The Sustainable Coexistence of Wetlands and Rice Irrigation: A Case Study From Tanzania

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An existing United Kingdom-funded water project, located in the Usangu Plains of Tanzania, aims to understand the causes for dry season zero flows in the previously perennially flowing Great Ruaha River, which drains from the Usangu wetland. Studies reveal that the common explanation of competition for water between wetlands and irrigation alone is insufficient to explain reduced flows. Instead, complex biological and hydrological processes influence the allocation of water between wetlands and irrigation. This article outlines these processes and proposes some hypotheses: (a) certain types of rice irrigation development may not be detrimental to the Usangu wetlands; (b) the sustainability of rice irrigation and wetlands can be supported by recognizing their dynamic nature; (c) the concept of efficiency of irrigation in areas with a semiarid climate should be treated with caution. The studies will assist in the sustainable management of water for both environmental and developmental needs.

Competition over water between agriculture and the environment arises from values that humans derive from or ascribe to these sectors. A well-documented conflict exists between natural wetlands and irrigated agricultural production (Barbier & Thompson, 1998; Maltby, 1986; Postel, 1992), where, commonly, wetlands are perceived to be under threat from the expansion of crops (e.g., rice) that use the water that would otherwise maintain the wetlands. Masija (1993) has drawn attention to this conflict in Tanzania. This article does not examine the values associated with wetlands or rice irrigation but identifies the processes of water allocation between the two. We argue that in any given basin, these processes exist and that situational analysis could expedite capacity building and policy regarding water allocation. As Burke, Jones, and Kasimona (1994) argue, "integrated development and management of the Kafue sub-basin must appreciate the role of the hydrological and hydro-geological processes operating within its catchment" (p. 420).

The identification of these processes stems from initial studies of a natural resources project on the Usangu Plains in Tanzania, funded by the British government. Although it is not styled an integrated river basin management project, it approximates such aims by increasing

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benefits from water via interventions to save and reallocate water between different users. As such, the project is a product of the current trend for integrated water management within a river basin context (European Commission, 1998; Mitchell, 1990; Newson, 1997; Sharma et al., 1996).

Geographical Background

The Usangu basin in southern Tanzania covers an area of 21,500 km^2 and forms the headwaters of the Great Ruaha River. It may be broadly divided into the central plain and a surrounding higher catchment consisting of the Kipengere Range to the south, the Mbeya Range to the west, and lower hills to the north. The plain receives 600 to 800 mm average annual rainfall. There is a rainfall gradient onto the high catchment (to 1,500 mm). Less runoff occurs from the hills along the northern border and the plains themselves. Most of the rain falls in one season from mid-November to May. Six main water resource subsystems can be differentiated here, as shown in Figure 1: (a) the high catchment, (b) irrigation schemes, (c) alluvial fans, (d) central wetland, (e) Ruaha National Park riverine reach, and (f) Mtera/Kidatu hydropower schemes. There are five perennial rivers and a large number of seasonal streams draining from the high catchment. These surface flows, rather than groundwater, are used for domestic and agricultural water use.

Most irrigation is located on the upper parts of the alluvial fans. There are a number of different types of farms including large-scale, state-owned farms, traditional smallholder, improved smallholder, and smallholder peripheral to the state farms. The total irrigated area ranges between 20,000 and 40,000 ha depending on annual rainfall. The large state farms are Kapunga (3000 ha), Mbarali (3200 ha), and Madibira (3000 ha), which is presently under construction.

Downstream of the irrigated areas, drainage is discharged into smaller streams and swamps located toward the tail of the alluvial fans. Some streams reach the Ruaha River, the main channel supplying the wetland. Beyond the alluvial fans, the plain consists of savannah, woodlands, and perennial and seasonal wetlands. The exit from the wetlands consists essentially of a rock bar. When the water level is low, no water leaves the exit. As the water level rises, water spills over the lip into the Great Ruaha River and keeps flowing until the water level decreases once again below the lip. Although the swamp is a maze of channels and lagoons, many at different levels, it can be represented conceptually as a simple reservoir with a fixed spillway. After leaving the wetland, the Great Ruaha River is joined by a number of ephemeral rivers as it flows through the Ruaha National Park. Downstream, the Mtera Reservoir

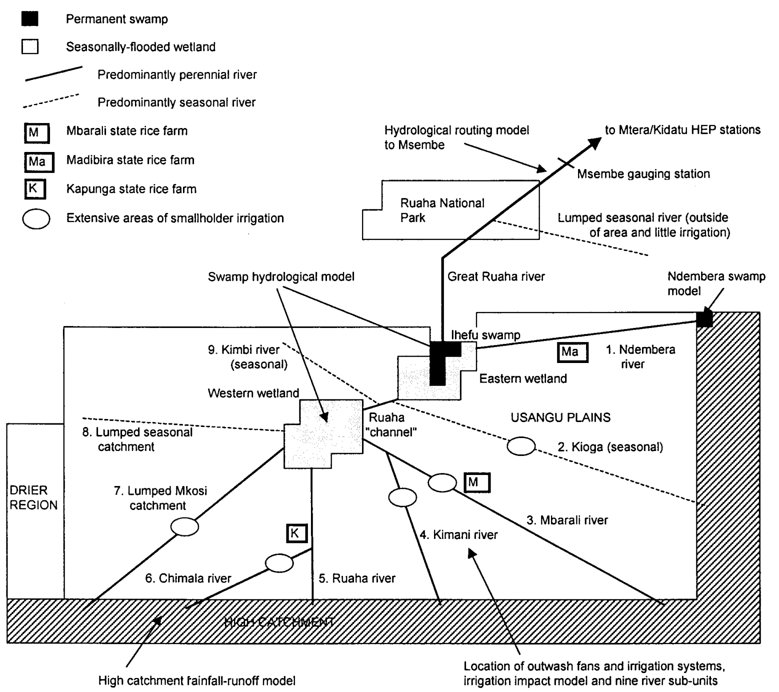

Figure 1: Water Resource Subsystems of the Usangu Basin

collects water from the Great Ruaha and a number of other rivers. Besides having an 80 MW generating capacity of its own, it also acts as a regulating reservoir for the larger 204 MW Kidatu hydropower scheme further downstream.

The Case Study

The project, Sustainable Management of the Usangu Wetlands and Its Catchment (SMUWC), was established by the United Kingdom's Department for International Development in 1998. Based in Mbarali District, it reports to the Rufiji Basin Water Office of the Ministry of Water and to local councils. It is also operating within the framework of the World Bank-funded River Basin Management and Smallholder Irrigation Improvement Project (RBMSIIP). The area was the site of a wide-ranging study conducted in the 1970s (Hazelwood & Livingstone, 1978).

The project arose out of concerns about water management in the Ruaha basin. National concern about the Usangu wetlands first surfaced in 1995, when power had to be rationed due to low water levels at Mtera reservoir. Water shortages, however, had been previously experienced in 1992 and 1994, as well (Danida/World Bank, 1995). The low water levels were commonly attributed to decreased flows in the Great Ruaha and, more specifically, to reduced dry season flows from the Usangu wetlands. The Usangu catchment (Great Ruaha River measured at Msembe) provides about 56% of the average annual inflow at Mtera. (An alternative explanation, advanced by some commentators, is that the existing operating rules for Mtera Reservoir have not been strictly followed since 1988, when generating turbines were installed at this site).

Local concern surfaced earlier when the Ruaha river in the Ruaha National Park dried up in 1992-1993. This recurred in 1993-1994 (3.5 weeks), 1994-1995 (6 weeks), 1996-1997 (8 weeks), and 1998-1999. Wildlife in the park is dependent on the river and its tributaries, and extensive mortality of fish and hippopotami was reported in 1996-1997. Less recognized but as critically important is the wetland itself. If indeed it is drying up, as sometimes claimed, then an important ecological resource for both resident and migratory species may be lost. The wetland also provides fisheries-based livelihoods. Hollis and Acreman (1994) present a list of functions and values of wetlands, many of which are applicable to the Usangu wetlands.

Although water shortages at Mtera and at Ruaha National Park have focused attention on the Usangu plains, these two events are not necessarily causally linked. In the past, even in the best of years, dry season flow rates from the Usangu plains were minimal (0.5 – 1.5 m^3/sec), and only made marginal contributions to water volumes at Mtera dam. In addition, the drying up of the river, which affects the National Park, must be placed in context. Although this occurrence is often referred to as unprecedented, the record shows that the river dried up in 1947, 1954, 1977, and possibly in other years as well. Two factors are, however, critical. First, the current sequence of dry flow years, combined with the increasing length of the dry periods, is unprecedented in recent history. Second, despite an exceptionally wet year in 1998, the river still dried up before the end of the dry season.

Unfortunately, since the problem arrived on the political agenda, there has been a search for a simple cause and effect relationship; as noted by Danida/World Bank (1995), scantiness of data has led to interpretations "apparently . . . informed rather by the partisan interests of the participants" (p. 8). The causes are frequently presented as self-evident truths, with little or no supporting quantification. As a result of this misunderstanding of the complexity of the problem, misconceptions have been built into the resulting political action. The SMUWC project, therefore, is faced with the task not only of identifying the causes of the problem, but also of dealing with untenable conclusions that have achieved political credibility. The four most common environmental causes presented (HTS Ltd, 1999) are

1. *Irrigation abstractions*: The progressive expansion of irrigated land, in both formal and traditional schemes, has resulted in ever increasing abstraction of water from rivers upstream of the wetlands. Danida/World Bank (1995) estimate that water use for irrigation in Usangu is equivalent to 9% to 15% of average annual inflows at Mtera. But the beginning of problems at Mtera coinciding with the opening of the Kapunga irrigation scheme is given as evidence of lower water yield to the wetlands on account of expanding irrigation schemes.

2. *Increasing livestock*: Increasing numbers of livestock and the resultant overgrazing are frequently cited as a major causal factor in the drying up of the Usangu and previously waterlogged areas. Kikula, Charnley, and Yanda (1996) argue that increases in livestock population result in soil compaction, which increases the volume and velocity of runoff, leading to a deepening of natural drainage channels and a lowering of the water table, thus increasing spate flows and reducing storage. Bare patches with sealed soil surface and compacted subsurface in grazing areas are cited as evidence. Aside from the fact that this complicated cause and effect relationship stands up rather poorly on close examination, there has been no sudden recent increase in livestock. Rather, their number has risen steadily since the 1950s (see Charnley, 1994). About 1 million to 1.5 million livestock are commonly said to occupy the plains in the dry season. But this is evidently an exaggeration; a recent count by the project estimated just 300,000 cattle.

3. *Deforestation and general environmental degradation*: Although there has certainly been deforestation, land use conversion, and erosion in the upper catchment, and commercial species have been removed from the Miombo woodland, the initial reconnaissance has not uncovered evidence of either extensive deforestation or generalized degradation in the plains. Moreover, deforestation in the high catchment should have led to an increase in spate flows and flooding in the plains (Danida/World Bank, 1995), although evidence suggests that the wetland is shrinking.

4. *Sedimentation in the wetland and reduction of storage capacity*: Although large volumes of water, and presumably of sediment, flow from the upper catchment, the inflection point between hills and plains is generally sharp. The resulting rapid reduction in energy results in fan or delta type formations. Thus, it appears that coarser sediment is deposited early and not transferred into the wetlands. Moreover, water stored in the wetland below the level of the rock lip is in dead storage and

cannot contribute to flows downstream during the dry season. In effect, sedimentation in the wetland should have a beneficial effect by decreasing the volume of dead storage.

The points made above should not be seen as an outright rejection of the traditional explanations for the drying up of wetlands. These mechanisms may be contributory and will be investigated in the course of this study. However, the contention here is that either singly or in combination, they may not fully explain the changes in water flow. The Danida/World Bank study (1995) reaches a similar conclusion regarding the problems at Mtera: "No single factor can be picked out as the only responsible" (p. 11).

The Coexistence of Wetlands and Rice Irrigation

Initial research by the SMUWC project on water transfer between wetlands and irrigation indicates that a variety of processes and interactions exist, to the extent that wetlands and extensive areas of irrigated rice might coexist given certain conditions. Four main factors—climate, hydrology, irrigation characteristics, and wetland characteristics—together with a number of subfactors controlling such conditions are given in Table 1, drawn from the situation found in the Usangu Plains. The table is constructed to argue cases supporting and inhibiting coexistence. This method departs from the usual one of examining wetland hydrology by concentrating on the water budgets of the wetlands themselves (see Mitsch & Gosselink, 1993). The need to identify and quantify the principle causal factors involved, nevertheless, would be relevant in a wider analysis and could be used for a future, more comprehensive methodology to understand the wetland-irrigated agriculture interface. The table is explained in greater detail in the following paragraphs.

CLIMATE

Each year, the rainfall–evaporation balance affects the potential to generate runoff volume passing through the plains to downstream Ruaha. The balance, in turn, affects the degree of interdependence of the water users. A balance that increases rainfall over evaporation would reduce interdependence, whereas a fall in water sufficiency would increase competition between users. Thus, in drier years, the upstream rice cultivators tend to obtain the greater share of water due to their advantageous position. This was what happened in the dry year of 1998-1999, when inflows were found to be negligible as late as February 1999, and the core area of the perennial swamp shrank to about 85 km^2.

Table 1
List of Factors That Promote or Prevent the Coexistence of Wetlands and Rice Irrigation

	Condition in Usangu Enabling Coexistence	*Condition in Usangu Inhibiting Coexistence*
1. Climate		
Rainfall-evapotranspiration (P/ET) balance	(P/ET) balance remains within normal limits	(P/ET) balance alters throughout the basin
2. Hydrology		
Rainfall-runoff relationships in upper catchment	Upper catchment rainfall-runoff relationships remain unchanged	Increasing irrigation and/or change of upper and/or change of upper increased storage of water and evaporation and therefore lower runoff
Rainfall-runoff relationship on plains and fans	Rainfall-runoff relationships remain insignificant or unchanged	Rainfall-runoff on plains and fans is significant and changes due to increased rice cultivation
Changes in and magnitude of evaporation processes	Evaporation from runoff on outwash fans is replaced by evapotranspiration from smallholder rice (the latter exists in an evaporative niche)	Smallholder rice extends the area of diversion for the area of diversion for given P/ET balance thereby increasing the volume evaporated
3. Irrigation characteristics		
Source of water supply	Source of water for rice is mainly rainfall for the smallholder systems	Source of water is mainly rivers as in the large irrigation schemes
Balance between supply and demand over whole year	Positive balance between rain/river supply and demand from all users over the year	Negative water supply balance over the year as domestic/agricultural demand increases
Proportion of runoff after diversion re-entering drainage lines	Significant runoff from diversion systems re-enters natural drainage lines to swamp	Runoff does not drain back, but ponds and evaporates
Efficiency and volumes of river abstraction	Diversion structures inefficient at abstracting all river water	Diversion structures being upgraded either in robustness or volumetric capacity

(continued)

Table 1 Continued

	Condition in Usangu Enabling Coexistence	*Condition in Usangu Inhibiting Coexistence*
4. Wetland characteristics		
Volumes of water held in permanent swamp	The permanent wetland holds sufficient water to last throughout a drought event	The volume of water in the permanent swamp is insufficient to secure a core swamp area
Loss of water from wetland via drainage	The wetland is not drained via groundwater seepage or rundown from surface water drainage	Abnormal run of drought years leads to substantial evaporative loss of water
Internal drainage and routing of water within the swamp	Water is channeled through the swamp margins to refill core swamp area	Water spills from main channels to refill swamp pools and shallows
Encroachment on wetland by rice	The wetland is not encroached on by rice	No threat from this process
Use of wetland-sustaining rivers	The Ndembera may be the only remaining perennial river	All perennial rivers continue to be under threat (e.g., Madibira scheme)
Supply of groundwater to wetland	Groundwater from upstream seepage losses recharges the wetland	Groundwater moves to geological water or to recharge water tables further down the basin

This contrasts with the wet year of 1997-1998, when rice expanded to about 50,000 ha, and the area of seasonally flooded grassland stood at more than 2,500 km^2. This dynamic response of both swamp and rice in wet years—without observable conflict—indicates that a static competitive scenario with sequential consumption of water is too simplistic.

HYDROLOGY

The first two hydrological factors are the rainfall–runoff relationships on the upper catchment and on the plains, both of which translate rainfall to runoff. The cooler, wetter, higher catchment is the more significant runoff contributor to the Usangu wetlands; the rainfall–runoff relationship on the plains is currently unknown.

However, two alternative scenarios affect the coexistence of wetlands and rice. Coexistence is favored if the introduction of rice has little effect on runoff from the plains, or if prior to rice cultivation, runoff was relatively insignificant. In contrast, if the presence of rice reduces downstream rainfall-generated runoff, then this would have a deleterious effect on the wetlands in normal and drier years as the moisture-holding capacities of soils here are very high (200 to 400 mm, or more). Second, an examination of the surface of the soil reveals widespread and deep natural cracking, even where there is strong evidence of cattle. This would be expected in environments with clay soils that combine strong wetting and drying cycles, and it suggests that cattle do not have a long-lasting effect on infiltration. Third, the low gradients (between 1:200 to 1:3000) of the plains promote localized ponding of water and subsequent infiltration. Although the addition of 100 to 150 mm storage due to ponding in bunded rice fields combined with higher canopy factors of evaporation may be important, it has to be measured against the capacity of the natural environment to store and evaporate water.

The third hydrological factor considers changes in runoff from the diversion of water out of rivers onto land. In other words, this factor describes the change in magnitude of loss of river flows via spreading and evaporation due to the expansion in the area or change in type of irrigation. Conditions in Usangu would favor coexistence under this factor if certain kinds of rice irrigation fit into an evaporative niche, giving rise to—or exploiting—the evaporation of water that otherwise would occur naturally after spreading onto outwash fans or after refilling of intermediate fan swamps. This braiding and spreading is a consequence of the sharp break in gradient from the escarpment and high deposition of sediment loads under reduced kinetic energy. Smallholder, indigenous systems may be the main kind of rice cultivation that fits this criterion. Here, rice is grown on outwash fans close to perennial and seasonal rivers, using both river and rainwater.

IRRIGATION CHARACTERISTICS

There are four key characteristics of rice irrigation that influence the amount of water abstracted from the river systems, thereby reducing downstream supply for the Usangu wetland.

The first is the timing of cropping and the arrival of rains. There is evidence to indicate that, by necessity, most of the smallholders wait until the onset of rains before planting their rice fields. Although they do indeed abstract water from rivers during rain, the latter reduces their demand for river water as the sole source. Therefore, at certain flow rates, a higher proportion of river water is likely to reach the wetland.

However, the dependence on rains is not found on the large-scale state farms. The intense use of perennial rivers throughout the dry season to prepare land and germinate unwanted weeds constrains the ability of the river system to supply water to both rice and wetland.

Measurements and discussions with farm managers indicate that up to maximum intake capacity (about 8,000 l/sec), the state farms take 70% to 90% of available river water. The design of the offtakes (see subfactor d) is important in assisting this abstraction.

The next subfactor is the annual volumetric balance between supply and demand. This factor is significant because of the wetland's capacity to store water, with a positive balance recharging it. With a given supply dictated by climate and hydrology, coexistence is favored by improving demand management by upstream users, which involves measures to control the area under irrigation and the specific demand per unit area. Area is limited in five ways. First, after February, transplanting ceases (due to low end-of-season temperature regimes), thereby fixing the area at whatever has already been established. After this, only maintenance flow of water remains. Second, some farmers say that restricted availability of labor stops them from preparing land sooner. Third, dry season agriculture is traditionally rare, although it is becoming more widespread. Fourth, both the lay of the land and river water levels may set the area under command. Last, area limits may be set by managerial/community decisions. When the irrigated area is fixed, specific demand (l/sec/ha) becomes a controlling factor. Then, soil wetting, evapotranspiration, seepage, and on-field water management affect water demand at the field level, which in turn is also determined by the choice of crop—basin-irrigated or other rice.

Basin-irrigated rice has a higher water demand than most crops because of presaturation of the soil profile and the need for a standing water layer. The question of the appropriateness of growing rice in a water-stressed area such as the Usangu plains is a valid one. The political economy of rice cultivation is too large a topic to enter into here, but currently, from a farmer's point of view, the rice market is well established and lucrative as compared to the market for other crops.

If rice is grown, field demand can be reduced by adhering to a target depth of water in field preparation, minimizing the time between first irrigation and transplanting, achieving a uniform water depth by leveling fields and altering the size of bunded plots, adequately controlling the small amounts of water used in nursery preparation, puddling and smearing soil to reduce seepage, adhering to a target depth of standing water during the growing season, reducing the overall season length through varietal selection, and draining water near the end of the cropping season when rice yield is less sensitive to water.

Pressure exists to use more water and cultivate more land. New farmers are arriving to either rent land or provide labor for existing farmers, who then open up more fertile lands elsewhere within the potential command area of the rivers. Furthermore, dry season irrigation appears to be on the increase, as is the demand for security and domestic water, particularly under state schemes that provide water to large numbers of surrounding homesteads and villages.

The third subfactor concerns the volume of water from fields that re-enters drainage lines feeding the wetland. This is an important facet of the argument that irrigation schemes in the Usangu can be locally inefficient while efficiently fitting into the hydrological context by ensuring runoff to downstream users. This point was raised by Keller, Keller, and Seckler (1996) and Seckler (1996) in their analyses of local efficiency as compared to basin efficiency. Coexistence is, therefore, favored if a greater proportion of the system's drainage water flows back into the rivers. Ideally, irrigation systems would be situated adjacent to rivers. However, if drainage is poor because existing and new irrigated areas are far from connected drainage lines, or because drainage lines are blocked, then true losses from the system will take place via evaporation from ponded and spreading water.

The fourth irrigation characteristic is the mechanical efficiency with which irrigation systems divert water at larger river-flow rates. At comparatively low flow rates, irrigation diversions are able to abstract most of the river water, but during flood conditions, more water bypasses the diversions to feed the wetland. This division is affected by the design of the irrigation offtake in four ways. First, the construction of the operating mechanism affects the timeliness of response, which can occur either instantaneously by automatic means (such as a fixed weir) or with a delay if by human input. Second, the design of the head control mechanism (e.g., a weir) controls the proportion of water abstracted for a given river flow rate. For example, the Mbarali scheme weir diverts 100% of the river flow up to the maximum possible capacity of the scheme's main canal, if the head gates are opened fully, whereas the Kapunga offtake has no weir and relies on human adjustment of a series of control gates. Third, the maximum abstraction rate allowable sets the ceiling beyond which water is not diverted and necessarily remains in the river. This maximum rate is either controlled by the gate dimensions or the capacity of the main canal downstream from the gate. Fourth, the robustness of the offtake to withstand high flow rates affects its ability to continue to abstract when the river is in spate. The sand and gravel embankments used by smallholders are washed away in flood conditions, and it can take several weeks to rebuild them to provide water to downstream users.

There is upward pressure to increase abstraction, not only because new intakes are being constructed but also because many farmer groups want to enlarge or upgrade their intakes to permanent concrete (principally to save labor and costs of repair). This increases the volume of abstracted water.

WETLAND CHARACTERISTICS

The final six factors are those that relate to the characteristics of a wetland. The first concerns the storage characteristics of the permanent wetland and its ability to capture wet season runoff. A permanent wetland can expand to 2,500 km^2 or more. It has been suggested that sedimentation is reducing the volume that can be stored. However, this may simply change the form of the inundated area (i.e., more extensive, but shallower) rather than lead to an absolute decrease in flooded volume. The total volume/area of water in the permanent swamp has yet to be measured by the SMUWC project.

The second factor is the drainage of the wetland affecting both surface and groundwater during dry periods. The Usangu swamp is resilient to drainage because of low seepage rates and because the rock lip at the tail end of the swamp, which is resistant to erosional scouring, stops water being drained off by gravity. The area of the perennial swamp at this point is probably between 150 and 250 km^2. However, the swamp is under threat from evaporative losses during an abnormal run of drought years. Depth tests of the swamp will determine the interannual storage volume available.

The third factor depends on the assumption that a proportion of the water available to the whole swamp may have a higher functional value in certain areas of the swamp, such as the core area. This area could have more important rural livelihood functions, such as supporting fisheries and wildlife during extended drought periods. If this is the case, then the internal drainage and routing of water will determine where that water ends up. In a sense, this creates an efficiency factor in the supply of water to meet the demand required by a core swamp area. The coexistence scenario requires a higher swamp-supply efficiency, whereby water arrives at the swamp margin channels through to the core area rather than being used in refilling temporary pools and shallows in the seasonal swamp area.

The fourth factor is the encroachment into the wetland by rice fields. This would normally happen at the periphery of the wetland by the establishment of canals, drains, and bunds. This is not found in Usangu, where the upstream borders of the wetland are protected from encroachment due to unsuitable soil types and subdued topography prone to deep inundation. It is important that the wetland is not threatened by downstream development of irrigation because of hilly topography.

Fifth, rivers differ in their ability to directly supply the wetland. It has been noted that some Usangu rivers do, or recently did, play key roles in sustaining the wetland. These rivers are (or were) less prone to natural diversion and spreading and therefore channel water more directly to the swamp, in contrast to diverted rivers where a more significant proportion of the flow does not reach the swamp either due to natural or

Table 2
The Four Types of Rivers Feeding the Usangu Wetlands

		Flow Routing	
		Channeled (A given increase in inflow results in a proportional increase in outflow to swamp)	Diverted (A given increase in inflow results in a much smaller increase in outflow to swamp)
Regime	Perennial (Flow throughout the year)	Only possible exception is the Ndembera (the Mbarali River, with no natural swamps, was this type before the offtake was constructed)	After the construction of the Madibira farm, it is likely that all perennial rivers will now be of this kind
	Seasonal (flow ceases during dry season)	Probably no examples	All seasonal rivers are probably of this type as all spread to some extent on deltaic fans

human diversions. This classification (see Table 2) extends the commonly perceived nature of riverflow (perennial and seasonal) to a matrix of four types whereby, in terms of importance for the swamp, the following sequence is proposed: channeled–perennial, diverted–perennial, channeled–seasonal, and diverted–seasonal. Criteria to classify the Usangu rivers have yet to be decided, but it is known that the Mbarali river was a deep channeled river that supplied the swamp until it was blocked and diverted for the Mbarali Scheme in 1974, thereby turning it into a diverted–perennial river. Thus, conditions under this factor are not promoting the coexistence of rice and wetland. The Ndembera is the last remaining perennial river that has not been diverted to any great extent, but this, too, is under threat from the new Madibira large-scale scheme, which could divert up to a ceiling of about 8,000 l/sec all of the available river water.

Sixth, groundwater movement might transfer water from either the high catchment or irrigated lands to the wetland. This would depend on the scale of seepage movements and whether the wetland represents the level of the basin water table in this area. If groundwater from upstream seepage recharges the swamp, then this favors both rice, which releases water as seepage, and the wetland, which recaptures the water. If, however, groundwater moves to geological water or recharges water tables further down the basin, then irrigation seepage becomes a true loss to this subsystem.

Sustainability Issues

The above analysis suggests that both wetlands and rice irrigation are sustainable, given a number of arguments. First, policies to promote the sustainability of wetlands should explicitly acknowledge the nonequilibrium dynamics that are increasingly recognized as a defining feature in the ecology of semiarid sub-Saharan Africa (Behnke & Scoones, 1993; Scoones, 1991). A key feature of the Usangu wetland is the expansion and contraction both of the perennial swamp and the seasonally flooded grassland. However, livelihoods and fisheries dependent on the swamp require a resilient core that can last through drought periods of a year or more. This is the scenario in Usangu at present, although it remains to be seen whether substantial changes occur as a result of prolonged drought conditions.

Similarly, rice irrigation sustainability cannot be viewed in usual terms due to its dynamic response to the amount of water available to the system. The area cultivated in a wet year is not sustainable in a dry year. Farmers understand this; they treat the reliability of water as risk prone and view rice as a cash crop rather than the main staple, which is rain-fed maize. However, like the resilient swamp core area, the perennial streams supply core irrigated areas, which consist of the state farms and the top-end areas of some of the smallholder irrigation systems.

The sustainability of the coexistence of rice and swamps is dependent on rice cultivation being the small-scale type, with its niche-fitting properties and practices. Therefore, the ratio of small– to large-scale irrigation becomes important, as does the area under large-scale irrigation. At present, about 29,000 ha is defined as small-scale, and 11,000 ha is large-scale. This latter figure may be the maximum possible, beyond which there would be real trade-offs between water used in situ and downstream releases.

Threats to this sustainability exist. There is upward pressure on the area of smallholder irrigation. More seriously, the 3,000 ha farm, Madibira, could take water from the last untapped perennial river supplying the wetland. There are also threats from an increasing desire to upgrade to permanent concrete offtakes and build new ones for smallholder irrigation systems and to use water during the dry season.

Some Implications for Water Policies

The justification for irrigation improvement projects in Usangu is made on the basis that water saved through improvements in efficiency will be returned to the river system, contributing directly to increased flows downstream at Mtera. However, this does not take into account crucial physical linkages in the hydrological system. Considerable losses occur through evaporation in the wetland itself, with the result that a cubic meter of water saved in the irrigation systems or river flows in the Usangu basin does not represent an additional cubic meter of water flowing through the turbines at Mtera. The challenges facing the concept of re-allocation under integrated water management in sub-Saharan Africa are considerable, to the extent that it may throw doubt on the initiative, a point raised by Carter (1998) in his studies of water policy in Nigeria.

Another important set of policy options relates to the use of water for irrigation, which provides the most obvious point at which to try and influence the water balance of the basin. Current interventions are mainly aimed at improving the efficiency of smallholder irrigation and at changing the management and perhaps ownership of large-scale farms. Smallholder improvement projects (which are still being promoted; e.g., Danida, 1998) must be based on appropriate concepts of irrigation efficiency. As said earlier, the efficiency of smallholder systems is very high in the early part of the season, when all available water is used for irrigation. Measures to increase upstream control may not result in any increase in system efficiency at this time but may conversely lead to increases in conflicts and inequity between top enders and tail enders. Conversely, during the middle of the rainy season, irrigation efficiency may be very low, with considerable runoff occurring. However, during this time when water, particularly river water, is abundant, low measures of inefficiency have little real meaning. A new way of addressing dynamic irrigation efficiency is required in such water-variable environments.

Similarly, the impact of any change in management or ownership of the large-scale state farms must also be carefully considered. Their size and extensive irrigation infrastructure make them potentially very significant users of water, even if at present their area of cropping is far less than maximum potential. The main policy interventions in regard to irrigation are water rights, water charges, and organizational arrangements such as irrigation management transfer, water management committees, and water users associations. Simply increasing the ratio of farmers to irrigated area on the state farms may promote sufficient internal competition and care for water to decrease the specific demand for water at the field level.

The different types of rivers feeding the wetland imply that a situational analysis could lead to refined policies at this level. For example, the success and monitoring of water rights might fare better in perennial rivers with fewer offtakes than on seasonal rivers with many smallholder offtakes.

Conclusions

This case study illuminates some facets of water management and provides important conclusions. The Usangu hydrological environment is complicated and potentially provides rainfall and evaporative niches into which types of rice irrigation may fit alongside wetlands. This analysis describes the kind of conditions that are found in sub-Saharan Africa and extends the framework of understanding of these processes so that other river basins may be examined in a similar manner. Although not posed as a model of competition between wetlands and agriculture, this analysis could form the basis of deterministic modeling of water between sectors within a river basin.

Some lessons are emerging from the work done to date. First, policy formulation must be underpinned by a sound understanding of the physical, economic, and institutional linkages of the water resource system. In the case of Usangu, for example, these linkages are imperfectly understood. With respect to the specific issue of attempting to release more water downstream from the plains, it is imperative that the site-specific nature of irrigation in a river basin context and its fit with the conditions within the river basin should be understood. Guerra, Bhuiyan, Tuong, and Barker (1998) stress the need for flexibility by using a systems approach within the river basin to determine where water may best be saved. Interventions may be tailored based on the identification of sites and situations whereby water may be cost-effectively released downstream.

Policy makers should also recognize the disequilibrium of water regimes in the area. The uncertainty of climatic and hydrological dynamics complicates matters considerably; at one dry extreme, no water exists to be reallocated, and at the other, there is sufficient for all, well distributed by natural processes. Such extremes are not rare in sub-Saharan Africa. It may be important to begin to foster policy thinking that distinguishes between stable and dynamic irrigation systems—the latter being marked by their ability to dramatically change the area irrigated, planting schedules, number of farmers supplied, runoff volumes, and efficiency. Clark and Gardiner (1994) examine the implications of uncertainty in river basin management and conclude that realistic assumptions and attitudes that acknowledge uncertainty will be the basis of good policy and decision making.

This situational analysis of the basin should be viewed as a central part of capacity building for the people and institutions involved. On the basis of a review of the papers in the special thematic issue on capacity building for integrated water management (Biswas, Hartvelt, & Tortajada Quiroz, 1996), it would appear that the need to understand the processes of natural and technical re-allocation of water is given a low priority. Even less appreciated is the notion that this understanding can be used to design capacity building more appropriately.

Rice irrigation is multifaceted and cannot be viewed in narrow terms. Its many facets include ownership, location on river type, prevailing in-field water control practices, design of intake, changeable areas, cropping and water use calendar, re-use and runoff characteristics. Irrigation efficiency is also multifaceted, often poorly defined, and dynamic. Efficiency interventions funded by agencies are unlikely to result in savings. To date, improvement projects applied to the water management of smallholder schemes have shown no evidence of improving efficiency or yield. Thus, certain types of smallholder systems may already be relatively efficient and fit with the hydrological environment. SMUWC aims to conduct research to determine indicators of efficiency and the area of smallholder irrigation that can fit alongside the wetlands.

It is proposed that the sustainability of coexistence of wetlands and rice requires an understanding of nonequilibrium dynamics of both rice cultivation and wetlands, acknowledging core areas of both, which may be relatively resilient features. Only in exceptionally dry years would both come under some degree of threat. In the future, as there is continuing upward pressure on the amount of land converted from bush to rice, the balance may be upset, thereby favoring upstream agriculture over downstream wetlands.

Suitable water resources policies have yet to emerge. These will have to recognize the complexity of water resources management in the area and be targeted at site-specific processes, conditions and issues. Reevaluating irrigation efficiency will be an important part of that. However, establishing local capacity to manage water competition within and between irrigation systems using the concept of river committees remains an important priority. Perhaps the greatest challenge will be the measures needed to constrain and manage the area that continues to be converted from bush to rice. This will depend on local village organizations, which are aware of the problem, and the enabling policy and support environment provided by local and national governments.

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