Real or imagined water competition? The case of rice irrigation in the Usangu basin and Mtera/Kidatu hydropower, Tanzania

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ABSTRACT

Water management and competition between users in water scarce river basins is a major challenge facing human race. The inter dependence of users in such basins, necessitates a clear understanding of each user in relation to the location, the water demand, and the duration of water need. An understanding of these factors, together, is very important for the management of the basins without which, it is argued that, the competition and conflict between users become increasingly high. As an example of this, the supposed competition between irrigation and hydropower generation is well documented in Tanzania. Yet, well-founded scientific analyses are a necessary part of this understanding, as they can inform us whether sectors are truly in competition or not. Likewise, such studies can allow us to quantify associated tertiary phenomena and factors that lead us to believe that these sectors are in competition when in fact they may not be.

This paper explores a study conducted in the Usangu basin, Tanzania, since the year 1999 to investigate the partitioning of water needs for irrigation, and what implications this has for downstream users particularly hydropower (HEP). The paper discusses the problems relating to arrangement and needs of the water users (irrigators, animals, hydropower stations, and environment) in the Usangu basin and it concludes that the commonly held views a) that irrigation is inefficient; b) that rice irrigation is in direct competition to HEP do not hold up to close scrutiny. This study tell us that wet season flooding is proportionally more important in recharging the reservoirs than visible low flows in the dry season. Looking to the future, this study tells us that inefficiency of irrigation is not a great problem in volumetric terms so much as the increasing area of rice and the total abstractive capacity in Usangu (circa 50 cumecs and rising).

INTRODUCTION

The Usangu basin is located in the west arm of the Rift Valley and it forms a top part of the Rufiji basin in Tanzania. It is formed by many perennial rivers, which originate from the upper catchment. The important rivers that flow into the Usangu basin are the Mbarali, Kimani, Ruaha, Chimala, Mkoji, and the Ndembera. Water in these rivers is abstracted for rice production immediately after the high catchment before they enter into the Usangu wetland (Ihefu). The Usangu wetland has a natural exit at Ng'iriama, which releases water to the Ruaha National park and thereby to the Mtera and Kidatu hydro power stations downstream.

The Usangu basin contributes about 14 to 30% of rice production in Tanzania and thereby supporting the livelihoods of about 30,000 poor households in Usangu (Kadigi et al., 2003, SMUWC, 2001). The area also provides good grazing environment for both livestock and wild animals. The water that flows out from the Usangu wetland is also important for hydropower generation at Mtera and Kidatu stations that, together, contribute to about 40% of power generation to the total national load in the wet season. The contribution increases to about 80% during the dry season (SMUWC, 2001). Therefore, the importance of water from the basin both at regional and national level cannot be overemphasized.

For the last ten years, however, competition between the water uses and users in the basin has increased. In particular the competition is between irrigators, hydro electrical power generation stations (HEPs), livestock keeper and wild animals (National Park). Also local and National concerns were raised over the drying of the Great Ruaha River during dry season since 1994 resulting into zero flow between Ng'iriama and the Ruaha National Park. For the past ten years now, the Great Ruaha River has continuously stopped flowing during dry season between September/October to December each year. The zero flows at Ng'iriama imply no water from the Usangu basin is going through to the Ruaha national park, and to the Mtera /Kidatu hydropower. This lead to many problems and of major concern, at national level, was unknowingly linking power rationing all over the country in the mid 1990s to dry season irrigation of rice in Usangu basin without much proven evidence. The expansion of rice irrigation with low irrigation efficiencies was narrated as the major possible cause among others for the drying of the Great Ruaha River. This argument is of great interest in this paper.

Following this situation, many research programmes were initiated to research on the causes of the problem. On the other hand some of the research works that were instigated to investigate the cause of the problem indicates/proves that, livestock population and expansion of inefficient rice irrigation systems (SMUWC, 2001; Faraji et al, 1992) are partly concerned to the problem. This paper analyses the impact of irrigation in the Usangu plains to the downstream flow of the Great Ruaha River. It also analyses the argument that irrigation systems in Usangu are inefficient and therefore unnecessary utilizing a large share of water.

MATERIALS AND METHODS

Two case studies were conducted during the 1999 - 2001 in the Usangu basin to investigate water use and its impacts in irrigation systems. The first case investigated the impact of irrigation to the total available water in Usangu while the second one analysed in details the use of water abstracted at irrigation system level. The approach of each study were as follows:

(a) Case Study 1: Available water in Usangu and irrigation impact

Data on river flows for eleven sub catchments that form the Usangu basin were collected from the river basin institution and a monitoring system was implemented to determine the amount of water abstracted for irrigation from the rivers in the sub catchments (Figure 1). The irrigated area for each sub-catchment was estimated using furrow survey and aerial photograph interpretation and GIS survey. The details of the approaches in obtaining irrigated areas and water supply and abstractions are as given below:

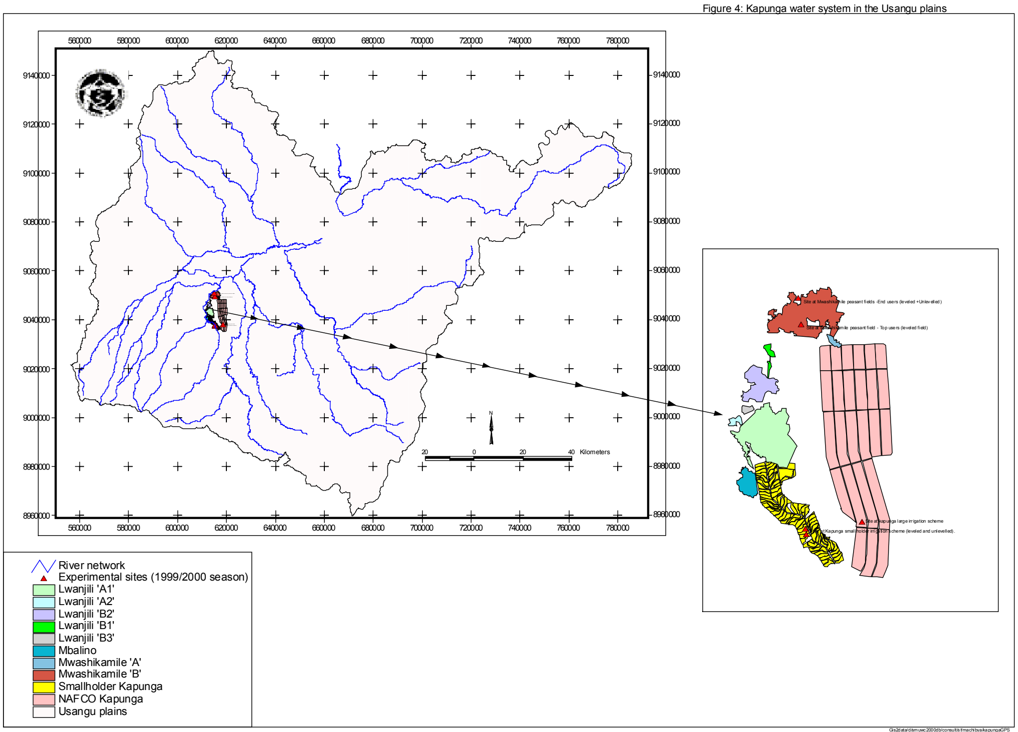

Figure 1. River network of Usangu basin and the case studies

Irrigated areas in Usangu.

Two methods were used to determine the maximum irrigated area for each sub catchment. The methods are the furrow survey (FS) and the aerial photograph interpretation (API) and GIS survey. In the FS method, both questionnaire and physical observation of furrows were used to estimate irrigated area. In addition, the survey gathered information such as how the irrigated area has changed over time and proportion of water abstracted from the source river. On the other hand, the area was estimated using aerial photograph interpretation, which were updated using GIS data when it was necessary.

River flows and abstraction

River flows and canal abstractions measurement programme was set up to monitor key points in all sub-catchments to update the long-term data on river and canal discharges that were obtained from secondary sources. The irrigation impact in percent was determined as the ratio of the abstraction flow for irrigation to source flow (Eqn 1).

$$\text{Impact coefficient, \%} = \frac{\text{Source flows - outflows}}{\text{source flows to river system}} \times 100 \qquad (1)$$

The discharge measurement was conducted once per month for the whole period of study. This survey also accounted for re-use of runoff by downstream irrigators. The Map of the Usangu basin showing the river network, which includes the nine key rivers and sub-catchments, is shown in Figure 1 above.

Impact Model

An irrigation impact model was developed using MS Excel program to analyse water inflow to the Usangu and outflow to the Mtera/Kidatu Complex (MKC) through Ruaha National Park. The model provides layers of details for each sub-catchment. Each layer summarizes the followings: water inflow and outflow, water abstracted for irrigation, canal abstraction capacity, irrigated areas, and the irrigation impact. The summary for all layers is then given in the separate layer. Then the total water inflows and outflows, and the overall irrigation impact in Usangu are derived.

(b) Case Study 2: Efficiency of water use in the Kapunga water system

A sample irrigation system was chosen for detailed investigation of how efficiently the water abstracted for irrigation is used. The Kapunga water system was chosen for this detailed analysis. The Kapunga water system (KWS) is among the irrigation system perceived as the most inefficient systems in Usangu. The system abstracts water from the Ruaha sub-catchment and it consists of three types of farms, which are Kapunga irrigation farm (KIF), Kapunga smallholder scheme (KSS), and Kapunga peri-smallholder system (KPSS). It was noted that the irrigation water in the KWS is reused several times before being returned to the source river. Further, the KWS form two-sub systems of water reuse within the KWS. The first sub system takes water via Kapunga irrigation farm (KIF), whose drain water is reused by the top drain users at Mwashikamile-A (KPSS-top) and further reused at Mwashikamile-B (KPSS-end). This subsystem is referred here as KIF-subsystem. The second subsystem takes water through Kapunga smallholder scheme (KSS) and the drainage being reused at Lwanjili-A (KPSS-top) and a second reuse at Lwanjili-B (KPSS-end). This subsystem is referred as KSS-subsystem. In addition to the study of the water use efficiency of the KWS as a whole, water use efficiency in the two subsystems were studied separately. Figure 2 illustrates the sketch of the two subsystems reusing water in the KWS.

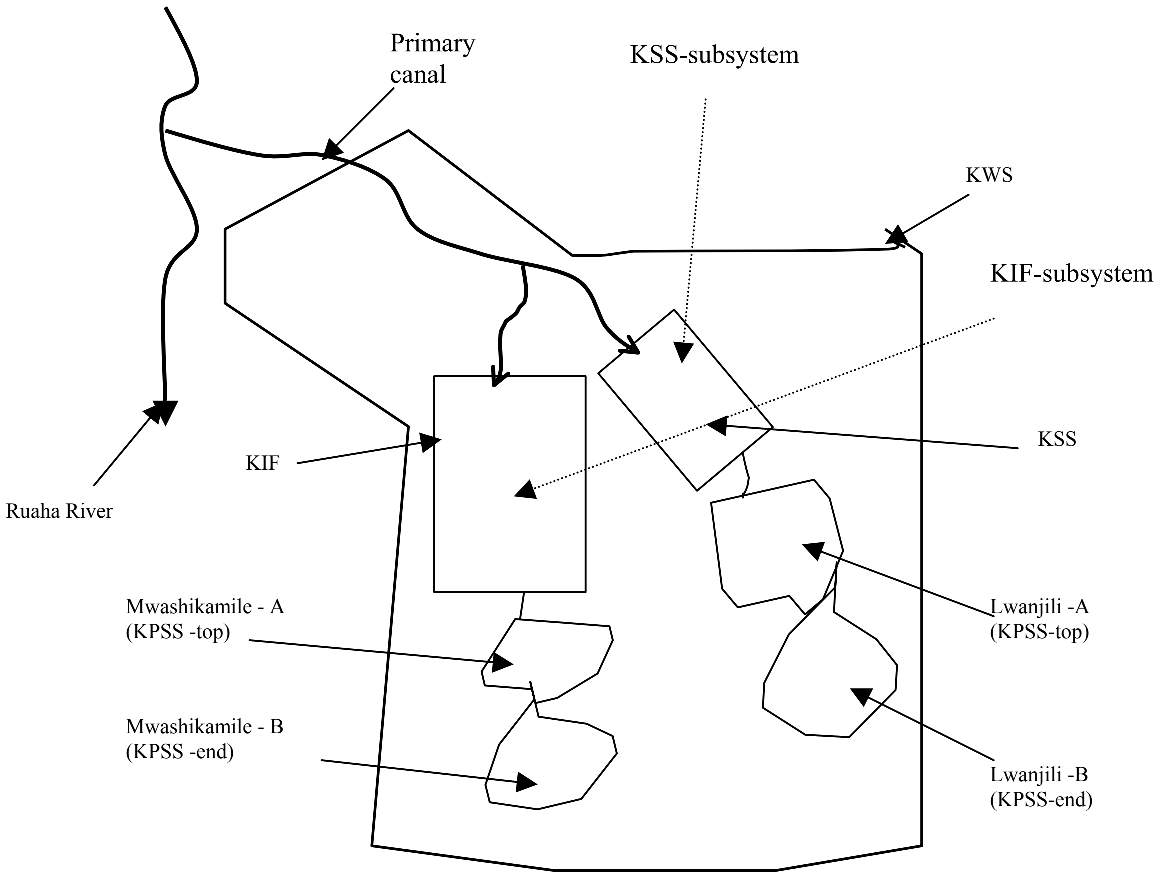

Figure 2: The sketch of the two sub systems of water reuse in the KWS

The water use efficiency of the KWS and its subsystem was investigated by analysis of the system and subsystem hydromodules. System hydromodule (SHM) is defined as a ratio of water supply in litres per second to the final cropped command area at the end of the season (hectares). It is an important indicator that shows how generally the system annually abstract, utilize and manage water.

The two important parameters needed for calculation of the system hydromodule were average annual system water use and final cropped area at the end of the season. The average annual water use in the KWS was monitored through daily records of water inflows and outflows for the system. The cropped area was estimated at the end of each season using GPS/GIS. The hydromodules for the whole of KWS and for its subsystems, which reuse water, was then estimated using model equation (2)

$$SHM = \frac{I}{A} \qquad (2)$$

Where:
SMH = System hydromodule (l/s/ha)
I = Average annual irrigation water used by the whole system or subsystem (l/s)
A = Total cropped area for the whole system or subsystem at the end of the season (ha)

RESULTS AND DISCUSSION

(a) Irrigation impact to the Mtera /Kidatu Complex

Area under irrigation in Usangu

The furrow survey (FS) method found about 40,933ha of irrigated rice during the study period, and the aerial photograph interpretation (API) and GIS survey found about 42,812ha (Table 1). The maximum irrigated area during wet season in a normal year was estimated at 42,000 ha which is between the FS and GIS surveys of irrigation methods.

Table 1: Area of rice irrigation estimated by two methods

	Furrow survey (FS)				API/GIS survey	
Sub-catchment	Total no. of furrows	Area in wet year (ha)	Area in dry year (ha)	Max area (ha)	Area in wet year (ha)	Area in dry year (ha)
Designation		**Maximum irrigated**	**Core irrigated**	**Maximum irrigable**	**Maximum**	**Core**
Ndembera	46	5004	3330	7623	4000	3000
Kyoga	31	7336	5554	14646	3586	596
Mbarali	58	7299	4228	8403	11434	3039
Mlomboji	1	20	0	20	0	0
Kimani	5	2397	980	3666	2140	717
Ruaha	4	4732	1928	5432	4317	2000
Chimala	8	2115	317	2115	3422	814
Mkoji	49	2403	1207	2847	9035	1664
Mswiswi/Mambi	36	7469	2872	7876	NA	NA
Itambo/Mpolo	24	1564	273	1877	4878	615
Mkoji subcatchment	109	11436	4352	12600	13913	2279
Mjenje	12	540	184	657	0	0
Kimbi	3	55	22	60	0	0
Northeast	0	0	0	0	0	0
Total	276	40933	20896	55222	42812	12445

N.B. The API/GIS survey did not determine the maximum irrigable area.

Current total abstraction capacity

Table 2 is the summary of the total abstraction (above given water rights) capacity of water by intakes from the Usangu rivers. These results are derived from the irrigation impact model and it is estimated that the maximum abstraction from Usangu basin is 45 cumecs. The efficiency of abstraction is estimated at 90%, meaning that until the river flow exceeds the intake capacity, 90% of the river flow discharge can be diverted down irrigation off-takes.

Table 2: Summary of total abstraction from rivers

Sub-catchment	Total maximum abstraction (cumecs)	% of total abstraction per sub-catchment	Proportion of river flow taken through intake until maximum capacity is reached
Ndembera	4.3	10	65%
Kyoga	7.0	16	100%
Mbarali	8.5	19	100%
Mlomboji	0.1	0	50%
Kimani	4.0	9	95%
Ruaha	5.0	11	85%
Chimala	2.75	6	100%
Mkoji	12.0	27	100%
Mjenje	0.6	1	70%
Kimbi	0.2	0	70%
Northeast	0.0	0	0%
Total	45 cumecs (rounded up)	100	90% (arithmetic mean)

Irrigation impact to water inflow in Usangu

The dry season irrigation impact in Usangu basin determined used various approaches during the study period and from previous studies (Faraji and Masenza and RBWO) indicates an impact range of 77-93%. The impact on sub-catchment basis is as high as up 100% for some of the rivers. These estimates are derived from summed abstraction method, which does not consider neither the reduction in size of intakes during the rainy season nor the return flows of drains into the rivers. In essence the impacts are perceived as being the upper limit (SMUC, 2001). Using the net irrigation demand modelling approach, dry season irrigation impact is estimated at 28% of the total inflow of 283.9Mm^3 while the wet season and annual impacts are at 25% of the total inflows of 1787.2Mm^3 and 1508.5Mm^3 respectively. The net demand modelling ignores the losses in water conveyance and distribution and the excessive water use within fields as a result of poor management systems. In all the approaches the impact is higher in late November and December, when total flows in the rivers are at their lowest, around the 6 to 8 cumecs level. The impact is smaller in the early part of the dry season when flows in the perennial rivers are greater. Despite the fact that irrigation impact is high (>90%) as indicated by the study, they are imposed on very low dry season flows (<8cumecs), which are hardly difficult to reach the Mtera HEP station.

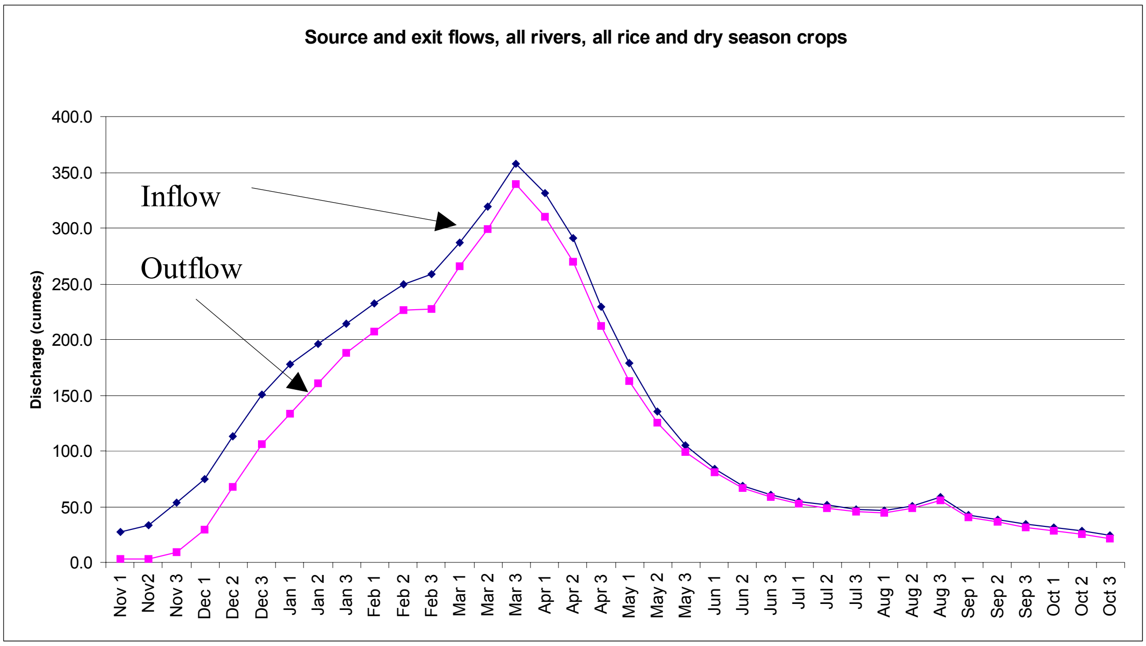

Figure 3: Source and exit flows for all rivers in Usangu Basin, indicating the irrigation impact

Water use efficiency estimated at basin scale

This section presents results on water use efficiency abstracted at basin scale using hydromodule analysis. For the entire of Usangu basin, a maximum of 45 cumecs is required to irrigate a maximum of 42 000 ha during wet season based on net water demand calculation. The hydromodule or water duty from the maximum water supply and the irrigated area is therefore about 1.07 l/s/ha. There are two conclusions, which can be made from this analysis. The obtained water duty is nearly half of the 2.0 l/s/ha which, was quoted as the water duty for paddy rice irrigation schemes in the Usangu basin, (Lankford, 2000; Faraji et al, 1992). In addition the obtained value is less than the designed hydromodule for many irrigation schemes in Usangu which ranges between 1.2 - 1.5 l/s/ha (Halcrow *et al*, 1992; Tarimo, 1994). However, it is not clear the level of water use efficiency that was included in such figures, but the current perception in Tanzania and Usangu in particular is that irrigation efficiencies are in the range of 15-20% (RBMSIIP, 2001), which are definitely very low. Therefore when 1.071 l/sec/ha derived from the ratio of supply to irrigated area is compared to the estimates of 1.5 -2.0 l/sec/ha, it is possible to argue that efficiencies in Usangu are underestimated. Alternatively, if efficiencies are around 20% in Usangu, it is difficult to justify where, when and how does the 80% of the water is lost in irrigation systems.

Efficiency of water use in the Kapunga water system

In 1999/2000, a dry year the annual mean water used (m^3/s) during paddy growing season was relatively less compared to the amount used in the wet year (2000/2001). The monthly mean of water use for the dry year was about 3.53 m^3/s, while in the second year, a wet year, the mean monthly water use was about 5.08 m^3/s (Table 3).

Table 3: Water use in the KWS for 1999/2000 and 2000/2001 seasons

Year	Monthly water use in m^3/s							
	Nov-99	Dec-99	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Mean
1999/2000	0.76	1.26	2.47	2.32	6.03	6.18	5.66	3.53
2000/2001	1.26	4.76	5.72	5.40	6.05	6.19	6.22	5.08

The abstraction impact of the KWS to the Ruaha river is illustrated by Figure 4. There was little water flow in the river in the dry year (1999/2000) compared to wet year (2000/2001). The results further show that in both dry and wet years, during the wet seasons, the river releases significant amount of water downstream. However, during dry seasons the river flow is very low and the available water is insufficient for either heavy rice irrigation or recharging the HEP reservoirs downstream. This water is however vital for domestic use and maintaining the environmental need (SMUWC, 2001). In reality therefore rice irrigation and HEP sectors are not in direct competition and neither of the two can potentially benefit from the low dry season flows. The rice irrigators cannot benefit because rice in Usangu is temperature sensitive and therefore does not perform well in dry season (Machibya, 2003). On the other hand the water is too little to recharge the reservoirs during the same period (Lankford, 2000).

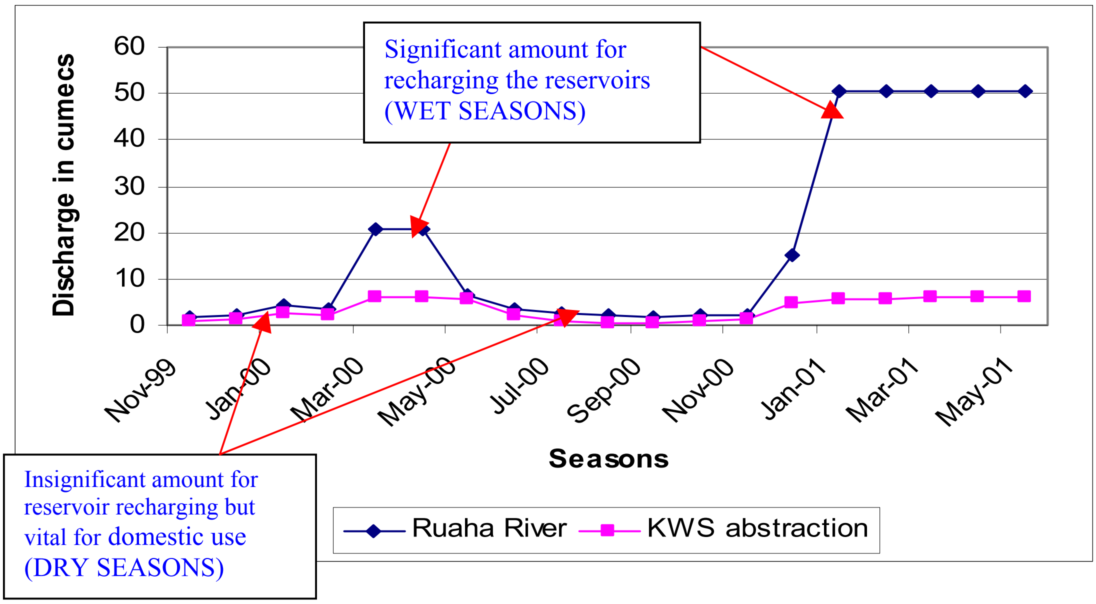

Figure 4: Dynamic water supply between seasons in Ruaha river and KWS abstraction

Area irrigated and hydromoduels

The distribution of water and cropped area of the KWS according to the two subsystems, which reuse water is illustrated by Table 4. The table shows that both subsystems in the KWS use less water (0.78 and 0.95 l/s/ha) for KSS subsystem and (1.00 and 1.10 l/s/ha) KIF subsystem for the dry and wet years respectively. Also the overall hydromodule for the KWS is estimated at (0.98 and 0.99 l/s/ha) for the dry and wet years respectively.

The results from both subsystems and the overall KWS show similar values close to 1.0 l/s/ha, which again is less than the range of 1.5 - 2.0 l/s/ha. Furthermore, the value is also less than the designed hydromodule for the Kapunga water system, which was set at 1.21 l/s/ha. This therefore shows that the water use efficiency of the KWS is even more than the estimated efficiency by the designer.

Table 4: Irrigated areas and hydromodules for the KWS and its water reuse subsystems

Subsystems	Seasons	Total area (ha)	Discharge (l/s)	Hydromodules (l/s/ha)
KIF-water reuse subsystem	1999/2000	2214	2430	1.10
	2000/2001	3662	3680	1.00
KSS-water reuse	1999/2000	1403	1100	0.78
Subsystem	2000/2001	1468	1400	0.95
The whole KWS	1999/2000	3618	3530	0.98
	2000/2001	5131	5080	0.99

Conclusion

The two case studies clearly demonstrate the dynamic availability of water in Usangu. At both subsystem and basin level, the results show that wet season river flows are more important in recharging the reservoirs than visible low flows in the dry season which may look serious but are not quantitatively important to suffice the HEP need. They are these low flows in the dry seasons which do not reach the downstream users that make people think that HEP and irrigation systems are in serious competition. In reality most of the water is neither used for rice irrigation as only 28% of the available water in the dry season is used for dry season irrigation.

The documented inefficiency use of water by rice irrigation system is not supported by both case studies. The irrigation hydromodules at basin and system level are about 1.0 l/s/ha, which shows that it is higher than the current perception of the hydromodule of 2.0l/s/ha. It is further argued that even in volumetric terms, rice irrigation in Usangu is not a great problem so much as the area of rice and the total abstractive capacity in Usangu is circa 50 cumecs.

Therefore saving from irrigation is not likely to benefit the HEP sector because of two reasons. The first reason is that irrigation uses little proportional (25% in wet season) and (28% in dry season) and therefore the saving will not be potential for HEP recharging. Secondly is that irrigation efficiency is not low since the hydromodules in Usangu are low (1.0 l/s/ha) compared to previously thought (2.0 l/s/ha). The previously efficiency associated with the 2.0 l/s/ha are likely to double. In this case there is limited amount of water which can realistically be saved from Usangu irrigation systems to Mtera/Kidatu HEP.

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