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Environmental flows allocation in river basins: Exploring allocation challenges and options in the Great Ruaha River catchment in Tanzania

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Abstract

Provision for environmental flows is currently becoming a central issue in the debate of integrated water resources management in river basins. However, the theories, concepts and practical applications are still new in most developing countries with challenging situations arising in complex basins with multiple water uses and users and increasing water demands and conflicts exemplified by the Great Ruaha River catchment in Tanzania. The research has shown that a flow of 0.5–1 m^3/s for Great Ruaha River through the Ruaha National Park is required to sustain the environment in the park during the dry season. But a question is how can this be achieved? This paper reviews the challenges and suggests some options for achieving environmental water allocation in river basins. The following challenges are identified: (a) the concept of environmental flows is still new and not well known, (b) there is limited data and understanding of the hydrologic and ecological linkages, (c) there is insufficient specialist knowledge and legislative support, (d) there are no storage reservoirs for controlled environmental water releases, and (e) there are contradicting policies and institutions on environmental issues. Notwithstanding these challenges, this paper identifies the options towards meeting environmental water allocation and management: (a) conducting purposive training and awareness creation to communities, politicians, government officials and decision makers on environmental flows, (b) capacity building in environmental flows and setting-up multidisciplinary environmental flows team with stakeholders involvement, (c) facilitating the development of effective local institutions supported by legislation, (d) water harvesting and storage and proportional flow structures design to allow water for the environment, and (e) harmonizing policies and reform in water utilization and water rights to accommodate and ensure water for the environment.

Keywords: Environmental flows; Integrated water resources management; Stakeholder involvement; Ruaha National Park; Great Ruaha catchment

1. Introduction

In recent decades it has been widely recognised that the impact of human society on the environment is beginning to threaten the basic foundation upon which humans depend for food, shelter and well-being. Of all the resources that are important to people, perhaps the one under most pressure is water (Schofield et al., 2003). Traditionally, the focus has been on providing enough water for human needs, with little attention to the environment. However it has been recently recognised that provision of water for the environment is one component of an intersectoral water allocation process in which the right to the use of water is distributed amongst various users. Thoughts on intersectoral allocation of water are well detailed in EC (1998), Abernethy (2001) and Kashaigili et al. (2003). In

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the past water allocation has been limited to consumptive uses and users, and has resulted in increased off-stream uses, resulting in substantial changes in the flow regimes of many rivers of the world. These changes in river flow have resulted into major impacts on aquatic habitats and ecology.

Worldwide there is growing awareness of the pivotal role of flow regime (hydrology) as a key driver of the ecology of rivers and their associated floodplain wetlands (Poff et al., 1997; Puckridge et al., 1998; Naiman et al., 2002; Bunn and Arthington, 2002; Arthington et al., 2003). Such an understanding has recognised that provision should also be made for environmental requirements. Nevertheless, an understanding of ecosystem values is still limited. Falkenmark (2001) argues that the inability to link environmental security, water security and food security is the greatest problem of our time. Putting it into context, Smakhtin (2002) noted that there is a need for an understanding of the trade-offs between fresh water for basic human needs, food production and the maintenance of the freshwater ecosystems. This is essential, as every aquatic ecosystem requires a certain amount of water to maintain its ecological integrity. But some of the most challenging questions are how much water is required to sustain specific levels of environmental benefits, how to balance the various sectoral water demands, and what water is available. These questions are the subjects of the ongoing debate and research on how to achieve sustainable allocation of water resources in the world.

With the ongoing global researches, the emphasis is gradually shifting from "a river is also a water user" type of attitude to the "water in a river is a resource for multiple uses and has to have an untouchable reserve" (Smakhtin, 2002). This has been the case in many river basins throughout the world where environmental water requirements have never been estimated or set. *Environmental flows allocation* requires that a certain amount of water be purposefully left in or released into an aquatic ecosystem to maintain it in a condition that will support its direct and indirect use values (King et al., 2002; Dyson et al., 2003). Environmental flows provide critical contributions to river health development and poverty alleviation (Dyson et al., 2003) and ensure the continued availability of the many benefits that healthy river and groundwater systems bring to society. It is apparently clear that the failure to ensure water for the environment has a detrimental impacts and consequences to many river users. However, addressing the water needs of aquatic ecosystems will often mean reducing the water use of one or more sectors (Dyson et al., 2003) and these are tough choices, but they have to be made to ensure the long-term health of the basin and the activities it encompasses.

Recently there has been an acceptance of the need to give explicit recognition to environmental flows allocation through the establishment of water entitlements for the environment. Examples include the cases of South Africa, Australia and North America. The South African Water Law (National Water Act 38 of 1998) was the first in the world to establish water entitlement to the environment. By this legislation only two 'rights' are provided: a small amount per person as 'basic human needs' and an amount for rivers, estuaries, wetlands and ground water that will allow their continued existence sustainably in the future.

In Tanzania, the new National Water Policy (MWLD, 2002) recognizes the need for allocating water for the environment. It advocates the determination of environmental flows in river basins and giving rights to the environment to maintain ecosystem health. While that has been explicitly emphasized, the theories, concepts and practical applications are largely new not only in Tanzania but also in most other developing countries. This paper is therefore, geared towards eliciting the challenges and options for environmental flows allocations. It also highlights some of the key environmental issues in the Great Ruaha River catchment (for instance the drying-up of the Great Ruaha River in the Ruaha National Park and shrinkage of the Usangu wetland). It draws on a case of the Great Ruaha River catchment within the Rufiji River Basin in Tanzania using evidence collected under the ongoing research work conducted by the Raising Irrigation Productivity and Releasing Water for Intersectoral Needs (RIPARWIN) project, a DFID-funded River Basin Management Research Project implemented by the Overseas Development Group (ODG), the University of East Anglia (UEA) UK, the Soil–Water Management Research Group (SWMRG) of Sokoine University of Agriculture (SUA, Tanzania) and the International Water Management Institute (IWMI) through its Regional Office in South Africa. The paper seeks to contribute to the national debate on how to shape water management through the paradigm of "Integrated Water Resources Management (IWRM)" which advocates a holistic approach to water management of water resources for the benefits of all while ensuring environmental sustainability.

2. Area descriptions, methods and material studied

2.1. Area descriptions

The study area is located in the southwest of Tanzania approximately latitudes 7°41′ and 9°25′, South, and longitudes 33°40′ and 35°40′ East (Fig. 1). The Great Ruaha River catchment draws the name from the Great Ruaha River (GRR), which is one of the Tanzania's major rivers and an important tributary of the Rufiji River draining an area of about 68,000 km^2. It lies within the eastern arm of the Rift Valley, marked by distinct escarpments in the southern and eastern parts and forms the upper catchment of the Great Ruaha River. This is a main tributary of the Rufiji River, which forms the largest drainage basin in Tanzania, covering some 177,000 km^2 or about 18% of the Tanzanian mainland. Located in the upper part of the Great Ruaha catchment are the Usangu Plains with a total area of 20,811 km^2—about 12% of the total Rufiji Basin.

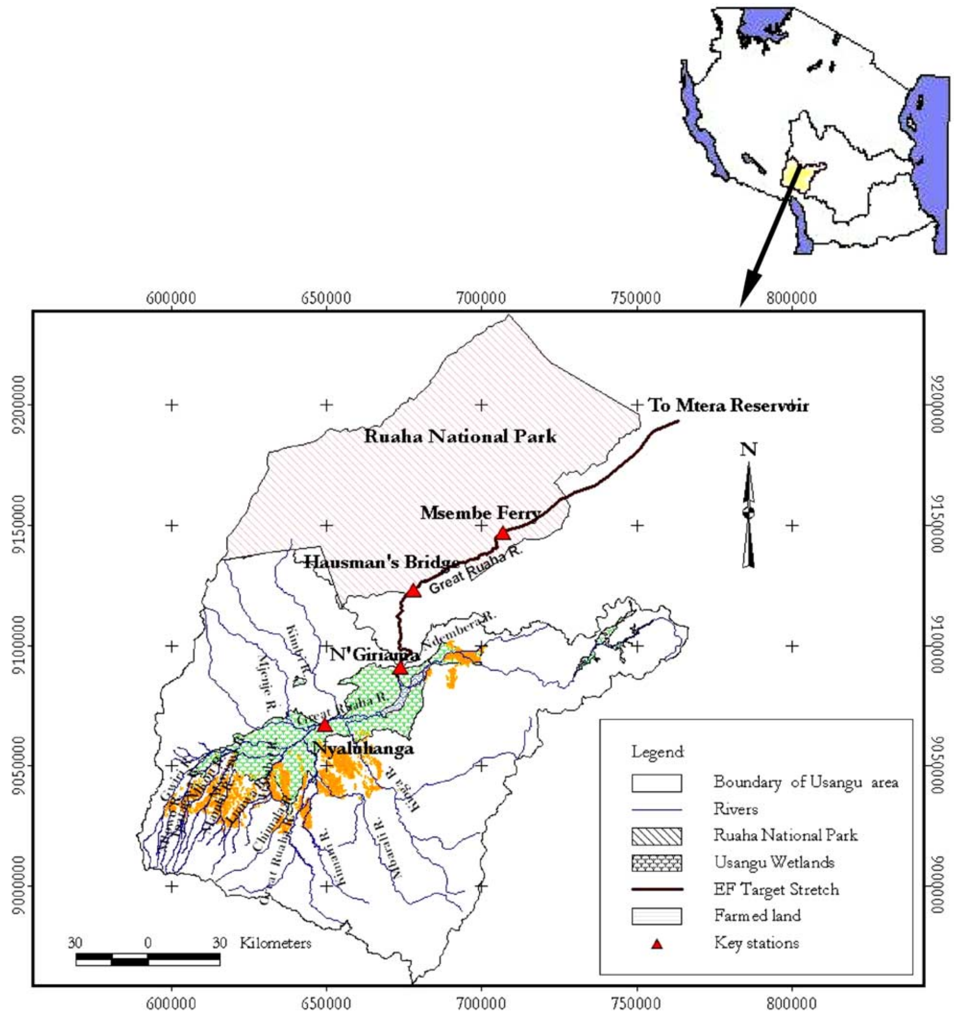

Fig. 1. Map of Tanzania showing location of the study area within the Rufiji River Basin.

Within the plains, several other rivers flowing from the highlands join the Great Ruaha River. The major one being the Mbarali, Kimani and Chimala whereas the small ones include Umrobo, Mkoji, Lunwa, Mlomboji, Ipatagwa, Mambi and Mswiswi rivers. The Great Ruaha River flows as a single river passing through a constriction at Nyaluhanga to supply the Eastern wetland, including a perennial swamp (Ihefu) within the Eastern wetland. From the Usangu wetlands, the Great Ruaha River flows through the Ruaha National Park (RNP) serving as the main source of water for the Park. Thereafter, together with the Little Ruaha River, the river supplies water to the Mtera hydropower plant, which was commissioned in 1988 and generates about 80 MW to the national power supply. Below Mtera, the GRR flows westward to the Kidatu reservoir, being joined on the way by the Lukosi and Yovi rivers, supplying water for hydropower generation at Kidatu, which was commissioned in 1975 and generates 204 MW of the total national power supply. From the Kidatu reservoir the GRR flows into Kilombero Plains being joined by Kilombero River before joining the Rufiji River (just above Steigler's gorge), collecting en route the Kitete and Sanje rivers. The GRR provides about 56% of the total runoff to Mtera Reservoir, while the Little Ruaha River, which joins the GRR downstream from the Usangu Plains, provides an additional 18% and the Kisigo River 26% of the total runoff to Mtera. As it flows, the GRR serves many uses, including irrigation, livestock, domestic uses to neighbouring villages, fisheries and the aquatic flora and fauna.

The mean annual air temperature varies from about 18 °C at higher attitudes to about 28 °C in the lower and drier part of the basin. Rainfall is extremely seasonal, highly localised and spatially varied, with a single rainy season from November to April and strongly correlated with altitude, with the higher areas receiving up to about 1600 mm of rain. Rainfall on the Usangu Plains is low, ranging between 500 and 700 mm per annum.

The Ruaha National Park covers an area of about 10,300 km^2 and is the second largest National Park in Tanzania after Serengeti. The Park is located in Central Tanzania between latitudes 6°45′ and 8°00′ South, and longitude 33°50′ and 35°25′ East. Elevation ranges from 710 m above sea level in the northeastern corner of the Park to 1863 m above sea level in the southwestern corner. Most of the

Park is made up of a plateau at more than 1000 m elevation to the North and West of the Rift Valley escarpment where the dominant vegetation comprises miombo woodland. The core of the Park is the watershed between the Great Ruaha and Mzombe rivers, which run along the southeast and northwest Park boundaries. Annual rainfall averages at 500 mm per annum, occurring from late November till late March or early April and increasing with altitude towards the west of the Park. The mean maximum and minimum air temperatures lie between 20 and 40 °C and 16 and 30 °C, respectively. The coolest months are from June to August with a mean temperature of 21 °C, and the hottest months are October to December, with a mean temperature of 25 °C.

2.2. Water uses and users in the Great Ruaha River catchment

The Great Ruaha River Basin is a complex basin with diverse multisectoral water uses and users. A great proportion of the population of the basin is sustained by irrigation and water-related livelihoods such as fishing and livestock keeping. Irrigation in the basin is a major activity and largest water user, mainly during the dry season. Dry-season irrigation is concentrated in the upper courses of the rivers, irrigating high-valued crops such as green vegetables, onions, tomatoes, beans and maize.

The dry season is a water-scarce period most associated with conflicts and disputes over access to water. During the dry season, villagers along the rivers in the mid catchments divert water to both fallow and cropped irrigated fields in plot-to-plot distribution and to the villages for consumptive domestic uses as well as for brick-making, both commercial and domestic. Downstream of the main highways and below the irrigation schemes, most rivers, except for the perennial rivers: the Mbarali, Kimani, Chimala and Great Ruaha, dry up. Though perennial, these rivers retain very minimal flows in the dry season. Towards the end of the dry season, flow in the Great Ruaha River, the main river that drains into the Eastern wetland, is very small and the total inflows into the Eastern wetland fail to maintain an outflow from the wetland to the RNP. Failure of adequate outflows from the Eastern wetland has resulted into a drying-up of the GRR downstream of the wetlands. The drying-up of the GRR in the RNP has brought a lot of environmental concerns that led the Government of Tanzania to committing its support to a programme for ensuring that the GRR receives year-round flow by 2010.

2.3. Methods and material studied

The hydrological approach (a method relying on historical flow records) was carried out to assess the environmental flows (EF) required for ensuring perennial flows for the Great Ruaha River downstream of the Usangu wetlands in the Ruaha National Park. Due to data paucity on habitats, substrata and quality at a range of flows, the analysis was limited to the hydrological approach alone. The hydrological method entailed the analysis of flow duration curves (FDC) and low flows, utilizing data at a station located within the Ruaha National Park at Msembe. The analysis considered the three windows namely: (a) the pre-1974 window (natural flows), (b) the 1975–1985 window (intermittent period), and (c) the post-1985 window (high abstractions upstream of the Usangu wetlands). From the FDC, indices of low flows were extracted and analysed for an optimum environmental flows recommendations.

To gain an insight into the impacts of the drying-up of the GRR, and the magnitude of the problem, semi-structured interviews were conducted with the Ruaha National Park Officials, Friends of Ruaha Society (FORS) and key informants within the Usangu Plains. A review of the literature on intersectoral water allocation in river basins and environmental flows assessment informs Section 4 of this paper.

3. Results and analyses

3.1. Estimate for environmental flows and available surface water resource in the dry season

The preliminary findings under the RIPARWIN research work show that a flow of 0.5–1.0 m^3/s at the exit of the Usangu wetland to the Ruaha National would be required to sustain the environment in the park during the period of low flows (July–November) in the dry season. To maintain that flow, inflows into the Usangu wetlands will have to be maintained above 7 m^3/s. Analysis of the available surface water resources before abstractions upstream of the wetlands has shown that, in order to maintain the estimated inflows into the Eastern wetland and environmental flows at the exit, upstream flows of the perennial rivers (Mbarali, Great Ruaha, Kimani and Ndembera) in the dry season (July–November) will have to be divided 20% for agriculture and 80% for the environment to feed the wetland.

The challenge is that the 20% allocation for agriculture in the dry season might not be sufficient to cater for the demands of an increasing human population, leading to more demand for water allocation. Experience in the area has shown that the population is on increase as a result of immigration of people from other areas, compounding to the problem of water availability. As Kadigi (2004) has argued, water scarcity in the Great Ruaha River catchment is becoming rampant, largely because of human population growth and over-abstraction of water resources by upstream irrigators in the Usangu Plains. In this regard, allocating water for the environment for the Great Ruaha River is a challenge in itself, as the basin already has multisectoral water uses and users and the great population is sustained by irrigation and other water-related livelihoods.

3.2. Environmental issues, concerns and impact for the drying of the Great Ruaha River

The national concern about the Great Ruaha River has increased after the drying-up of the river in Ruaha National Park. Since 1993 (over the past ten years) the Great Ruaha River has started to experience considerable impacts from extensive and relatively rapid development. The development includes an increased human population as a result of in-migration, irrigation expansion, rainfed expansion, increased livestock population and other socio-economic activities. As has been argued by SMUWC (2001a), the key environmental impacts, including, the drying-up of the GRR in the Ruaha National Park and shrinkage of the Usangu wetland, can be attributed to various developmental interventions within the catchment.

The investigation for the drying-up of the river in the Ruaha National Park showed that the river dried up sometimes in 1947, 1954 and in 1977 and possibly in other years as well, but not repeatedly as it has been experienced from 1993. Table 1 shows the period for zero flows as observed in the RNP from 1994.

With the increasing political pressure to revive the annual flows of the Great Ruaha River, several studies have been conducted in an attempt to identify the causes of the drying-up. Some of these include SMUWC (2001a), Charnley (1996) and DANIDA/World Bank (1995). Despite the suggestions arising from these studies, a compromise is yet to be reached on the causes. For example, the DANIDA/World Bank (1995) study concluded that “No single factor can be picked out as the only responsible”, and the same has been agreed in principle by Lankford and Frank (2000). This reveals the complexity of the situation in the Great Ruaha River catchment.

Table 1
Drying-up of the Great Ruaha River for the period from 1994 to 2004 (observations at Sue’s Camp)

Year	Date flow stopped	Date flow started	Period of no flow
1994	17 November	15 December	28
1995	19 October	23 December	65
1996	17 October	16 December	60
1997	20 September	22 November	63
1998	18 November	9 March 1999[a]	87
1999	21 September	20 December	90
2000	17 September	22 November	66
2001	12 November	23 December	41
2002	2 November	24 December	52
2003	21 September	16 January 2004[b]	104
2004	3 November	4 December	31

Source: Sue Stolberger’s records at Jongomero Camp in the Ruaha National Park (UTM: 679147E 9127828N).

[a] The river dried up on 18th November 1998, started flowing on 19th January 1999, stopped again on 12th February 1999 and started flowing again on 9th March 1999.

[b] The river stopped flowing on 21st September 2003, started flowing on 14th December 2003, stopped again on 21st December 2003, started flowing on 30th December 2003, stopped on 5th January 2004 and started flowing again on 16th January 2004.

Drying up of the Great Ruaha River has resulted in not only social conflicts between upstream and downstream users but also a denial of adequate water to maintain the fragile ecosystem in the RNP (Kadigi, 2004). It has disrupted the lives of animals that depend on it for their survival by causing widespread mortality of fish and hippopotami in the Park. An interview with the RNP Ecologist revealed that 5,000 fishes and 49 hippos (30 males and 19 females) died in 2003 as the result of drying up of the Great Ruaha River. When the river dries up, few portions in the river remain with stagnant water as isolated pools or ponds that continues decreasing in size as the dry period heightens. During hot weather conditions the water heats up, animals become congested in the pools, drinking contaminated water full of excreta. Such condition results into outbreak of diseases such as Anthrax, leading to deaths of different animals including fish. When most fishes die, ecosystem imbalances occur (disruption of the food chain); as a result, some of the lives of secondary and tertiary consumers are affected and they normally migrate to other favourable areas (Kadigi, 2004). Since the river, as a habitat, gets reduced into several small ponds, competition among aquatic creatures occurs resulting into overcrowding in aquatic habitats, starvation and disease infections. During such situations elimination of some species may occur.

Another impact of the reduced dry season flows is that of shrinkage in size of the Usangu wetlands. The Usangu wetlands have continued decreasing in size (see for example Kashaigili et al., 2004; SMUWC, 2001b; DANIDA/World Bank, 1995). The recent study conducted by Kashaigili et al. (2004) revealed that the vegetated swamp, a major component of the Eastern wetland, has decreased by 67% over the 16 years from 1984 to 2000 in the dry season. Such abrupt shrinkage in size may have an impact on the hydrological balance of the wetland. In the past, before irrigated agriculture started to take so much of water from rivers in Usangu Plains, the Usangu wetlands used to flood every wet season. But presently, while the eastern half is flooding regularly, the western part does not. The Mkoji River—one of the tributaries of the Great Ruaha River—is now typically dry in the dry season, as it is often the case for the Great Ruaha River in the western wetland (SMUWC, 2001a). The shrinkage in size of the Usangu wetlands could be viewed as a decreased capacity for holding water and for releasing it slowly downstream.

4. Discussion and conclusions

4.1. Discussion

The first estimate of environmental flows for the Great Ruaha River through the Ruaha National Park in the dry season (July–November) was found to lie between 0.5 and 1.0 m^3/s, depending on the rainfall and its distribution over the course of the year. However, the analysis is limited to the hydrological approach, so the reliability of the results is lower than would be the results of holistic multidisciplinary approaches, which require the involvement of several stakeholders at various levels of determination and in decisions about water allocations (King et al., 1999). However, the analysis is limited to the hydrological approach, so the reliability of the results is lower than would be the results of holistic multidisciplinary approaches, which require the involvement of several stakeholders at various levels of determination and in decisions about water allocations (King et al., 1999). The analysis has gone further to showing the complexity of water demands in the dry season and identifying the various impacts for the drying-up of the Great Ruaha River within the Ruaha National Park and the Usangu wetlands. The challenge is to ensure water allocation for the environment under the prevailing competing demands. This is complex and very challenging and has to be approached very carefully as in it are embedded some livelihoods-based issues. It could be argued that, the success in environmental water allocation would probably depend on institutional arrangements and stakeholder involvement backed up by legislation.

4.1.1. Policies, legislation and institutional aspects of water allocation in Tanzania

An account on the legislative and institutional aspects of water allocation in Tanzania is well detailed in Kashaigili et al. (2003) and Sokile et al. (2003). An important note is the order of issuance of water rights as provided by the legislation where, in granting water rights, priority for use is given to domestic supply, followed by the environment and other users respectively. This implies environmental water to be second in allocation after domestic requirements. Despite the provisions of the legislation, it has never been practised. If such provision were to be applied, it is likely that the environmental water allocation would be ensured.

The need for environmental water allocations has also been articulated well by the new National Water Policy of Tanzania (MWLD, 2002). The policy provides for the development of sustainable means of managing water resources. It advocates intersectoral allocation of water with much emphasis on the need by the environment for water, prioritising domestic supply followed by environment and then others. It accentuates the necessity of environmental flows (in-stream flows) for sustainable management of riparian biodiversity, wetlands systems, and the freshwater/seawater balance in deltas and estuaries. It cautions on reducing flow volumes and the effects this has on aquatic life through reductions in the concentrations of dissolved oxygen and nutrient supplies. The policy goes further, commenting on the impact of depleted dry-season river flows in the Usangu plains: "terrestrial and aquatic animal species in the Great Ruaha National Park (Rufiji Basin) suffer from depleted dry season flows caused mainly by dry season irrigation in the Usangu plains". The clue here is the need for allocating water to the environment to maintain ecosystem health. Despite the good policy, as we might see it, the Water Utilization Act No. 42 of 1974 (Control and Regulation) and its subsequent amendments (currently under review) should be amended to empower the implementation of the new national water policy.

4.1.2. Community participation through WUAs: is it a solution to sectoral water allocation?

The new national water policy in Tanzania advocates and recognizes Water Users Associations (WUAs) or Water User Groups (WUGs) as the lowest appropriate level of water management organisation and encourages the formation and transfer of water rights to them. The principle water act—Water Utilization (Control and Regulation) Act No. 42 of 1974 and 1981 has been amended to provide for WUAs. The 1997 amendment acknowledged WUAs as a promising set-up for handling water resources management. A critical observation of the existing WUAs in the Usangu Plains, for example, reveals that irrigators, with little or no acknowledgement of other users, dominate WUAs (Table 2). The connotation is that other users are overwhelmed by one sector. This leaves many unanswered questions like, how best can WUAs ensure environmental integrity; how can WUAs be fair to other sectoral needs if dominated by one sector; how best can environmental flows be taken care of by WUAs? One would expect that the formation of WUAs would integrate various sectors, and that environmental integrity and fair allocation could be realized. Following realization of the biases and the complexity of the situation, RIPARWIN is facilitating a dialogue of water users via the river basin game (RBG)[1] to decide for themselves to instigate river users committees.

4.1.3. Current understanding of environmental flows assessment in Tanzania

The theories, concepts and practical applications of environmental flows are largely new not only in Tanzania but also in most other developing countries. They form a new concept in water management through a new paradigm of "Integrated Water Resources Management (IWRM)", which advocates a holistic approach to the management of water resources for the benefits of all while ensuring environmental sustainability. As a new subject it has not previously been included in the curricula of most Tanzanian educational institutions. Of late, the realization of the need for ecosystem health has marked a potential for inclusion into university curricula. Such developments are being spearheaded by outsiders as subject mentors due to the limited expertise available within the country. Understanding is still at an infant stage and being externally driven. On the research side, some projects are pioneering the issues of environmental flows assessment. One of these is the RIPARWIN river basin management research project within the Great Ruaha River Basin. Other initiatives have

[1] The River Basin Game (RBG) is a role-play tool (a prototype of a river basin) which is used to promote dialogue and elicit meaningful options in allocation and management of water resources in a river basin.

Table 2
Some water user associations/apex water user entities in Usangu

Name of association	Catchment	Main water uses
Mapogoro, Mfumbi Resource Management Association (MAMREMA)	Kimani River	Irrigation, livestock, domestic
Halali Water User Association	Halali River	Irrigation, domestic and livestock
Mkoji Catchment Management Association	Mkoji River	Dry and wet season irrigation, domestic and livestock
Chimala Water User Association	Chimala River	Irrigation
Ndembera Water User Association (just started the process)	Ndembera River	Irrigation and domestic

Source: abstracted from Mwaruvanda (2005).

started in the Pangani basin under IUCN support. However, the experience of RIPARWIN has shown that most data required for a full EF assessment are still missing.

4.1.4. Way forward towards environmental flows allocation: think of naturalizing the flow?

The decision on how much water is needed for environmental flows entails answering questions like when, how often and for how long river flows are needed in order to protect various river ecosystem components. Various scholars like King et al. (2002) and Arthington et al. (2003) embrace this but then indicate that a natural flow regime is the optimum one. According to natural flow paradigms (Poff et al., 1997), the purpose of environmental flows is to conserve key elements of the natural regime, or to mimic or restore them. But in many cases, achieving naturalization of the natural flow regime is difficult for water-stressed basins with multiple water uses and users, which is the case for most river basins in developing countries. Should the reversal order be made aimed at naturalization of the river flow regime, there is a possibility that many peoples' livelihoods may be impacted. As Arthington et al. (2003) argued, "*in situations where a riverine ecosystem is already highly modified due to other factors, or where it has been exposed to a modified flow regime for so long that it has fully adjusted to the new regime*, *reversion to the natural regime may threaten existing ecological and societal values*". How to address such circumstances is one of the major challenges of environmental flow studies and usually extends beyond the realms of science into the political sphere (Arthington et al., 2003). This would obviously require integration of various stakeholders through a participatory approach to address and reach a common consensus on the allocation of the common property "water" to avoid the "tragedy of the commons".

Involvement of various stakeholders is central to environmental flows water allocation in river basins. Scholars provide different schools of thoughts on the roles of various stakeholders in environmental flows determination and allocation process. Such stakeholders include the communities, NGOs, politicians, policy makers and government officials. All these stakeholders need be aware of the environmental flows concepts by means of capacity building through awareness creation. This is crucial in making decisions about the future character and health status of ecosystems. The community should be involved in all aspects of water allocation including making decisions about environmental water provisions. As Dyson et al. (2003) argue, awareness is the first step towards increased capacities in environmental flows design and implementation. This is due to the fact that environmental flow is a relatively new issue for the water sector and there has been lack of awareness throughout the sector and the general public on the concept and its application. In this regard, raising awareness about the river conditions and the best interests of the community is critical. It is also very important to empower and educate politicians to better understand the societal costs of not establishing environmental flows. A failure to invest in capacity building might lead to continued mismanagement of water resources, as pointed by Dyson et al. (2003), a fact difficult to refute. The above argument seems to be true for the situation in the Great Ruaha River catchment, now overstressed by dry season abstractions, where various stakeholders could come together, to discuss and to agree on the future of the catchment and its environment.

4.1.5. Summing issues, challenges and options for the way forward

The determination and allocation of environmental flows in a river basin is both challenging and multidisciplinary. It requires coordinated involvement of several stakeholders during various determination and allocation processes. The challenges intensify when there is not much expertise, but many uses and users of water in the basin under consideration. Despite being a challenging process in itself, other challenges also need to be considered. These include the following facts:

- the concept of environmental flows is still new and not well known,
- there is limited data and understanding of hydrologic and ecological linkages,
- there is insufficient specialist knowledge and legislative support,
- there are no storage reservoirs for controlled environmental water releases,
- there are contradictorying policies and institutions dealing with environmental issues.

Despite the challenges, this paper has identified the options towards environmental flows determination and allocation. These options include:

- conducting training and awareness campaigns to communities, politicians, government officials and decision makers on environmental flows,
- capacity building in environmental flows and setting-up a multidisciplinary environmental flows team with stakeholders involvement,
- facilitating the development of effective local institutions supported by legislation,
- water harvesting and storage and proportional flow structures designed to allow water for the environment, and
- harmonizing contradictory policies on environmental issues by reforming water utilization and water rights to accommodate water for the environment.

Other options could be:

- zoning and prioritization as a means to provide ecological flows as presented in Lankford (2001),
- new formal water rights—licences based on available water resources after accounting for the environment.

4.2. Conclusion

The study has revealed that a flow of 0.5–1.0 m^3/s at the exit of the Usangu wetland to the Ruaha National Park would be required to sustain the environment in the park during the dry season. In order to maintain that flow, inflows into the Usangu wetlands will have to be maintained above 7 m^3/s. This is an environmental water allocation that need be met through the overstressed water situation in the Great Ruaha River catchment to maintain the environment. The challenges underlying all the processes of environmental flows determinations and allocation have been highlighted. One would suggest that environmental water allocations should be part of an integrated approach to environmental management and we can attribute the present failure to manage water sustainably to lack of knowledge. The community has a role in deciding on the management of natural resources and thus on their future. It is also important to realize that economic prosperity depends on the continued existence of healthy aquatic ecosystems and that environmental water allocation, is not a vote against economic development. As Schofield et al. (2003) pointed out, rivers that are managed sustainably can satisfy a wide number of important needs, environmental and aesthetic as well as economic. In that regard, saving water from the irrigation sector (the most *blue*-water user) and allocating it to the environment and other needy sectors will be necessary for the sustainability of the environment in the Great Ruaha River catchment.

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