
Maximum duration of water in one field plot (days)		120 days
Total duration of season (days)		270 days
Flow taken during dry season (cumecs or %)		20% of river flow
Monitoring of closed gates after harvesting (%, yes, no)		50% of all closed gates
Agreed wet season dates		
Agreed dry season dates		
Administrative and institutional		
No. of WUA meetings held/year		5
No. of bye-laws in place		15
Percent fees collected		75%
No. of canals installed		6
Apex body meetings convened/year		4

5 Evidence that smallholders manage water carefully

Farmers are concerned about waste that they themselves define and observe each day. For example, the river basin game generates heated discussion of what constitutes waste and what to do about it. The table below are given a number of documented agreements on the management of water at the farmer level. These discussions build upon general agreement that productivity of rice need not be reduced, and indeed be increased with better water management.

1. Farmers explore economic solutions to demand management – that farmers themselves had agreed to a land-based village-originated tax/byelaw that encourages people to manage a few acres of land that can then be supplied with water rather than hopelessly optimistic land clearing and planting	Video 'Talking about Usangu'
2. Local traditions – "people unable to plant until chief does so at Mahongole village" Vivian Bahemereru 9 Oct 2000, memo on cropping.	SMUWC fieldwork
3. "Because of high demand for water from the furrow, the furrow leaders instigate an allocation sequence whereby each secondary furrow receives water for 12 hours (6am to 6pm) in turn. Within the group of farmers using an individual secondary furrow there is no system of allocation. This is partly because water flows from one farmer's fields directly to another farmer's fields and so on, therefore once one farmer receives water, the neighbouring farmers automatically receive water. Secondly, there is a by-law that nobody should block the furrow entirely in order to divert all of the water into his or her fields, but that water should be left to flow in the furrow. In most years, this by-law is strictly adhered to since there is a fine of between TSh 2500 - 10,000. As a result, most people along a secondary furrow get water eventually".	Gillingham Report for SMUWC. Community Management 1999. Pages 6-16
4. "No one furrow intake should take all of the water in the stream, but about half of the water should be left in the stream for downstream users. There is a TSh 50,000 fine if any individual or furrow user group is found to be taking all of the water from the stream. As a result, none of the furrows abstracting from the Nyamaluluja have a diversion weir right across the stream. Instead the intake structure reaches to 1/3 – ½ way across the stream."	
5. "All members should participate in furrow cleaning work (including female heads of household). If a member fails to contribute to furrow cleaning work, the Furrow Committee refers them to the village office, where they are fined TSh 500 for every day that they failed to contribute. In return for contributing to the maintenance of the furrow, all members have the right to abstract water from the furrow for irrigation."	

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6. Regarding Kapunga Smallholder Scheme: "Water is used for land preparation and irrigation from October through to May. Water is not formally allocated when the paddy is at the nursery stage, although there is evidence of competition for water, since the tail-end farmers prepare their land and nursery fields later (November/December) than top-enders (September/October) because of the lack of water. In theory, when there is high demand for water and water scarcity (notably at the beginning of the rainy season in November and December), there is a system of allocating water between the different tertiary canals. This system was put in place by the advisors from Mbeya Zonal Irrigation Office when land was originally distributed to farmers. Water is allocated to each tertiary canal for 24 hours (from 6 a.m. to 6 a.m.) in turn. This allocation sequence continues until the rains begin and water is no longer scarce. However, farmers reported that in recent years, if this allocation sequence has been put in place it has not been followed because the control gates have been broken and leadership poor. Top-end farmers reported that they take water as and when they need it, and reported that they did not know of any system to allocate water between different tertiary canals at times of water scarcity. The new Irrigation Committee is planning to replace the gates and reintroduce the allocation sequence in order to maximise the productivity of the system. Under the scheme by-laws, those who break the allocation sequence are fined TSh 3000. This fine is imposed at times of great water scarcity. For example, several farmers were fined in the 1998/99 season, which was very dry. They were fined for being argumentative and causing fights, rather than for breaking the allocation schedule per se."	
7. Farmers gave a very interesting experience on area control from Inyala area that uses water from Umrobo River. Farmers are allowed to cultivate only 0.5acre and water distribution timetable within fields has to supply for only 0.5-acre. Many farmers who had cultivated large areas than the agreed area had to lose their crops. Also farmers who rent the plots are normally notified of the existing regulation prior to start of the farming activities and they have been very successful in managing water by following the set regulations.	River basin game report. RIPARWIN. Dec 02. Pages 2-4. Other research by RIPARWIN team Mdemu et al 2003.
8. The use of raised bunds (vijaruba) was sited as a major means for infield water control. The observed problem with this method was construction of large bunds which some times denied water for downstream users. Farmers appreciated and acknowledged the use of appropriate bunds for retaining only the required amount of water at the same time allowing excess water to neighbour field plots.	
9. Most smallholder farmers practice cleaning of canals, but the problem comes when cleaning starts from upstream users who do not cooperate once the canals have been cleaned up to their fields. Introduction of field canals that supply water to all farmers without waiting until the upstream farmers have irrigated their fields was suggested and that it could reduce water use conflicts between irrigating fields. Construction of field tertiary canals for equitable and timely access of water within the fields.	
10. "Land preparation, raising seedlings and transplanting should be restricted between November and February and not beyond that" – Farmers ideas for improved management of water	
11. Improved farming which takes care of quality seeds, use of fertilizers and good husbandry of field crops. This requires further agronomic research especially on variety and seed selection to use those that can perform better on different locations with different micro-climatic conditions. With this kind of farming according to farmer's point of view, only 1 acre up to 1 hectare could be a sufficient area for each farmer. The farmers cited the high yield cases in like Lower Moshi irrigation schemes and Kimani Schemes to be some of the areas with sufficient harvest.	

6 Case study of improving productivity (NAFCO farms)

6.1 Introduction

This case study considers the productivity gains of irrigation management transfer (IMT) of the NAFCO irrigation Farms in Usangu to smallholders. IMT is a global development process found on medium to large-scale systems to achieve principally two aims; a) reduced expenditure for government-owned systems; and b) improved water management as a result of greater involvement of farmers in system management. The two Government-owned NAFCO systems in the Usangu plains are Mbarali (3000 ha) and Kapunga (3000 ha). These systems are hydrologically important in the Usangu Plains due to their location on perennial rivers and ability to abstract large amounts of water (8.1 m3/sec and 4.8 m3/sec respectively) throughout the year. Research by SMUWC and RIPARWIN indicates that water abstraction during the wet and dry seasons is greater than necessary and that water management could be improved. Transfer of the NAFCO farms to smallholders generates various productivity gains and meets various desirable goals of GoT:

- Improved water management. It is estimated that the NAFCO farms use 2600 mm water while the smallholders use 1700 mm water. Each hectare transferred saves 9000 cubic metres of water (and further savings are possible).
- Distribution of water more equitably downstream to Mtera/Kidatu, Ihefu wetland and Ruaha National Park. It is estimated that a 20% reduction in the intake flow would result in nearly 3 cumecs being made available.
- Increased rice production. It is estimated that smallholders produce about 1.5 tonnes rice/ha more than the NAFCO fields, which could lead to about 9000 tonnes rice could be produced (this includes the reduction in the intake flow).
- A pro-poor focus. It is estimated that an additional 5000 families could be provided for at one family per hectare (this includes the reduction in the intake flow).

6.2 Background information

A number of observations provide the rationale to consider IMT to smallholders. The key observation is that farming and irrigation on the smallholder plots peripheral to the NAFCO farms is more productive than the latter. Although factors such as climate, soil, water supply and crop varieties remain the same, the peri-NAFCO smallholder systems are owner-operated while the NAFCO farms are state owned and managed. Some outcomes of this management (and design) difference are described below and in Box 1.

Average yields on the NAFCO systems are between 1 to 3 tonnes/ha whereas, with the same varieties, traditional smallholders are achieving 2 to 5 tonnes/ha. There are multiple causes of low yields of the NAFCO farms, such low planting density, poor water level control and weed infestation. These suppress water productivity, resulting in a low return for water on the NAFCO farms.

Water level control on the NAFCO systems is variable because fields are large, the soil surface is uneven and smaller plots (vijaruba) are not employed to control water level and movement. On the smallholder systems, plots (vijaruba) are smaller enabling greater care over water levels. The sunken tertiary canals in the NAFCO fields also lead to substantial use of water in wetting up fields (see Box 1 for explanation).

In the recent past, a high non-crop use of water on the NAFCO systems was observed. From August through to November, NAFCO abstracted water and dissipated it on fallow fields and into drains. Dry season irrigation for smallholders is restricted to smaller areas of maize and vegetables.

At the beginning of the rice cropping season, peripheral smallholders irrigate, hold water within the plots and transplant within about 7 days. The NAFCO farms however dry plough, irrigate

heavily ploughed fields, rotavate, drain water, broadcast or transplant, and then irrigate again. This process takes longer, between half a month to two months.

As a result of using the sunken tertiary canal the NAFCO fields use about 600-700 mm water to wet up their fields whereas the smallholders use about 100-150 mm water. See Box 1 for more details.

Thus in total the NAFCO farms tend to use about 2600 mm water throughout the season, which lasts about 300-320 days. On the other hand the smallholders tend to use about 1400-1700 mm water, irrigating for about 140 days. By switching ownership of the farms to smallholders, and by instigating improved water management practices, each 1000 hectares of NAFCO farm can save approximately 9 million cubic metres of water.

Box 1. Design and management of NAFCO farms in Usangu

Regarding irrigation management, the large NAFCO farms are termed 'modern' while the smallholder systems are termed 'traditional'. These labels carry serious meaning in Tanzania (and elsewhere in the world). Modern is argued to be efficient and traditional is argued to be inefficient. However studies by SMUWC and RIPARWIN show that the efficiencies are exactly the opposite. Water management on the **modern** systems is **inefficient** while traditional systems are generally efficient (but could be more so).

The difference is due to their management of water and physical design, which was and remains the original design proposed by the consultant engineers. It is this design that makes the term 'modern' indefensible. The relevant part of the design referred to is the tertiary canal that runs alongside the boundary of each field. This tertiary canal is sunken below the level of the field. The sunken canals are not found in the smallholder systems where canals are placed on top of the soil. The sunken nature of the NAFCO canals (trenches) means that water has to be raised to the top of the canal to start to flow across the field but when filled up, this water level is not above the level of the field surface, *it is at* the level of the field. This means that there is no head difference between the canal water and the field water. This in turn means the water moving across the field encounters proportionally very high friction losses. This means water moves very slowly across the field which in turn means that water seeps more into the field. The test of this design is that when the fields are wetted up, they take about 300 mm in the soil profile to become saturated. This was measured on numerous occasions and a memo written by the British engineers who helped establish Kapunga indicated they were shocked to find the same. Some NAFCO fields receive two irrigations taking 600 mm before any rice has been grown (a full crop of rice can be grown on about 750-900 mm).

This contrasts with the smallholder systems, the canal water level is probably 5 – 15 cms above the level of the field. This allows water to move quickly across the field sealing the surface of the soil quickly – a well-known way of saving water. (And when plot to plot irrigation takes place in the smallholder systems, water can surge from one plot to another which wets up the next plot quite quickly). Under this system, the fields accept about 100 to 130 mm. In other words, for the same amount of water the smallholders can irrigate two to three times the area.

Another way to save water is to improve management of water, i.e. have stricter scheduling of watering so that the NAFCO fields;
a) don't use water to soften mud and germinate weeds;
b) don't use more than necessary water to maintain nurseries;
c) are put through wetting and drying cycles;
d) utilise shorter-season rice (e.g. basmati types);
e) are dried off 3 weeks before harvest;
f) are then not re-irrigated by accident or on purpose to catch a few fish that come through the outlet.

6.3 Rationale for IMT to farmers – the three wins

A transfer to **smallholders** provides a critical opportunity to generate significant benefits. Current smallholder practices provide arguments for considering IMT: greater yields on smallholder fields; greater care for water levels within fields; higher density of smaller plots (vijaruba); greater use of labour in preparing fields and ensuring higher planting densities; and greater attention to capturing rainwater within fields. A transition stage to new management may present an opportunity to to redesign the intakes and reduce the existing water rights in particular the dry season water right of the NAFCO farms. There are three wins with transfer to smallholders:

Win 1. Greater production of rice. It is estimated that rice production could increase by 9400 tonnes (nearly 11000 hectares total by 3 tonnes average).

Win 2. More livelihoods secured (an estimated extra 5100 households at the settlement rate of 1 hectare per family).

Win 3. Savings of water for downstream users (if total intake is reduced by 20%, a figure which requires further discussion, an estimated reduction of 2.6 cumecs of the water right can be made during the wet season. Over a period of 170 days this corresponds to about 40 million cubic metres). Savings are also possible during the dry season when partial closure of the intakes can generate an additional 3-5 cumecs flowing downstream towards the wetland and Ruaha National Park.

6.4 Summary

Thus, it is the savings in water on a per hectare basis that allows the water right to be reduced while still increasing the numbers of farmers and total production. Although the intake flow decreases, improved water management spreads existing water further, perhaps providing an extra 1000 ha of cultivated land. During the dry season, provision of borehole water for villagers with some canal water allows higher river flows to be delivered downstream.

7 Appendix A. Interviewing farmers about water management

These questions are grouped together under headings, and are designed to help you begin thinking about water management in different ways. These questions could be used in a questionnaire.

Planning and calendars

When is your rice season? What months does it cover?

When are the first rice seed beds/nurseries made?

When are the last rice fields harvested?

Do you plan water/cultivation/the cropping calendar? How is this planned?

What is your main constraint? What affects the calendar (land, water, labour, seed, machinery, money)?

What are your bye-laws on dry season planting? What are your plans for future dry seasons?

Do you change your management for a dry year, compared to a wet year? If so, how?

What are your rice varieties? How many days do they take to ripen/harvest?

How many days to prepare a field?

How many days does the rice stay in the nursery?

Calendar & Time questions

When is your water right for?

When do you most need water?

When do you least need water?

When do you start to order more water?

Does this coincide with transplanting? What is the delay between first irrigation and transplanting?

How long does a field take to irrigate at the beginning of the season?

How long ***should*** a field take to irrigate at the beginning of the season?

How long does a field take to irrigate (to top-up) during the main growing season?

How many hours a day do you irrigate for? How many days a week do you irrigated for?

Water scheduling, sharing and cycling questions

How do you tell if water is short for a crop? When is the crop stressed?

How do you decide when to start irrigating a field, and when to stop irrigating the field?

Can you tell, or do you monitor, if one field gets more water than another?

Do you cycle water between fields?

How are flows shared between the fields?

For how long do you provide water to a single field? (hours per day, or days per week?)

How long between cycles (meaning how long before water comes back to the same field, in days)?

Area questions

What is the **total** area do you normally allow to be transplanted in your farm?

What area of rice is related to your water right? (What area is allowed by your water right?)

Do you plan the total area to be transplanted?

How accurate are you to this target?

What is the **rate** of area transplanted (answer in area in hectares per week or per 10 days or per month, or number of fields per week or per 10 days or per month). What is the rate in September, October, November, December, January, February, March?

What controls this rate of area transplanted (ie. what slows it down, or speeds it up?)

What is the maximum area of transplanting possible with the water available?

What is the area for nurseries? (hectares or % of total area)

Water flow questions

What is your water right?

What instructions do you give regarding water/gate openings at the main intake?

What is the maximum flow you use? (cumecs, or l/sec)

What is the normal flow you use? (cumecs, or l/sec)

What is the minimum flow you use? (cumecs, or l/sec)

What is the flow for each field? (cumecs, or l/sec)

Do you ever close the main gate? Do you close it during heavy rains?

Water demand and supply questions

What is your water right? What is your water right at different times of the year?

Is the water available enough for the area irrigated?

What creates the most water demand from your fields? (evap?, wetting up? field design)

What is the water demand per area (l/sec per hectare?)

What depth of water applied per season? (mm per field)

What depth of water is required to wet up the field at the beginning of the season (days, mm, cubic metres)

What depth of water is applied per year? (mm depth per field per 12 months)

What depth of water is required to create the standing water layer? What is the depth of water in your fields?

How much does this farm depend on rainfall or river flow during a normal year for its water. In other words which does the farm depend on - rainfall or river flow? (answer in words, or in percentages?)

What is the maximum flow of water in the river and when does this occur?

What is the minimum flow of water in the river and when does this occur?

What percentage of river flow do you think you take during a normal year? (irrigation impact)

What percentage of river flow do you think you take during a dry year? (irrigation impact)

What percentage of river flow do you think you take during the dry season? How much is left in the river?

When do you think there is no demand for water on your farm? What months, or what dates?

When do you stop irrigating before harvesting? How many weeks before harvesting?

Canal water management

Is water delivered by field to field irrigation or by channels?

How do you manage water control in your canals? How do you adjust water flows?

How is flow switched from one canal to another canal?

In-field water management questions

Who manages the spreading of water inside the fields?

Is the depth of water variable inside the fields?

What is the difference between smallholders and NAFCO water management?

Does the sunken field-edge canal inside the field increase water demand?

Which uses more water - dry seeding or transplanting?

Location questions

Where do you put your nurseries? Are they grouped together?

Which fields are transplanted and irrigated first?

Water efficiency questions (water losses)

Do you have irrigation (water) losses? Are your losses great or small?

What do you think your losses are? (% of inflow, cumecs or l/sec?)

Where are the losses mostly occurring - meaning from where are they arising? Who is causing them?

When do you think most of the losses are occurring?

What are the effects or results of these losses?

Are there causes of losses that you could correct and fix?

Are there times when your fields are using water but are not growing rice? Why is this so?

Is water returning to the rivers? What percent of water abstracted is returning to the rivers?

Who uses your excess water? How much land is irrigated using your runoff?

Water allocation questions

Which method do you use to allocate water - time, flow, cycling, switching, dividing water, area served?

People making decisions

Who makes the decisions about water management?

How are these decisions arrived at?

Saving water

How do you think you can save water? What are the main ways in which you can save water?

When is the best time to save water?

How much water can you save at different times of the cropping calendar (cumecs, litres/sec, or percentage, or days, or leaks)?