International workshop on '*African Water Laws: Plural Legislative Frameworks for Rural Water Management in Africa*', 26-28 January 2005, Johannesburg, South Africa

A framework to integrate formal and informal water rights in river basin management

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The paper explores a water management framework for bringing together formal water permits and informal water agreements to effect intra- and inter-sectoral water allocation. This framework is based on setting and modifying seasonally applied volumetric and proportional caps for managing irrigation abstractions and the sharing of water between users and sectors in river basins. The volumetric cap, which establishes the upper ceiling of irrigation abstractions in the wet season, relates to formal water permits and maximum intake capacities. The proportional cap, which functions in the dry season beneath the volumetric ceiling, builds on customary water negotiations and on the design and adjustment of intakes by users. The analysis is informed by conditions found in the Great Ruaha River Basin, Southern Tanzania, where rivers sequentially provide water for irrigation, a wetland, the Ruaha National Park, and for electricity generation. A working example of the framework helps explain its effect on inter-sectoral re-allocation.

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Keywords: water management, interfaces, formal, informal rights, irrigation intakes

Introduction

To change the distribution of water between sectors in river basins needs the resolution of three matters; establishing a vision of water allocation (river basin objectives for who gets what water); creating and sustaining the physical, legal, economic and institutional means of distributing water according to this vision; and monitoring outcomes so further adjustments can be made to both vision and means. Of these three, the most difficult is the second, requiring the deployment of a water governance architecture that utilises various allocation devices, involves and recognises many stakeholders, accommodates issues of scale and timing and is underpinned by an appropriate legal and institutional framework. With regard to the latter; the gaps, overlaps and contradictions occurring between formal and informal legal agreements that fit within that architecture pose particular problems. Arguably, this is the key challenge for integrated water resources management in Tanzania (Sokile, 2003), and how this challenge might be met is the subject of this paper.

Although theoreticians may articulate ideal legal and institutional frameworks, in reality such frameworks commonly suffer from incongruities that exist between institutional functions, practices, objectives and biogeographic properties (Moss, 2004). Water frameworks have to help achieve river basin objectives, work within the limitations imposed by inherent conditions, fit other economic and infrastructural devices, and often build on existing progress made. The scope for re-thinking a wholly new institutional matrix may be severely restricted. In this regard, this paper's contribution builds on existing legislation in Tanzania. Furthermore, systemic challenges also exist: for example, research may point to the benefits that local user agreements can play at the local level, but how do we ensure that local user agreements collectively result in large-scale and bulk-water re-distribution, and how should local agreements that may operate well at the irrigation level be applied to the catchment level? If informal arrangements are not carefully dovetailed into higher-level formalities and other allocation devices, new legislative and institutional frameworks will probably only partially succeed.

The paper explores a framework that aims to fit together legal, institutional and infrastructural water management provisions, recognizing the synergy between different components of water management, building on present-day policy directions and acknowledging contextual properties and processes (Velasco, 2001). The framework emphasizes the division of water management into wet and dry seasons, arguing that formal water rights have a role in the wet season, and that customary or local water agreements relate better to conditions found in the dry season (though clearly a variety of on-going discussions and consultations are required throughout the year – this is not to propose a mutually exclusive division). The two key assumptions here are that formal rights relate to access to water quantities measured by a flow rate (e.g. litres/second) and that customary agreements relate to access to water quantities described by an approximate share of the available water (e.g. "about half of what is present in the stream"). The assumptions are valid because formal rights are denominated in volumetric terms while customary agreements in their original form (an important distinction since customary rights can be transmuted during formalization procedures into volumetric measures) are founded on a notion of access to an (unmeasured) quantity of water, combined with the notion that not all the water can be abstracted from a stream or irrigation channel (Gillingham, 1999; SMUWC 2000). Therefore customary agreements, for the purposes of this paper, pertain to negotiations over water *shares* that theoretically range from 0% (no water is abstracted) to 100% (all the water is abstracted) of the available water, with the observation that streamflows are divided by trial using proportionally-based intakes rather than by measuring flow using gauges, weirs and adjustable gates.

The framework explicitly designs other dimensions around the wet/dry season separation to assist rather than undermine these legal pluralisms and water re-allocation objectives. This fits the call by Maganga et al (2003) for an approach that "combines elements of RBM and customary arrangements at the local level". The framework is not a classification framework such as proposed by Meinzen-Dick and Bakker (2001) who examined rights associated with different water purposes. The proposed arrangement here concerns mainly agricultural productive use of surface water that also meets domestic purposes in villages within the command area. It should be emphasized that the paper (which utilises research from two projects - SMUWC[1] and RIPARWIN[2] - that have studied river basin management in the Great Ruaha River, part of the larger Rufiji Basin) is exploratory in nature, and does not represent policy advice at this stage. The paper also briefly discusses some concerns related to the sustainability and workability of the new arrangement.

River basin management initiatives in Tanzania

The Rufiji and the Pangani are two basins that have been supported by the Ministry of Water and Livestock Development (MOWLD) and a World Bank Project (RBMSIIP) to manage water at the river basin scale via the establishment of river basin offices (RBO's). Although detail on these projects is available elsewhere (Maganga, 2003; World Bank, 1996), two[3] key activities of the Basin Offices are described here.

Formal water rights

Water for irrigation is managed via the issuance of formal water rights ('permits') to water users against the payment of an annual fee that are expressed in quantitative flow units (e.g. cumecs) (Mwaka, 1999). Associated with this is the registering of users and establishment of water user associations as legal entities. Maganga, (2003) outlines the new thinking in the Water Policy (MOWLD, 2002) that has been part incorporated into the new Water Strategy (MOWLD, 2004) which aims to regulate water use on the basis of statutory legal systems. Therefore, formal water rights are the key means for achieving redistribution in Tanzania (World Bank, 1996). However, as Maganga points out, law-making to date has not recognised the role that customary agreements play at the local level, though space for customary agreements is given in the new putative legislation and therefore a future activity will be to incorporate customary arrangements in ways that fit the rubric of the new legislation.

Recent research (Lankford et al., 2004; van Koppen et al., 2004) supports the view that customary rights have not been fully recognised, and in addition, shows that the formal statutory rights may be structurally flawed in three ways; firstly payment for water is not related to volume used, and so they may not dampen demand, as they are supposed to do, but instead help increase demand. This lack of fit relates to discrepancies between the water permit abstraction rate and the designed intake abstraction rate as is explained below. Secondly, they mainly address water availabilities found in the wet season rather than the dry season when important re-distribution objectives are equally, if not more, critical. According to the RBWO, there is a nominal 50% reduction in the water right during the dry season, but this too is not against measurement, and does not relate to the real proportional decreases found in river flows which are closer to 10% of the wet season flows. Thirdly, they demand high levels of supervision that are not commensurate with resources available to the basin authorities.

Discussions with the Ministry of Water and Livestock Development seem to indicate that there is no plan to change the policy on the use of statutory rights, and that water permits will continue to be issued. That said, the RBWO has recently been requested by its Board to review the current status of permits already issued with a view to bringing them into line with water availability. An appropriate accommodation of customary agreements might be highly beneficial as research (Gillingham, 1999; SMUWC, 2000) shows that in parts of the Great Ruaha Basin, local users negotiate and share river flows at the irrigation system level and sub-catchment scale.

Irrigation improvement programmes

Where identified, smallholder irrigation systems have had their intakes upgraded from traditional construction (e.g. stones and mud) to that of a concrete and steel gate design. Theoretically this allows some improvement over control and the possibility that water flows can be measured – and has long been thought to raise irrigation efficiency (Hazelwood and Livingstone, 1978). However, in many cases, these structures enable dry season flows to be completely abstracted without allowing the passage of any downstream compensation flows, are unable to affect internal water management and efficiency, and in all cases water measurement is missing (Gowing and Tarimo, 1994; Lankford, 2004a). Upgrading of intakes and improvement of water control at the intake are commendable objectives – however it is the end purpose that should be re-thought. As this paper argues, there is a case for designing improved intakes so that they work in harmony within a catchment rather than solely for the irrigation system in question (Lankford, 2004b).

Case study description

The Great Ruaha River Basin is found in Southern Tanzania. Previous articles, to which the reader is referred, describe in detail the geography of the area (Baur et al., 2000; Franks et al., 2004). Some of the conditions relevant for this analysis of river basin initiatives (described in the next section) are as follows:

- The size of the sub-basin (68,000 km^2) poses logistical problems for managing water by formal rights alone that require monitoring and policing. To reduce these costs and to manage conflicts at the sub-catchment scale requires robust forms of subsidiarity.
- The basin experiences a single rainy season (of about 600-1000 mm average depending on climate and altitude). Rivers swell during this period, but shrink dramatically during the dry season between May and November, a period that suffers from water stress and conflict. This considerable dissimilarity in water availability and associated dynamics suggest that the wet and dry seasons need different forms of management, and that in particular the dry season necessitates special care.
- The area lacks an aquifer or any large-scale storage that can support irrigation (although the downstream hydro-power has storage). Irrigation has to rely on run-of-river supplies, and this points to the need to manage surface water resources carefully without the benefit of storage buffering.
- There is competition between the sectors of rice irrigation, a RAMSAR wetland, the Ruaha National Park, and hydropower in both wet and dry seasons, although this is not on the scale of the competition envisaged under the RBMSIIP programme (Machibya, 2003). In addition the policy for the river, 'restoring the all year-round flows of the Great Ruaha River'[4], presents a specific goal by which river basin management can be tested. During a normal year, competition is mainly found during the dry season but is impacted upon by wet season abstractions that make it more difficult to throttle demand during the dry season. This, combined with the changeable climate that brings shortages during the wet season, means that water management is required throughout the year. Furthermore, the authors argue that purposive decisions over inter-sector allocation should replace the *ad hoc* unplanned change in distribution that has arisen within the last 30 years and may continue in the future.

The challenges ahead

Reviewing the discussion above, we see that there are a number of concerns for water management in the basin:

- To build on the water rights currently provided so that they help achieve river basin objectives.
- Another aim would be to improve the system that caters for both the wet and dry seasons, and that manages the switch in water availability and demand between the two seasons.
- A further objective would be to draw up an arrangement that incorporates without conflict both formal and customary agreements.
- In addition, it is necessary to draw together the water permits with the infrastructural works so that these match, and together fit the hydrology of the catchments in question.
- That the National Water Policy is implemented effectively especially with regards to its institutional framework.

The paper aims to answer these concerns and the call by Moss (2004) for "creating better fit" (p 87) between institutions and other components, and is a contribution to the request in the Water Policy Paper (MOWLD, 2002; 28-29) "Thus the legislation needs to be reviewed in order to address the growing water management challenges". It should be emphasized that the paper does not seek to select and set a distribution of water scarcity but to show a means of how available water might be shared between sectors. In addition, the framework described here is relevant in other closing and closed river basins such as the Pangani in Northern Tanzania.

Inter and intra sectoral water allocation - definitions and theory

Because irrigation is the major upstream water abstractor in the basin, it is the main determinant explaining the share of water within this sector, and between this sector and downstream sectors. Simply put, water for downstream users is the remainder after irrigation abstraction has occurred (following the observation that return flows of drainage water are a minor proportion of abstracted flow or are accounted for). This relationship is captured in Figure 1 and is explained here. The abstraction flow-rate to feed a single irrigation system is a function of four factors (see Equation 1); the design of the intake capacity; the number of irrigation intakes feeding that system; any operation of these intakes that adjusts their discharge; and the flow of water in the river which affects the head of water at the intake. Intake design incorporates a stage discharge relationship between intake flow, orifice size and head of water at the weir so that for most intakes, without adjustment, intake flow increases as the river flow increases. As has been shown by Lankford (2004b), the intake rate is a function of supply rather than of responding to changes in irrigated area or of crop water demand, except when intakes are throttled to safeguard fields from extreme and rare damaging floods.

Equation 1: Q (single irrigation system) = f [intake design, intake number, intake operation, supply in river]

By simple mathematical balance, the flow for downstream irrigators is the remainder of the river flow once upstream intake abstraction has occurred (see Equation 2 and Figures 1 and 2).

Equation 2: Q (downstream irrigator intake) = (Q river supply – Q upstream intake)

The flow of water being abstracted into the irrigation sector (a summation of all intakes within a catchment) is a result of the river supply and the total intake capacity combined with any cumulative effect of operational decisions (Equation 3):

Equation 3: Q (total irrigation) = f [all intakes design, number of intakes, cumulative operation, river supply]

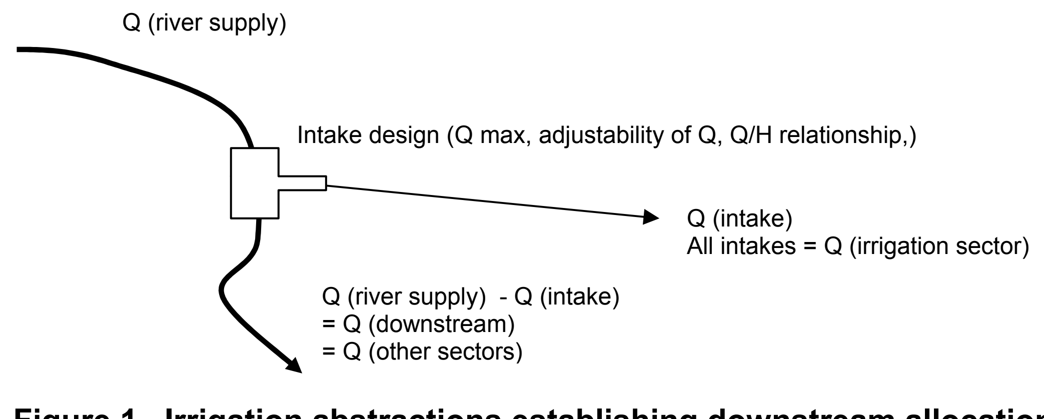

Figure 1. Irrigation abstractions establishing downstream allocation

Source: Authors

When applied to 'between sector' computations (Equation 4); it is the cumulative irrigation abstraction within a catchment that determines the water available for downstream sectors.

Equation 4: Q (other sectors) = (Q river supply – Q total irrigation intake)

Over one year, abstraction fluctuates as a result of the four factors, creating an abstraction pattern or hydrograph (Figure 2), which follows the river supply hydrograph with greatest abstraction during the wet season and lower abstraction in the dry season. Plus, a hydrograph can also be generated for a large river from individual hydrographs arising from management practices on tributaries converging into a single river. Via mathematical continuity, the pattern of intersectoral allocation will also be a function of the irrigation abstraction pattern. (Figure 2 is further explained in the discussion below on volumetric and proportional caps). It follows we can determine a simple indicator of river basin management; the 'irrigation allocation ratio' (IAR) of irrigation abstraction to total supply (Eq. 5), a measure of the equity of distribution between irrigation and other sectors. A figure of about 50% indicates that water is evenly divided between irrigation and other sectors, while an IAR of 90% tells of a highly skewed supply to irrigation.

Equation 5: Irrigation allocation ratio, IAR = (irrigation abstraction) / (upstream supply flow)

Volumetric and proportional caps

To manage the irrigation abstraction ratio in Equation 5 requires an understanding of intake design and operation. Figure 2 and the 2 x 4 matrix in Table 1 summarize the strategic tasks of setting two types of 'ratios' (other terms used in the paper are 'thresholds' or 'caps') that affect the irrigation allocation ratio (IAR). These two thresholds relate closely to the properties of intake structures and to the season, and it is important to note that this model is supply rather than demand driven because of the points argued in equations 1 to 5. The first threshold (left-hand column) termed here the volumetric cap is determined by the maximum volumetric capacity of the intake, or 'Q max'. This cap, it is argued, applies during the main part of the wet season when river flows are larger. Figure 2 shows this as a *fixed plateau* on each intake hydrograph where the maximum intake capacity stops more water from being abstracted. Note that the height of the cap plateau is only set from the zero on the Y axis for the first intake, but for the others, the level is set by counting up from the previous intake plateau.

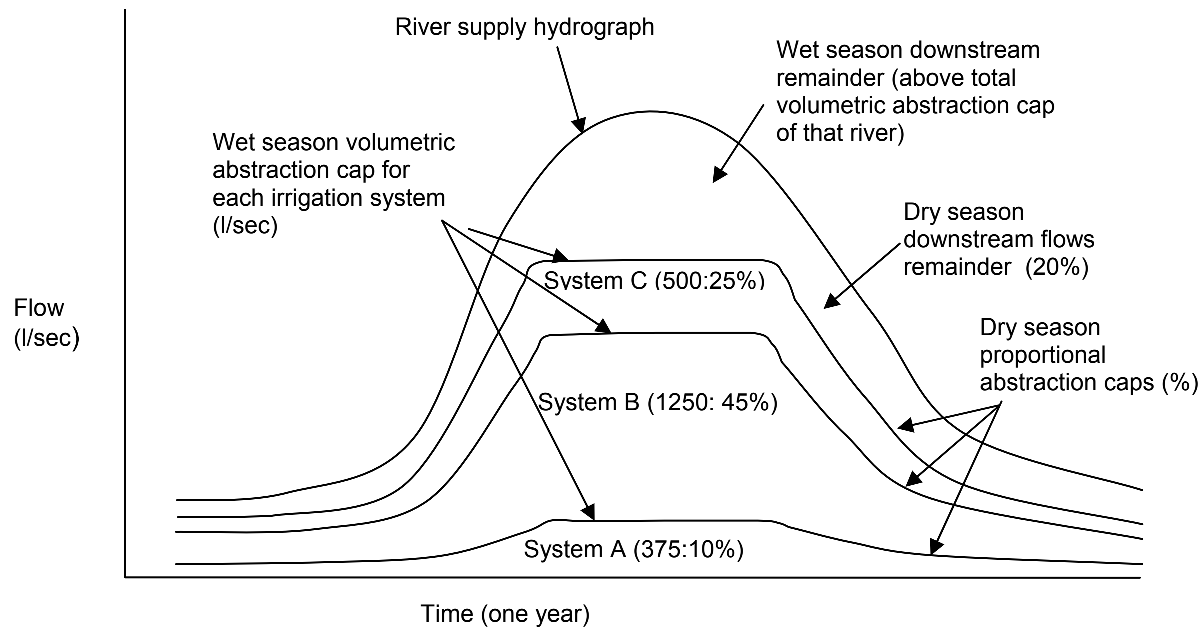

Figure 2. Supply, abstraction and allocation hydrographs

Source: Authors. (Numbers refer to worked example)

The second threshold (right hand column in Table 1) is the proportional cap. This cap, or ratio, sets the proportion of supply that is abstracted when river supply is less than maximum intake capacity. This applies to those periods of the hydrograph when the river flow is low (i.e. the beginning and ends of the wet season and during the dry season). Figure 2 shows this as a *proportional* change in abstraction as the supply hydrograph increases and decreases.

Referring to Table 1, there are two main ways of managing the IAR in both wet and dry seasons. The first is to build in *manageability* so that the design of the intakes assists in arriving at these distribution targets and relate well to institutional decisions and reforms. The second is to rely on *management* to persuade water users to frequently regulate any infrastructure so that these adjustments generate the intended outcomes. Regulation involves adjusting and closing intakes so that downstream flows are altered, or scheduled against time windows (i.e. one day for this intake, one day for the next intake and one day for the environment, etc). Either way, the aim is to ensure that over a given period of time each intake (or user or sector) receives a given portion of the available water providing the remainder for downstream sectors. The authors argue in this paper that the former approach – building in manageability – is the more appropriate as this assists users in negotiating over water.

Table 1. Proposed relationships between caps, design, operation and formal water rights

	Volumetric ratio or cap	Proportional ratio or cap
Season	Wet season	Dry season
Design	The design of the maximum capacity of the intake is a critical step, and will generally establish the maximum volumetric cap.	Maximum capacity is often above dry season river flows so operation is needed to affect the division of water between irrigation and other sectors during this period (See row below). Design can be used to implement proportional divisions (using fixed proportional gates).
Operation	It is unlikely that operation alone will reduce the maximum water abstracted, and thus the design of the maximum abstraction is very important (see row above).	Further adjustment of the intakes may be necessary to reflect on-going negotiations, but if fixed proportional dividers are well designed this need not be a regular or onerous activity.
Legal	Theoretically, the design fits the water permit or users adjust their intake to fit the water permit. (Note: The water rights as currently provided by GoT are volumetric in nature and pertain to high flows during the wet season).	The water rights as currently provided do not encourage users to adjust their water abstraction in a proportional manner.

Design affects the 'Q max' and adjustability of the intake discharge. 'Q max', the maximum discharge when orifices are fully open and head-adjusting structures are set to maximum, is an important design parameter because users tend to default to this setting – meaning gates are normally opened to their maximum. This is the reason why when the rivers are in peak flow, intakes tend to take the maximum flow they can, and why in the dry season intakes tend to abstract all the available water. (As well as being more likely to be washed away, according to custom, traditional intakes could not be built to block the whole river; Gillingham, 1999). 'Adjustability' is designed by considering how the orifice can be set at partial settings and how any head-controlling structure such as a weir can be adjusted. The actual operation of this gate is then the adjustment of the intake flow either by closing and opening the orifice gate, or by increasing or decreasing the height of any weir structure. It is this adjustability that also explains why in the wet season farmers will throttle down their intake when very high floods threaten their systems, and why in the dry season, negotiations between upstream and downstream farmers can be physically transformed into gate adjustments that release water downstream.

Although design and operation of the design is the *de facto* determinant of abstraction, adjustments could be influenced by the volumetric water rights specified to irrigators. This is expressed in the last row of Table 1. The theory is that the water permit/right either directly relates to the maximum capacity of the intake or the intake can be very easily adjusted to meet the right. In Usangu however, water rights do not relate closely to design capacity, and water-measuring facilities are rare. Therefore, the water rights, as currently conceived do not correlate to the design or to the operation of that design. Thus, at the moment, it is the intake design rather than water rights that establish abstraction patterns during the wet and dry seasons.

Water allocation management – readjusting the caps

Building on the previous section, we now discuss how to manage water allocation by using and modifying the volumetric and proportional caps. To discuss these changes requires us to unpack existing and future 'modified' objectives for both the wet and dry seasons, creating four cases to consider (Table 2 and Figures 3 to 6).

Table 2. Moving from existing to future visions of water distribution

	WET Climate season	DRY
Existing OR modified intra- & inter- sector distribution	Case 1. Wet season, existing intra/inter sector distribution of water. (Volumetric cap)	Case 3. Dry season, existing intra/inter sector distribution of water. (Proportional cap)
	Case 2. Wet season, future modified intra/inter sector water distribution. (Volumetric cap)	Case 4. Dry season, future modified intra /inter sector water distribution. (Proportional cap)

Case 1. Wet season, existing intra- and inter-sector distribution of water

Case 1 explains the existing distribution of water in the wet season. For intra-irrigation distribution, the division of water between intakes changes as the flow capacity is exceeded upstream by ever increasing flows. Once the wet season is in full flow, each intake accepts its own maximum intake flow, so that unless adjusted, the between-intake distribution is function of intake design. With respect to inter-sector allocation, when supply exceeds abstractive capacity, downstream supply is the remainder of the flow below the last intake and is therefore a function of the total river supply minus the total abstractive capacity (see Figure 3). For example in the year 2000, SMUWC found that about 45-50 cumecs was the maximum capacity. Once this was exceeded, then water would flow to the Usangu wetland and then on to the Ruaha National Park and the hydropower stations.

Case 2. Wet season, modified intra- and inter-sector distribution of water

To adjust or modify the intra-sector distribution of water, the abstraction capacities of individual intakes need to be revised. As Figure 4 shows, to alter intersectoral reallocation, the maximum total intake capacity needs to be revised downwards to 'force' excess water downstream to other sectors. This means bringing in a new volumetric cap. For Usangu, this might be determined on the basis of observations and modeling, and for example might be set at 50 cumecs, which although may be above the level of year 2000, it is below the potential level of 60 cumecs that might occur in the years 2005-2007.

Case 3. Dry season, existing intra- and inter-sector distribution of water

Case 3 explains existing patterns of water distribution in the dry season. In the Great Ruaha Basin, the upgrading of intakes has resulted in some taking all of the dry season flow because further adjustment is relatively rare. Thus, the intra-irrigation sector distribution is highly skewed to the improved intakes found in upstream locations. For intersectoral division of water, if supply is less than demand, then downstream supply is a function of the share between upstream irrigation and downstream users. From observations (SMUWC, 2000), we see that currently (in the dry season) the proportional cap is about 90 to 100% - in other words until the abstraction capacity was exceeded by flood water, nearly all the water was taken by irrigation in those catchments with irrigation. As Figure 5 shows, this means minimal or zero flow for downstream sectors.

Case 4. Dry season, modified intra- and inter-sector distribution of water

To alter water distribution during the dry season requires the partial closure or redesign (or both) of intakes so that less water is abstracted (Figure 6). A mixture of both modeling and local user agreements would feed into the process of negotiating the proportional cap, which if reduced brings compensation waters for other sectors. In Usangu, discussions on a modified proportional division between irrigation and downstream sectors are underway in some sub-catchments, which range from approximately 35-90%.

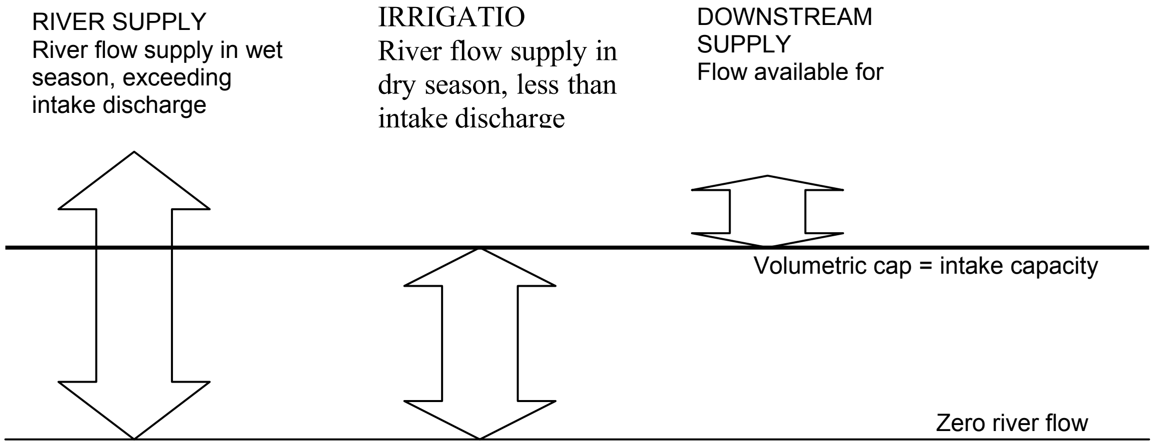

Figure 3. Wet season. Current volumetric cap

Source: Authors

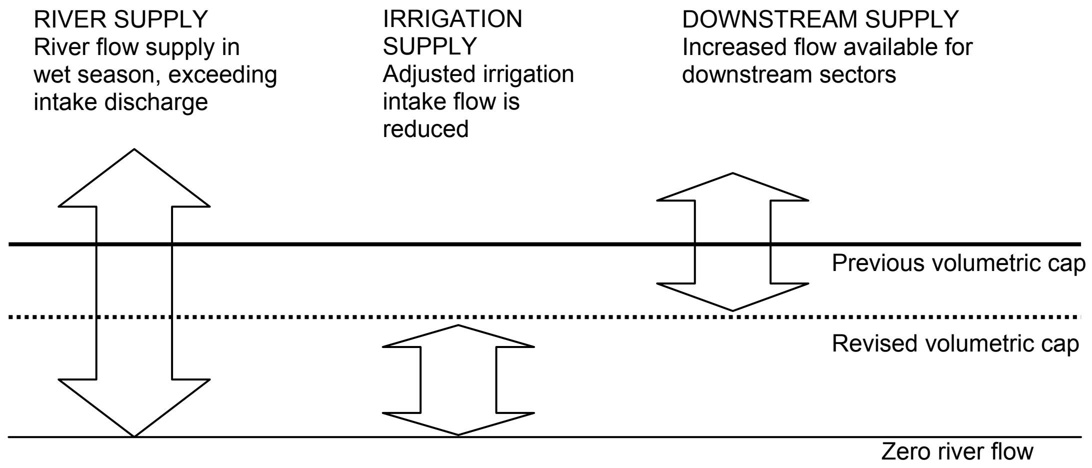

Figure 4. Wet season. Revised volumetric cap

Source: Authors

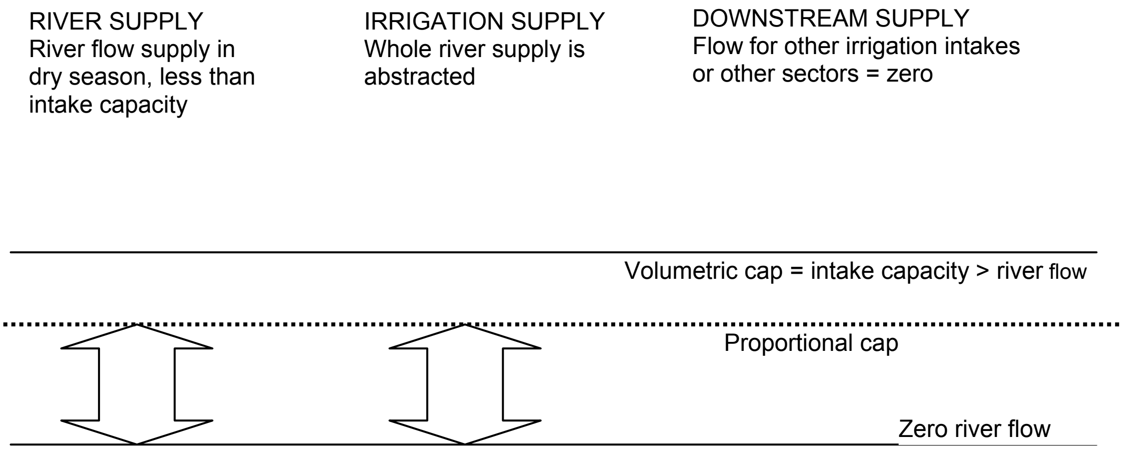

Figure 5. Dry season: High proportional cap

Source: Authors

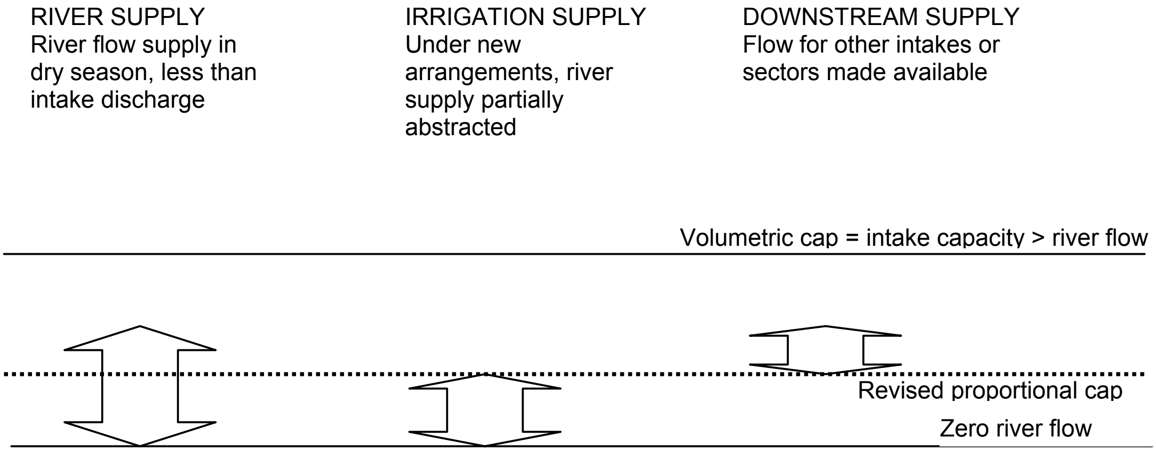

Figure 6. Dry season: Revised proportional cap

Source: Authors

Worked example

A worked example enables us to see how the volumetric and proportional caps work. This is explained in Table 3 and Figures 2 and 7. Three intakes feeding irrigation systems A, B and C are located in a single sub-catchment. The current design allows a maximum of 500, 2500 and 800 l/sec respectively, giving a total sectoral abstraction of 3800 l/sec (see Case 1 in Table 3). During the dry season when this flow is not exceeded (Case 3), then the share between A, B and C is 15%, 50% and 30%, providing 5% for downstream sectors. Under the modified arrangement, the volumetric caps are reduced (Case 2), giving 375, 1250 and 500 l/sec respectively (giving a total sub-catchment permit of 2125 l/sec) and when water does not exceed this volume, the share between A, B and C is 10%, 45% and 25%, providing 20% for downstream (Case 4).

The results of the shift in shares can be seen in Table 4. For example in the first three 10 day periods of September, part of the dry season in this part of Tanzania, the downstream flow has increased from about 8 to 13 l/sec up to 30 l/sec to 50 l/sec. In the middle of the flood season, say February, the remainder flow has increased from 5200-6200 l/sec to 6800 to 7800 l/sec. In annual volumetric terms, the amount of water diverted for irrigation has decreased by 29352 MCM (million cubic metres) from 75062 MCM to 45710 MCM, a drop of 39%. The same amount of water going downstream of 29352 MCM represents a 56% increase on the pre-modified situation. Calculation of the irrigation allocation ratio (IAR) indicators shows that the revised caps decreased irrigation impact on the hydrology of the catchment from 56% to 36%.

Table 3. Existing and modified settings for volumetric and proportional caps (worked example)

	Volumetric Cap Units (cumecs)		**Proportional Cap (Percentages)**	
Case	1 (Wet season, existing)	2 (Wet season, modified)	3 (Dry season, existing)	4 (Dry season modfied)
Irrigation system A cap	0.50	0.375	15%	10%
Irrigation system B cap	2.5	1.25	50%	45%
Irrigation system C cap	0.8	0.5	30%	25%
Volumetric (cumecs) and proportional cap (%) for irrigation	3.8	2.125	95%	80%
Remainder for downstream	Remainder	Remainder	5%	20%

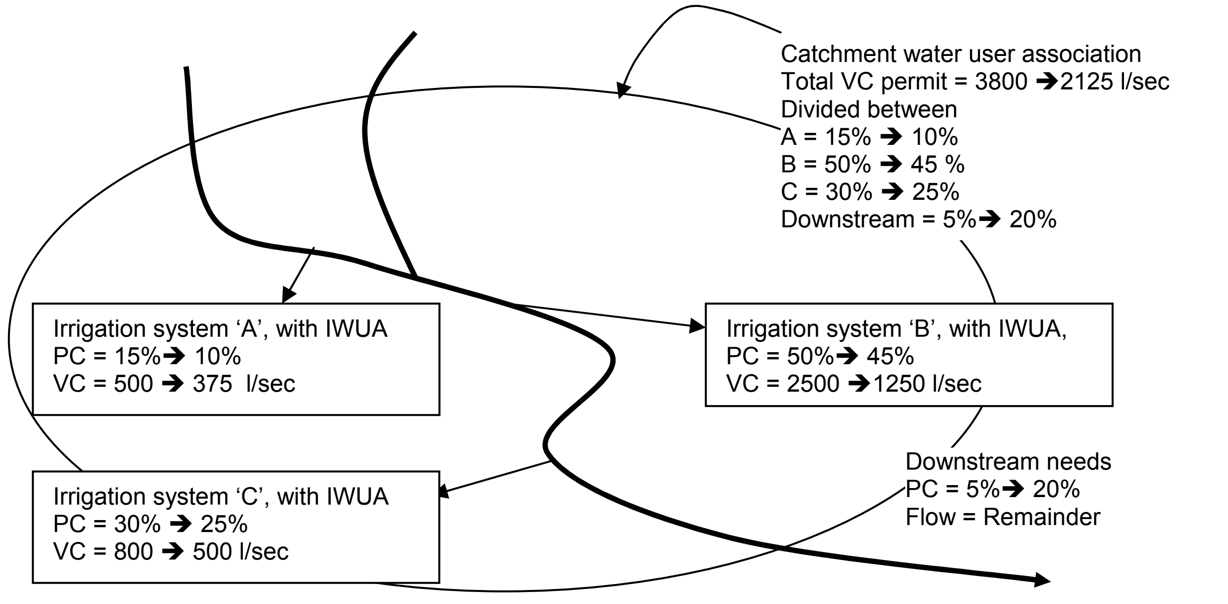

Figure 7. Volumetric and proportional caps applied to irrigation systems

Source: Authors

It is interesting that the downstream share benefited greatly from only slight reductions in each irrigation system's abstraction. This was particularly noted in the dry season, and is a result not only of the relative starting points of each sector, but the fact that three intakes were involved in releasing water. In effect, each only needs to give a 5-10% compensation to result in 15% to 30% extra water flowing downstream.

Table 4. Simulation of revising caps for modelled catchment (units = l/sec)

Dekad	River supply	Existing distribution pattern				Modified distribution pattern			
		Irrig. A	Irrig. B	Irrig. C	Remainder	Irrig. A	Irrig. B	Irrig. C	Remainder
Sep 1	150	23	75	45	8	15	68	38	30
Sep 2	200	30	100	60	10	20	90	50	40
Sep 3	250	38	125	75	13	25	113	63	50
Oct 1	300	45	150	90	15	30	135	75	60
Oct 2	400	60	200	120	20	40	180	100	80
Oct 3	500	75	250	150	25	50	225	125	100
Nov 1	700	105	350	210	35	70	315	175	140
Nov2	900	135	450	270	45	90	405	225	180
Nov 3	1500	225	750	450	75	150	675	375	300
Dec 1	1900	285	950	570	95	190	855	475	380
Dec 2	2600	390	1300	780	130	375	1250	500	475
Dec 3	3900	500	2500	800	100	375	1250	500	1775
Jan 1	5600	500	2500	800	1800	375	1250	500	3475
Jan 2	7800	500	2500	800	4000	375	1250	500	5675
Jan 3	8000	500	2500	800	4200	375	1250	500	5875
Feb 1	9000	500	2500	800	5200	375	1250	500	6875
Feb 2	10000	500	2500	800	6200	375	1250	500	7875
Feb 3	10000	500	2500	800	6200	375	1250	500	7875
Mar 1	9000	500	2500	800	5200	375	1250	500	6875

Dekad	River supply	Existing distribution pattern				Modified distribution pattern			
		Irrig. A	Irrig. B	Irrig. C	Remainder	Irrig. A	Irrig. B	Irrig. C	Remainder
Mar 2	8500	500	2500	800	4700	375	1250	500	6375
Mar 3	8200	500	2500	800	4400	375	1250	500	6075
Apr 1	8000	500	2500	800	4200	375	1250	500	5875
Apr 2	7500	500	2500	800	3700	375	1250	500	5375
Apr 3	7000	500	2500	800	3200	375	1250	500	4875
May 1	6500	500	2500	800	2700	375	1250	500	4375
May 2	6000	500	2500	800	2200	375	1250	500	3875
May 3	5000	500	2500	800	1200	375	1250	500	2875
Jun 1	4500	500	2500	800	700	375	1250	500	2375
Jun 2	4000	500	2500	800	200	375	1250	500	1875
Jun 3	3500	525	1750	1050	175	375	1250	500	1375
Jul 1	3000	450	1500	900	150	375	1250	500	875
Jul 2	2000	300	1000	600	100	200	900	500	400
Jul 3	1000	150	500	300	50	100	450	250	200
Aug 1	200	30	100	60	10	20	90	50	40
Aug 2	200	30	100	60	10	20	90	50	40
Aug 3	150	23	75	45	8	15	68	38	30
MCM	127829	10297	47282	17483	52767	7698	26704	11308	82119
MCM = Million cubic metres		Irrigation total MCM = 75062			52767	Irrigation total MCM = 45710			82119
		IAR = 75062/127829 = 59%				IAR = 75062/127829 = 36%			

Synthesis: a framework of water legislation and management

We can now explore, via a framework, some synergies between the different water management, design and legislative dimensions. This framework, which expands Table 1, is presented in Table 5. Each column represents either the wet or dry season. For each season a 'water management structure' is proposed. This several-layered structure coheres the type of water threshold decision to be made (volumetric or proportional), the design of the maximum capacity, the adjustability of intakes, the type of property right (formal or informal), the level of stakeholder decision-making (river or irrigation user association) and the nature of water payment made.

Following Table 5, in the wet season, to distribute water between irrigation and downstream sectors requires first a maximum cap on abstraction. This cap is physically designed in by constructing the maximum apertures of the intakes so that no more water than this cap can be abstracted. This cap is underpinned by the formal water rights sold by the Government (requiring the current system of volumetric water rights to be improved so that this cap is set accurately and legally). In turn the legal permit relates to either individual water user associations that represent irrigation systems, or to the catchment water user association (CWUA) that represents the irrigation sector within that catchment. If the latter occurs, then the CWUA can divide up the permit to its various constituent intakes volumetrically. Either way the individual intake and total intake capacity must be expressly related to the maximum permits and managed both at the individual and catchment level. Water basin officers would then be interacting with representatives of both individual intakes and the whole catchment to iteratively ensure coherence between these dimensions.

Table 5. Framework of seasons, caps, intake design, rights and WUA's

Water governance structure	Wet season	Dry season
Type of cap	Total volumetric abstraction cap	Proportional abstraction cap
Part of intake design most closely associated with this	Maximum aperture Q max Focus = [litres/second]	Either design allows adjustability of gated intake flows or allows passive proportional abstraction of available river flow Focus = [% of division]
Part of intake operation most closely associated with this	Advised to rely on Q max rather than on throttling. Gate is opened to maximum setting	Adjustments of intakes or scheduling of water is advised.
Type of rights most closely associated with this season	Formal water permit (volumetric)	Customary agreements and rights (proportional, or time schedule basis)
Role of catchment water user association (CWUA)	Water permit to CWUA and division of permit to irrigation WUA representatives	Division of river supply agreed between users or irrigation WUA's.
Institutional connections	Basin Office to facilitate and mediate catchment water user association negotiations	Intake to Intake representatives of irrigation water user associations plus RBWO mediation
Payment structure	Fixed payment for water right	No payment for proportional share

In the dry season, on the right hand side of Table 5, new arrangements begin to operate because the designed-in maximum capacity for abstraction is now above the river supply; thus the small river supply needs sharing out between irrigators, and between irrigation and downstream sectors. This requires a maximum threshold on the share provided to irrigation. This allocation is more likely to be implemented by the regulation (partial throttling) of gated adjustable intakes but could also be 'designed in' by using proportional weir type structures (e.g. castellated weirs – see Lankford 2001). Since the 'rights' to these dry season flows are below the flow rates set by the formal rights, the dry season shares (or 'rights') have to be negotiated informally between all users in and below the catchment and then backed up by a mixture of intake design and adjustment. These latter rights would have to be articulated not in the form of flow rates (l/sec) but proportions of the water, for example 'an intake would receive 20% of the river flow water'.

The role of the river basin officer would change in the dry season when the formal permits were no longer 'active'. Greater emphasis would be placed on conflict resolution services to assist the WUA's in sharing more equitably the available water, altering the proportions of water according to changing circumstances, or encouraging stakeholders to permit more water to remain as in-stream environmental and domestic flows.

With regards to payments for water, in the current legislation, payments are for the water right/permit pegged to the allocated amount rather than the actual measured amount. This same arrangement could be applied to this framework, which therefore does not at least in the initial stages envisage a volumetric basis to determine a water charge, although this would be a future goal that various stakeholders might wish to explore. The agreements over the dry season shares do not involve financial transactions, instead being derived via discussions held within the catchment users' organization, mediated by the basin authority.

Details…

Although theoretically the framework resolves the contradictions of how formal and informal rights can operate together by splitting them into different seasons, in reality this will present some problems. It is difficult to foresee all of these complications, but four are identified here. These, discussed below, form inter-related concerns that would collectively influence the success or failure of the framework.

Setting thresholds

Setting the caps will inevitably create winners and losers as shares increase for some and drop for others. The process by which the caps are set will benefit from being participative, and informed by good quality hydrology and observations of current patterns of water use. Incremental adjustments might be advisable during different parts of the river hydrograph; indeed for the very lowest and driest part of the year, local users might agree that all water should be kept in the river with only domestic (rather than productive) quantities being tapped.

Sharp-eyed readers will have noticed that by definition the wet season begins once the total abstraction capacity of all intakes on the sub-catchment has been exceeded by river flows, and that a dry season is that time period when the river is less than this threshold. Also, the dry season is, by definition, the period when the river flow no longer exceeds intake capacity, and that negotiated customary agreements need to interject. This can be realised by setting conditions with the permits that recognize these negotiations. These definitions do not follow other ways of naming the two seasons (start of rains, or based on long-term records, or related to other farming activities). It follows that the higher the abstraction capacity the shorter the wet season until the point where total abstraction might grow to exceed all but the highest peak flows in which case throttling and adjustment is necessary nearly all the time. Clearly, the thresholds and resulting design modifications have to be set so that expectations of irrigators and other sectors match the hydrology and climate of the area.

Transparency and information

The test of the arrangement will be the switch from the wet season to the dry season, a transition period of care and attention. The switch will not happen automatically – though it could be very much assisted by a combination of *appropriate* water measurement and intake infrastructure (see below). It is possible to envisage problems with a river flow that exceeds the capacity of the uppermost intake but that has not yet exceeded the capacity of all the intakes combined. The upper irrigators will probably feel, on observing 'good flows' that it is their right to tap this water with their gate set at maximum, even though this will skew their proportion above that agreed. Key to this transition, and to the management of the arrangement as a whole, will be passive robust water measurement or transparent water division (structures that split water without the need for measurement).

Re-tuning river basin infrastructure

Central to the success of the framework will be a commitment to revising the existing intake infrastructure in each sub-catchment. A re-design programme will have to meet various objectives to promote the *manageability* of river basin management via the framework and could draw on an extensive literature based on irrigation designs (e.g. Yoder, 1994):

1. The maximum abstraction capacity, Q max, will need to be designed in, necessitating the contribution of each intake to that total to be reviewed. This also relates to the question of definitions regarding wet and dry seasons posed above.
2. Each individual intake will have to be designed so that its maximum flow relates iteratively to a number of factors; area of irrigation, crop types, re-negotiated shares (e.g. an agreement to drop one intake by 10% so this can go to another). Simply deriving irrigation intake designs on the basis of crop water requirements may not work in this highly dynamic environment (Lankford, 2004b).
3. The operability and adjustability of the intakes will need to be re-thought so that the intakes can be altered. Alternatively, it should be possible to build in proportional intakes to support proportional rights.
4. Robust and simple water flow measurement may be required so that users are able to compare between each other and to detect incoming flows in order to switch to the 'dry season' sharing agreements.

Allowing flexibility and change

It would be mistaken to impose this arrangement on water users without allowing them to bring their own ideas and suggestions (even rejecting it!). Clearly each sub-catchment has its own properties and dynamics, necessitating a flexible, situational response. In addition, the system should be allowed to change over time responding to shifts in demand, problems arising and possibly changes in supply. It is possible that in the future the volumetric caps (permits) and proportional caps might be traded between intakes and sectors, a facility now recognised in the new water legislation.

Institutional ownership and sustainability

It would be a truism to argue that the arrangement would depend on all stakeholders meaningfully agreeing to the constraints and benefits imposed by it. However, some significant factors that promote institutional sustainability might be:

1. The four concerns above (process of setting thresholds; information needs; the role of design, allowing flexibility) are important.
2. The river basin office would need focus on delivering a variety of services, including conflict resolution, re-setting the caps (and permits) and ensuring follow up modifications to infrastructure.
3. The paper has focused on the question of 'supply management' (though by capping and sharing supplies, not in the usual sense of augmenting supply), rather than on 'demand management' (persuading farmers to be more water efficient so that intake flows can be reduced). Although demand and supply management are often connected 'chicken and egg-wise', the success of any supply reduction would depend on whether productivity of water can be raised, which research in the area suggests it can (Mdemu et al., 2003).

Conclusions

The paper shows how two decisions – setting the maximum volumetric cap and maximum proportional cap – determine the allocation of water in a river basin characterised by an order of abstraction, and the presence of irrigation and wet and dry seasons. These decisions allow us to think of ways how (if irrigation is upstream of wetlands and hydroelectric plants) irrigation abstractions could be managed and modified by design and by operation. Moreover, this think-piece provides possible means to rationalize the interface between formal water rights (that establish and relate to the volumetric cap) and customary agreements (that relate to negotiations over shares of the in-stream water). Thus, with respect to the latter the paper demonstrates how, if strengthened and supported, local customary negotiations combined with water management interventions, might help set and relate to the proportional cap of water abstraction that applies during the dry season. Furthermore, the paper argues that the design of irrigation intakes, in terms of maximum capacity, adjustability and any proportional capability, needs to be re-visited and re-tuned so that the intakes fit and help support any newly modified caps and their associated sharing arrangements.

The formulation here is presented as an exploratory piece, and fully acknowledges that such a framework is not being presented as policy-advice. That said, further discussion on water management in the Great Ruaha is advised – whether that focuses on the ideas presented here, or on other wider issues such as the role of storage, water productivity and so on. In addition, the authors are well aware of some of the problematic aspects of this framework if it were to be operationalized.

These conditions, which invoke this framework as an option, are found in the wider Rufiji Basin, and in parts of the Pangani Basin. The latter also suffers from considerable conflicts that have arisen both due to increasing demand but also to the imposition of a formal water rights structure that has yet to be further refined. Although one option is given here, various possibilities include managing the status quo, an outright return to customary rights, constructing storage or building in volumetric water measurement to charge for water used. Substantively, the paper therefore calls for further discussions on the way ahead, made relevant to the issues found at the sub-catchment scale rather than at the basin scale.

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Acknowledgements

This paper is an output of the RIPARWIN research project (Raising Irrigation Productivity and Releasing Water for Intersectoral Needs), funded by DFID-KAR (R8064) and the International Water Management Institute (South Africa Office). It is co-managed by the Overseas Development Group (ODG, University of East Anglia, UK), the Soil Water Management Research Group (SWMRG, Sokoine University of Agriculture, Tanzania) and the International Water Management Institute. The authors gratefully acknowledge the discussions held and inputs made by N. Hatibu, H. Mahoo, S. Tumbo,, D. Merrey, B. van Koppen, H. Sally, H. Lévite, M. McCartney, D. Yawson, C. Sokile, M. Mdemu, K. Rajabu, R. Kadigi, O. Wahure, J. Kashaigili, J. Cour, M. Magayane and R. Masha. The authors would particularly like to thank reviewers of the paper for their comments.

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Notes

1. SMUWC – Sustainable Management of the Usangu Wetland and its Catchment, a natural resources research and development project funded by DFID in year 1999-2001.
2. RIPARWIN - Raising Irrigation Productivity and Releasing Water for Intersectoral Needs, a research project funded by DFID KAR during 2001 to 2005.
3. A third activity is the monitoring of river flows in selected sites using automatic gauging stations, although some of these are now not functioning. Although this is a vital part of river basin management, such measurements are not related to demand or management of water, and consequently users have no stake in this information being collected and distributed.
4. Up to 1993/94, the Great Ruaha was a perennial river flowing through the Ruaha National Park. Since that date, the river has dried up for between 2-8 weeks each year during the tailend of the dry season. The main explanation for this is continuing abstraction into irrigation intakes for a variety of productive, domestic and non-productive purposes. RIPARWIN and RBWO (and other stakeholders) share a common vision of water distribution, which can be distilled down to the need to return the Ruaha River to year round flow by 2010. This directly relates to the statement by the Prime Minister of Tanzania, Frederick Sumaye, in London, (6th March 2001), made with PM Blair for the Rio+10 Summit; "I am delighted to announce that the Government of Tanzania is committing its support for a programme to ensure that the Great Ruaha River has a year round flow by 2010. The programme4 broadly aims at integrating comprehensive approaches towards resources planning, development and management so that human activity does not endanger the sustenance of the Great Ruaha ecosystems.". Achieving year-round flow would be, from a number of perspectives, a marker of success in achieving integrated water management in the Basin.