Available online at www.sciencedirect.com
SCIENCE DIRECT
ELSEVIER
Agricultural Water Management 69 (2004) 135–153
Agricultural water management
www.elsevier.com/locate/agwat

Entrenched views or insufficient science? Contested causes and solutions of water allocation; insights from the Great Ruaha River Basin, Tanzania

Bruce Lankford[a,*], Barbara van Koppen[b], Tom Franks[c], Henry Mahoo[d]

[a] *School of Development Studies, University of East Anglia, Norwich NR4 7TJ, UK*
[b] *International Water Management Institute, South Africa*
[c] *Bradford Centre for International Development, UK*
[d] *Soil Water Management Research Group, Sokoine University of Agriculture, Tanzania*

Accepted 15 April 2004

Abstract

The case study describes large-scale environmental change related to, and recent responses associated with, growing water scarcity in the Usangu Plains, a catchment of the Great Ruaha River in south-west Tanzania. The analysis uses outputs from two recent projects to critically examine various theories of environmental change and the 'fit' of new river basin management strategies to the problems found, arguing that various perspectives are worryingly at odds with each other. We find that the investigators of the two projects presented a reasonable and sufficient case of the causes of water scarcity. Yet despite efforts to disseminate scientific findings, different stakeholder groups did not agree with this case. This, we believe, was due to three combined factors; firstly highly entrenched views existed that were also based on quasi-scientific reasoning; secondly, the projects' deliberations to date, in acknowledging their own uncertainty, were not assertive enough in ascribing causation to the various processes of change; thirdly, policy-uptake was not sufficiently managed by the scientists involved. We conclude that this complexity of the science–policy interface is a feature of integrated water resources management (IWRM) and that the norms of scientific uncertainty in the face of competing theories (held by their protagonists with greater certainty) obliges scientists to take a more active role in sensitively managing the advice-to-policy process in order to improve management of water within river basins. Thus, the paper argues, the nature of integrated water resources management is one of 'action research' to move towards an improved understanding of change, and of 'action policy-advising' to draw policy-makers into a cycle of considered decision-making.

Keywords: River basin management; Environmental change; Tanzania; Irrigation; Science; Policy; Institutions

* Corresponding author. Tel.: +44-1603-593378; fax: +44-1603-451999.
E-mail address: b.lankford@uea.ac.uk (B. Lankford).

0378-3774/$ – see front matter © 2004 Elsevier B.V. All rights reserved.
doi:10.1016/j.agwat.2004.04.005

1. Introduction—science in policy debates

The policy context of this paper concerns deliberations over how and why science contributes towards policy formulation and stakeholder-understanding within the realm of integrated water resources management (IWRM). This challenge is within the framework of long term, extensive environmental change (Lubchenco, 1998) that combines complex feedback loops between social, hydrological, biophysical, and economic causes and outcomes, and that are often studied using insufficient resources and time frames (Mills and Clark, 2001).

The paper argues that scientists working in IWRM face not only theoretical and methodological challenges in uncovering causes of environmental change but also face difficulties in ensuring that well-informed solutions are taken up by policy-makers to discuss and tackle such change. The authors find that IWRM is composite in nature and suffers from 'multiple jeopardies'. Firstly, environmental-change theories may mesh in ways that appear integrated or plausible but do not hold up to scrutiny or may cloud out more subtle 'integrated' causes. Secondly, we feel that insufficient resources, emphasis and time are given to research and that research should be on-going to monitor cause and effect relationships. Thirdly, an integrated approach should not preclude single-discipline contributions in both assessment and in providing efficient solutions to water shortages. Fourthly, and related to the previous point, IWRM is a relatively new science; many approaches are untested and, even if theoretically sound and respectable, may not suit a given situation. Fifthly, we believe that normal, acceptable scientific uncertainty in drawing up conclusions and policy recommendations generates special threats to their eventual acceptance by peers and stakeholders who might seek greater certainty in policy formulation. The measure of success of policy-uptake is not only adoption, but also whether we frequently revisit a policy's assumptions, objectives and means in order to refine or revoke it. Thus, successful IWRM is iterative IWRM. The paper concludes with a discussion on this reflective approach.

The paper does not concern itself so much with the role of science in affecting *public* perceptions of environmental change, itself a rich debate (Chopyak and Levesque, 2002; Collingridge and Reeve, 1986; Joss, 1999), but tackles instead the more direct interchange between advisory scientists and water policy decision-makers. It also does not deliberate on wider issues related to an examination of the positivist role of science in advising policy. Instead, it supports the view that it is a mistake to suppose that good science can always provide a 'right answer for science-based policy disputes' (Herrick and Jamieson, 1995), and concludes on ways in which scientists can actively solicit effective policies. Lastly, the authors are not concerned with definitions of policy; for the sake of this analysis, 'policy' loosely encompasses a range of activities attempting to alter social, institutional and individual management of natural resources.

This paper also does not tackle in great depth lessons learnt in the use of dissemination tools, since these are arguably a separate enough issue to be dealt with elsewhere. Nonetheless, dissemination tools and their strategic use are part of the interaction between scientists and policy advisers, and retrospectively lessons were learnt—for example, the use of a 'national champion' to promote policy advice was deemed useful towards the tailend one of the projects. Engagement with national press was also found to be important, since various inaccuracies about environmental degradation were being promulgated here.

Some of the theory of the multiple role of scientists in policy-making discussed by Farrell et al. (2001) highlights the merging of boundaries between advisers and policy-makers; "that individuals and institutions can and do play multiple roles in (and around) assessment processes. They often participate in scientific and technical assessment, policy recommendation, and policy-making—though usually in different forums" (p. 325). Bolin (1994) reminds policy-advisers to be aware of the context within which policy-makers are working, while Winstanley et al. (1998) caution scientists starting in fields that are already laden with value-judgements about cause and effect:

> Great care should be exercised in specifying the policy questions to be addressed by technical experts. Policy questions are often posed in highly value-laden terminology, which may be unnecessarily divisive and unsuitable for scientists to answer objectively. Words like degradation, adverse, impact dangerously, critical loads, targets, acceptable and safe often appear in policy-relevant questions, but these are value-laden and require nontechnical input to answer. (p. 54)

Winstanley et al. (1998) also point out the pitfalls of scientific certainty and uncertainty in policy advice, a point returned to in the conclusions of this paper.

> Not every piece of scientific information is of equal value in policy analysis: an 'educated guess' might be acceptable in answering some questions; 'near certainty' is required for others. For critical elements of policy analysis, a statistical confidence interval might be necessary. (p. 56)

In the case study introduced below, the funding agency asked that the project consultants determine the reasons for environmental change and then to feed this into the client's process for making policy. Thus the project explicitly envisaged direct linkages between advisers and policy-makers. This intended collaboration at the outset provides an interesting contrast to what retrospectively might be termed 'only relative success' in altering key water management policy.

2. Background and introduction to the case study

The geographical context of this study is the Great Ruaha river in the Southern Highlands of Tanzania (Fig. 1). The Usangu basin, or Upper Ruaha basin, covers an area of 21,500 km^2 and forms the headwaters of the Great Ruaha River, itself a major sub-basin of the Rufiji River. Usangu may be broadly divided into the central plain and a surrounding higher catchment. The plain receives 600–800 mm average annual rainfall with a rainfall gradient to 1500 mm onto the high catchment. Most of the rain falls in one season from mid-November to May.

This basin is of national importance due to the utilisation of its water for significant rice production, maintaining a RAMSAR wetland site, meeting ecological needs for the Ruaha National Park and for the generation of hydro-electric power. Thus, six main water resource users from upstream to downstream can be differentiated as: (1) rainfed farmers and domestic water users in the high catchment; (2) irrigators in the plains at the base of the escarpment; (3) domestic users and rain-fed maize cultivators in the plains; (4) pastoralists

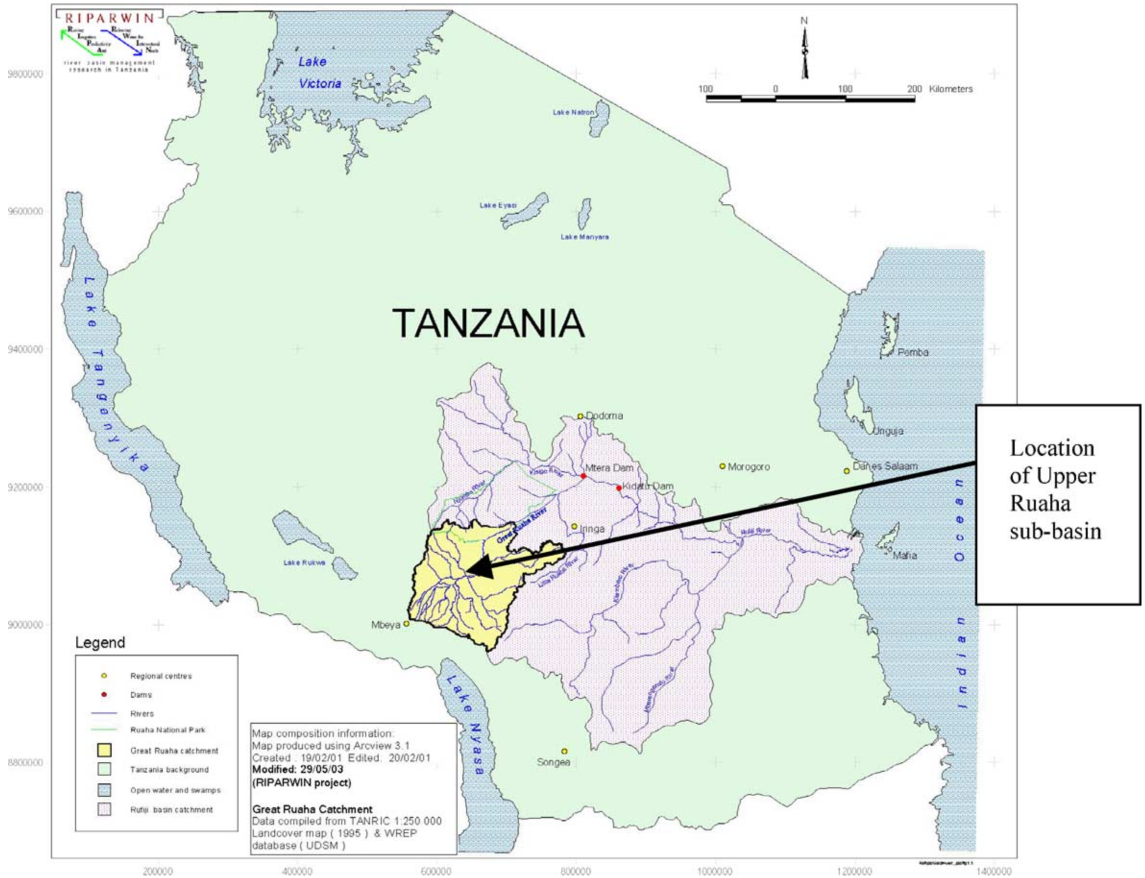

Fig. 1. Location of the Upper Ruaha Basin in the Rufiji Basin in southern Tanzania.

and fisherpeople in the central wetland; (5) wildlife and tourists to the Ruaha National Park that surrounds the riverine reach; and (6) the Mtera/Kidatu hydropower stations of the Tanzania Electricity Supply Corporation (TANESCO). Below these stations, the river basin has no further significant user, and after meeting the Kilombero river, becomes an open river basin.

Hydrological change was the rationale for the project “Sustainable Management of the Usangu Wetland and its Catchment” (SMUWC, 2001; DFID, 1998) which resulted from national and local concerns about the management of water and other natural resources in the Usangu basin in southern Tanzania. In particular, national power shortages in the mid-1990s were attributed to low flows to the Mtera/Kidatu hydropower schemes from the Ruaha. A reduction in low flows in the Great Ruaha where it passes through the Ruaha National Park was also noted. There has now been a succession of years in which the river in the park has dried up completely during the dry season, and for increasing periods. An increase in competition for water was noted in Usangu itself, leading to conflict and sometimes violence. Concern was also expressed that the wetlands in the project area were diminishing and degrading, and that a valuable natural asset was being lost. The case study is described in a number of articles (Franks et al., 2004; Lankford and Franks, 2000; Baur et al., 2000; Lankford, 2001).

There are five perennial rivers and a large number of seasonal streams draining from the high catchment. Surface flows, rather than groundwater, are used for domestic and agricultural purposes because groundwater is far less in quantity and its location less predictable. Most irrigation is located on the upper parts of the plains (Fig. 2) and consists of 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)—these farms also provide domestic water via canals to villages that have grown up within them.

Downstream of the irrigated areas, drains discharge into smaller streams and swamps located towards 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 seasonal wetlands, and at the deepest point, a perennial wetland. Although the swamp is a maze of channels and lagoons, many of which are at different levels, it is represented conceptually as a simple reservoir with a fixed spillway exit consisting of a rock bar. When the water level in the perennial wetland is low, no water leaves the exit. As the water level rises, water spills over the lip into the Great Ruaha River. After leaving the wetland, a number of ephemeral rivers join the Great Ruaha River as it flows through the Ruaha National Park. Downstream, the Mtera Reservoir 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.

3. Recent approaches to river basin management

The recent history of policy-in-action in the area reveals interesting dimensions to river basin management and integrated water resources management. In the Usangu Plains, essen-

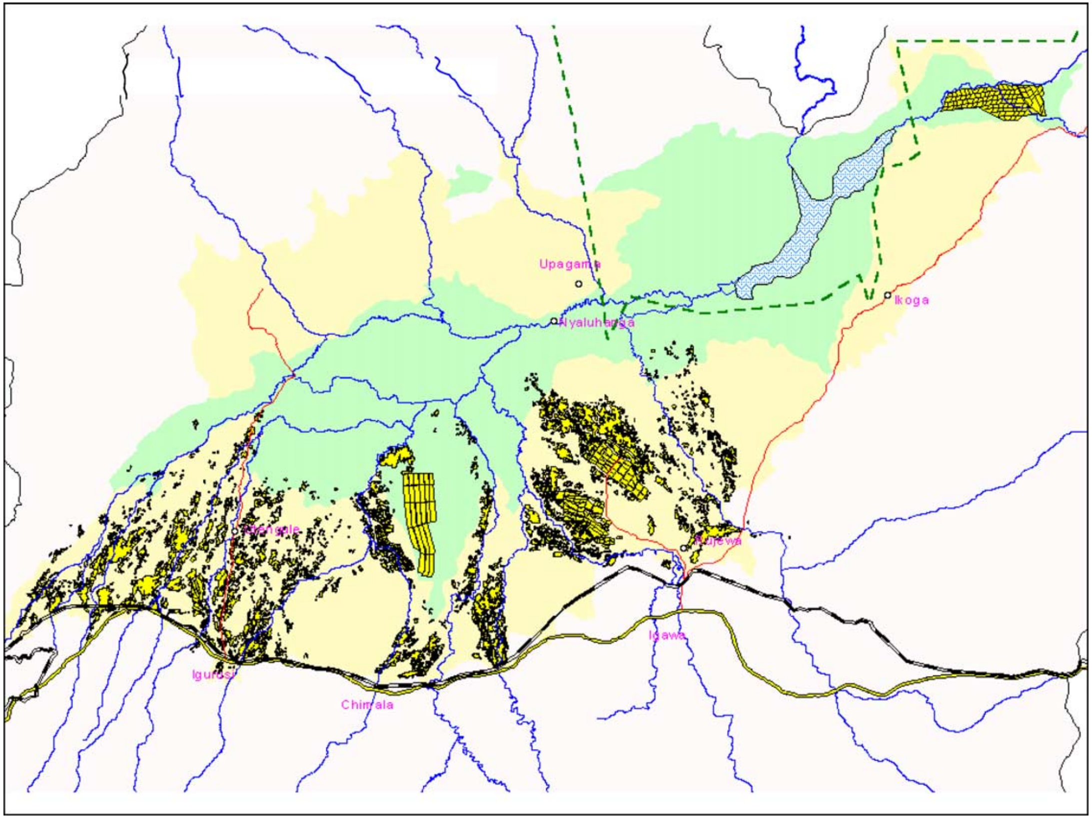

Fig. 2. Location of irrigated lands within the Usangu Plains.

tially three key river basin programmes were devised and implemented under the Ministry of Water and Livestock Development (MoWL) within the last 6 years. These are as follows.

First, the Rufiji Basin Water Office (RBWO). Basin Water Offices represent the new basin structure that the MoWL is gradually implementing nation-wide, with the Rufiji, the Pangani and Lake Victoria as the first pilot basins. A sub-office for the Usangu Plains in Rujewa, Mbarali District, was opened in 2001. The main activity of this sub-office is the issuing of water rights.

Second, the River Basin Management and Smallholder Irrigation Improvement Project (RBMSIIP) (World Bank, 1996). This project started in 1996 and is funded via a World Bank loan. The aims are (i) to strengthen the government's capacity to manage water resources and address water-related environmental concerns both at the national level, and in the Rufiji and Pangani basins (the river basin management (RBM) component under the MoWL) to help fund activities of the basin offices; and (ii) to improve irrigation efficiency of selected smallholder traditional irrigation schemes in these two basins principally by the construction of concrete weirs and intake structures with control gates (the SIIP component under the Ministry of Agriculture and Food Security). In the Usangu Plains, the RBM component is funding the sub-office of the Rufiji Basin Water Office. Also, two concrete intake structures have been constructed in streams shared by a number of traditional irrigation schemes under the SIIP component of the project.

Third, the "Sustainable Management of the Usangu Wetland and its Catchment" (SMUWC, 2001). SMUWC started in 1998 and ended in 2002. The direct client of this DFID-funded project was the MoWL (Rufiji Basin Water Office). The project also worked closely with the district administrations of the project area, as well as the Ministry of Agriculture and Food Security. SMUWC intended to investigate the nature and causes of hydrological changes, and to assist the Government of Tanzania and key stakeholders (both local and national) in the development of a sustainable natural resource management strategy. Ultimately, it expected to contribute to the maintenance and improvement of rural livelihoods. It had four main outputs (SMUWC, 2001).

1. Understanding the hydrological behaviour and water quality functions of the Usangu wetlands and their catchments.
2. Assessment of the land resource utilisation, biodiversity and environmental impacts of management options in the Usangu wetlands and their catchments.
3. Assessment of causes of conflict, community management options and institutional process relating to the natural resources of the Usangu Wetlands and their catchments.
4. Increase of local capacity (at different levels and in different institutions) to develop and implement an integrated natural resource management strategy, i.e. assist the Rufiji Basin Water Office (RBWO) and provide policy guidance for the World Bank River Basin Management and Smallholder Irrigation Improvement Project.

In partnership with the World Bank project, SMUWC contributed to the drafting of a national water policy, strengthening of basin management institutions and the rehabilitation and upgrading of the hydrometric network (DFID, 1998). In addition, there were a number of specialist studies, including: groundwater assessment, catchment degradation and conservation studies, water use and water rights surveys, participatory basin management, and water quality and environmental pollution monitoring. In partnership with the Rufiji Basin

Water Office, SMUWC initiated a partial canal closure programme, designed to ensure a reduction in dry season abstraction from the three key rivers feeding the wetland. To this end, negotiations with three main state farms reduced their water during the dry season to allocate enough water for domestic use rather than for irrigation of fields that were visibly not producing crops of any type.

Following SMUWC, the DFID/IWMI-funded 'Raising Irrigation Productivity And Releasing Water for Intersectoral Needs' (RIPARWIN) project aims to continue to study the role of irrigation efficiency and productivity in releasing water for intersectoral needs. The main partners in this collaborative research are Sokoine University of Agriculture, the Overseas Development Group of the University of East Anglia, and the International Water Management Institute.

Besides these programs, the Mbarali District Government with the support of the Ministry of Natural Resources and the Ruaha National Park pursues far-reaching land use measures to control livestock on the plains. These actions aim at the conservation of the Usangu Wetland and the restoration of perennial flows in the river Ruaha. For example, in 2000, the seasonally and permanently flooded areas south of the Ruaha National Park were gazetted as the Usangu Game Reserve. This implies that, formally, all human activity is prohibited. In the permanent wetland, major force has been applied since 2001 to oust pastoralists and poor fisher families. Also, in March 2001 the Tanzanian Prime Minister declared to the Rio+10 Summit in London that the river should return to year-round flow by 2010. In addition, other projects are being formulated that seek to support the return of a perennially flowing Ruaha, most notably the Worldwide Fund for Nature (WWF).

4. Contested causation: water resources assessment

Table 1 summarises the range of theories regarding how and why the wetland and river were drying up. The left-hand column lists the main stakeholders, and the middle column presents their predominant beliefs held during the nineties as a result of several studies and observations. In the right-hand column, their current day perspective is given. The table shows mixed results in terms of changing perspectives, but begins, in the top row, with our assertion that during the nineties, the general belief was that the wetland, riverine and lacustrine (reservoir) changes were interconnected and the single result of one or more causes. This grouped view can now be contrasted with a more disaggregated understanding, proposed by SMUWC investigators, that symptoms arose in different parts of the system for different reasons.

SMUWC and the Ministry of Water and Livestock developed a hydrological model and a monitoring programme that suggested multiple causes of the changes in the Ruaha and wetland flow regimes. In addition, by undertaking monthly spot measurements in key locations throughout the plains, SMUWC pinpointed where and when water losses were occurring. These assessments challenged the original assumptions that the reduction in wetland size and flows in the Ruaha were mainly due to overgrazing and excessive consumption of water by livestock and a reduced ability of the wetland to act as a 'sponge' holding back water for later release into the Ruaha. SMUWC calculated that maintaining a water flow into the swamp was more important in generating an outflow

Table 1
Stakeholder viewpoints on hydrological changes in the Usangu Basin and Ruaha River

Stakeholder group	Initial viewpoint mid-1990s of the causes of the drying up of the Ruaha	Probable predominant viewpoint 2003
General viewpoint on all symptoms seen	Shrinking wetland, drying river and low reservoir levels were all closely related	Shrinking wetland, drying river and low reservoir levels separated from each other
SMUWC/RIPARWIN	Various hypotheses were tested: combination of cattle, deforestation, climate change, irrigation abstraction of water, total flows into Mtera/Kidatu	Dry season abstraction and environmental losses lead to Ruaha River flows ceasing
		Miscalculation of draw-down of stored water lead to low reservoir levels
Ministry of Agriculture and Food Security	Inefficient smallholder schemes requiring funding for improvement programmes that improved would allow more water to flow downstream	More open interpretation being fostered; that smallholders might be in close competition over water and therefore be quite efficient in their management
Ministry of Natural Resources	Cattle and overgrazing are degrading the wetland reducing its ability to hold and release water	Cattle and overgrazing in the wetland remains the cause
	Deforestation in the upper catchment reducing base flows in rivers	Deforestation remains a problem
Ministry of Water and Livestock	Inefficient smallholder schemes	Inefficient smallholder irrigation
	Deforestation in the upper catchment	
RBWO (within MoWL, but closer to Ruaha)	Inefficient smallholder schemes	Dry season abstraction is the main cause of downstream regime alteration
Mbarali District	Cattle and overgrazing in the wetland Deforestation in the upper catchment	Cattle and overgrazing in the wetland Deforestation still the cause
Friends of Ruaha and WWF	Large-scale irrigation schemes are abstracting water during dry season Damaged wetland from overgrazing	Dry season abstraction into all irrigation schemes Damaged wetland
Electricity Supply Company	Scale and inefficiency of irrigation leads to lack of water for power generation	Scale and inefficiency of irrigation

from the swamp than any effect from over-grazing. The studies also refuted the strongly held beliefs that climate change and, in particular, deforestation were the causes of reduced baseflows of rivers flowing off the escarpment (Kikula et al., 1996). Thus, the presence of an estimated 40–50 cumecs abstraction capacity from a total of 100–130 intakes on the plains was shown to play a more important role in dry and wet season hydrological change than climate change or deforestation. With respect to the latter, it was shown that the natural alpine ecology of the highest of the Southern Highlands is grassland and not forest.

The study also showed the probable cause of the power cuts in the Mtera/Kidatu hydropower plants was not water shortages in the Upper Ruaha, as argued by various studies (Faraji and Masenza, 1992). The hydrological analyses showed that irrigation in Usangu abstracts around 25–35% of Great Ruaha, itself a proportion of the inflows into Mtera and Kidatu. In addition, there is evidence that mismanagement of the reservoir and excessive releases to maximise electricity generation caused a draining of the storage from which it became difficult to recover during a series of dry years.

The analysis also showed how evaporation from rivers spreading onto the plains and wetlands result in significant natural water losses. This factor makes outflow from the Usangu wetland highly sensitive to abstraction during the dry season when river flows naturally diminish. Below a threshold of about 6–7 cumecs entering into the wetland, there is effectively no downstream flow. Thus the perceived drying up of the Ruaha River is mainly a dry season phenomena and is a result of irrigation intakes abstracting water for domestic reticulation and wetting of rice fields extending into the dry season.

Yet, powerful downstream stakeholders contested these results in order to protect and even expand their existing land and water use and practices, blaming poor farmers upstream in the basin of overuse, thereby expecting them to release water. The electricity supply corporation continues to maintain that upstream irrigation reduces water inflows. Similarly, the Mbarali District Government continues to actively seek the removal of vulnerable fisherpeople and pastoralists whose livelihoods depend on the wetland, arguing that they degrade the wetland by overstocking (an analysis that is contested by the SMUWC studies).

In summary, as Table 1 shows, success in arriving at a consensus on the causes of hydrological change has been limited. Each stakeholder group, with the possible exception of the RBWO, has held on to viewpoints that were initially developed during the early nineties. However, awareness of alternative viewpoints has increased to the extent that internal debates in each stakeholder group about suitable ways forward are now discernible. Thus there is a tension between the confident rhetoric regarding the cause of the drying of the Ruaha and less confident discussions over policy.

5. Contested solutions—water management approaches

Alongside contested environmental assessment, a number of questionable policies were implemented that aimed to improve water management in the Basin. Although notionally appropriate in that they fit the current mainstream narrative of water management, as seen from a discussion of two such policy tools in this section, these were introduced without much reflection on their efficacy and relevancy for the situation, to the extent that they could be labelled as ‘incorrect IWRM’.

5.1. Problematic water rights

To improve water management, the Rufiji Basin Water Office (RBWO) is establishing water rights and fees for all irrigation intakes on the Plains. These rights aim to control the amount of water used by irrigators and to halt over-abstraction. The rights are flow rate-based (e.g. 0.6 cumecs), and focus on wet season rice—though rights are generally halved (on paper) for dry season period. The RBWO has records of approximately 300 irrigation users, however, interestingly, few irrigators interviewed by the SMUWC team had ever met an RBWO officer and rarely did they know if their association or co-operative possessed a customary or formal RBWO water right.

The water rights issued by the RBWO employ a simple flow rate. This format may have worked in other countries, but may not be appropriate in Usangu, for a number of reasons. In some cases, the rights are simply water duties (command area multiplied by 2.0 l/s/ha) without being reconciled with available water or downstream needs, in which case such water may not actually be available. In other cases, rights are not determined in a transparent way; they do not relate to the command area or crop water requirement, but appear to be based on customary rights, de facto rights, availability during the peak flow period, or other unexplained reasons. In addition, because riverflows change dramatically from wet to dry seasons, and from wet to dry years, the Usangu fixed rights approach only works for 'statistically mean' flows. In dry years, the right is greater than the available water, legitimising the abstraction of water until the river dries up. Conversely, for wet years, the right is less than the available water, and probably less than the actual abstracted amount because high flows surcharge the intake gates. Relating water use to right is problematic as water is unlikely ever to be metered and monitored and so farmers may take more than their right. Furthermore, with a fixed payment, farmers may not use the marginal rule. On the contrary, having paid for a right, they may be inclined to use more water than necessary. RBWO staff and transport resources to monitor water use are restricted and are unlikely to increase, and access during the rainy season is difficult. In summary, the water rights appear to be so poorly attuned to the situation that they are at the very least having no effect, or worse, may be undermining the very outcomes they purport to achieve.

5.2. *Inappropriate infrastructure*

The pursuance of an irrigation intake-upgrading programme by the World Bank project utilising irrigation-focussed engineering procedures is another case of mixed and unintended outcomes. The project intended to raise irrigation efficiency because irrigators are supposed to close down the adjustable gates during high flows, thereby reducing wastage of water. However, the provision of concrete weirs and intake works alone does not, and cannot, raise irrigation efficiency to the levels expected by RBMSIIP (from 15 to 40%). This is because efficiency is a function of many internal field level activities, and in any case, the irrigators very rarely close off their intakes except when floods imperil their irrigation canal network.

Secondly, the programme does not take a river basin perspective. The concrete intakes reduce downstream compensation flows through the weir and enable farmers to abstract water throughout the year. Evidence indicates that the modernisation of indigenous traditional smallholder schemes does not necessarily result in improved water control, greater equity and reduced user conflict (Lankford, 2004). Indeed such programmes may aggravate these by not understanding an already complicated situation. Thus, while the improved-intake farmers are pleased to see less labour and time needed to maintain their intake, the downstream irrigators are deprived of water, particularly during dry periods.

6. Reconciling differences—tentative lessons

The work in Usangu suggests several lessons, which are outlined below. These lessons provide the basis for our discussion and conclusions, relating them briefly to prevailing debates in the literature.

6.1. The need for large-scale, long-term interdisciplinary research

Long-term, large-scale, interdisciplinary science in partnership with key stakeholders has a critical role in identifying complex factors underlying environmental and hydrological change. Four aspects of research are discussed here, which show that research requires a scale and focus of funding and resources rarely seen in natural resource management projects.

(a) More detailed hydrological studies are required in Ruaha, particularly covering three or more dry seasons—the critical period of the year best studied to isolate with sufficient certainty the important drivers of hydrological and environmental change. A numerical model of the basin was prepared but this still requires continuous updating, despite considerable efforts made during its development to produce an accurate predictive model.
(b) Studies conducted by specialists within their field are required. It is interesting to note that studies on irrigation, which is central to the hydrological changes in the Plains, were not initially sought by DFID or proposed by most of the prospective consultancy firms during the SMUWC bidding process. It was the winning consultancy firm that suggested that hydrological analyses needed to be strengthened by detailed irrigation investigations (HTS Ltd., 1998). We put this down to the notion that irrigation, being unpopular as a donor-funded rural development product is, by implication, a research blind spot when considered as a hydrological/livelihood process.
(c) Another issue that urgently requires careful empirical analysis is the assumption that irrigation efficiency can be raised considerably and that the generated water savings can be delivered to 'more needy' non-agricultural sectors. The efficiency of irrigation in Usangu may already be high, and savings unlikely to be forthcoming. Furthermore, even if possible, the outcome of transferred water is not guaranteed because of social costs involved and because local irrigators may recapture 'spare' water.
(d) Hydrological and irrigation research should be complemented by participatory socio-economic research on the role of water in people's livelihoods, and on formal and informal water management institutions. A close examination of issues such as local arrangements of water allocation under competition along rivers and of the de facto consequences of formal water rights may considerably re-orient current directions of basin-level water management by the Ministry of Water and Livestock.

6.2. Challenging entrenched normal professionalisms

Despite attempts, it proved difficult to address the effects of 'normal water science professionalism', a term used by Chambers (1988) that describes a certain kind of approach taken by policy-makers or scientists. The hallmark of normal professionalism is that it inflexibly pursues conventional, over-simplified or mono-disciplinary interpretations of scientific causation and associated policy. In Ruaha, one example of normal assessment was the reverse-logic connection between reduced base flows in rivers and deforestation—that reduced river flows meant that deforestation was happening. Another example of professionalism resulted in mal-distribution of water during the dry season. The interventions on water rights and intake infrastructure improvements, mentioned above, appeared initially to be technically correct, but were then insufficiently tailored and refined by formal and informal river basin institutions to local conditions. Despite on-going discussions, a thorough re-drafting of these policies appears to be a long way off; managing water via formal legal systems and infrastructural upgrading is the accepted approach.

6.3. Understanding the role of powerful elites

Local, regional and national elites retain great influence in decision-making and effecting change, in spite of increased emphasis on local level and user decision-making. For example, it is clear that the statement by the Tanzanian Prime Minister in March 2001 to the Rio+10 Summit in London that the Ruaha should return to year-round flow by 2010 has ensured a surprising level of support for the canal closure programme at the district level.

Similarly, the gazetting of the Usangu Game Reserve justifies district officers in forcibly removing vulnerable fisherpeople and pastoralists from the swamp. This legislation was implemented by the Ministry of Natural Resources, so that both the legislation and enforcing officers are outside the authority of the Ministry of Water and Livestock. This allows Usangu Game Officers to interpret environmental remedial measures in ways that probably would not have been sanctioned by MoWL. Equally, it has proved difficult to communicate fully with electricity supply corporation officials in ways that promote a more open understanding of why Mtera/Kidatu reservoirs became exposed to shortfalls of recharging inflows. This too allows TANESCO to claim a priority need of Ruaha waters. Indeed, SMUWC found that the delivery of messages of conditional and multiple causes of environmental change was more successful when working through high-level stakeholders within Dar es Salaam, rather than the regional and local representatives with vested interests in particular interpretations.

6.4. The need for local water development solutions in managing basin-level water scarcity

Usangu is still an open basin in the sense that physical water resources are still available for development. Locally available untapped water resources, such as boreholes or stock dams in the Ruaha National Park or better water management in the electricity-generating reservoirs can solve downstream water scarcity. Even in the Usangu Plains, water scarcity during the dry season does not preclude further expansion of water use for irrigation during the wet season through new infrastructure development. The construction of more storage (constrained by the absence of suitable sites) or groundwater development could mitigate dry-season water scarcity especially for domestic users. From a livelihoods perspective, such local water development is certainly a more desirable solution for basin-level water scarcity than the originally proposed re-allocation of water from poor to powerful water users.

Fig. 3 shows schematically the difference between the current solution of water shortages, sought via river basin wide reallocation of water, and an alternative solution of developing local sources of water to meet local shortages. Interestingly, the latter solution remains ‘off the table’ because (a) the river-basin wide theory remains dominant and (b) the Ministry of Natural Resources will not sanction boreholes in the Ruaha National Park because such a move implies direct interference with its ecology, an approach not allowed in areas with ‘National Parks’ status. The fact that the river’s regime has itself changed due to upstream human activity is not reason enough to consider mitigating action in this case.

7. Problems with IWRM—‘integrated’ is not enough

This section builds on the case study to review the knowledge system and context of interdisciplinary water science and its relationship to effective policy-making. A key argument is that managers of IWRM should continuously refine and enrich the knowledge base, perceptions and processes of hydrological and system change with the aim of framing ‘an appropriate institutional response’. We should not be satisfied with what appears to be an integrated water resources management approach, but instead critically unpack its components and identify modes of IWRM that take account of the science, issues and responses at stake, to deliver tailored effective solutions. This ‘recommendation’ reflects the fact that IWRM is a new discipline prone to first-approximation thinking in both assessment of causes and deployment of solutions. Strategies that appear sensible and functionary may, after even rudimentary analysis, be seen to be highly flawed and over simplistic; paraphrasing Perry (1998); existing knowledge about integrated water management is insufficient to develop sound policies.

Integrated water resources management therefore requires not only the services of specialists working in their own fields, but also contributions towards a more detailed framework of the new science of integrated water management. It is worth noting that an institution, in which this rich interchange can occur, could be formalised, embodying constant review, and ‘learning by doing’. Although the basin offices in Tanzania were supposed to facilitate this exchange and thus avoid having many parallel institutions they are staffed by a handful of people who mainly have hydrology backgrounds. In contrast, The National Rivers Consortium in Australia is designed to overcome inherent difficulties posed by the complex and interdisciplinary nature of water (Edgar et al., 2001).

The pre-requisite for rigorous science conducted by subject matter specialists working with local knowledge is unquestionable (Garin et al., 2002). Integrated water management should not omit highly focussed single-discipline studies. Indeed such focussed work may illuminate simple and relevant solutions that negate the need for more cumbersome integrated approaches. Approaches should be receptive of the fact that untried methodologies suited to unusual large-scale fluctuating environmental and livelihood processes may be required. For example, the existing theories of irrigation productivity and efficiency may be inappropriate to conditions found in Usangu. New methods developed by RIPARWIN researchers are obtaining much higher measures of efficiency, indicating that scope for

Sector (moving downstream)	Water demand	Mainstream (re-allocation) RBM theory applied to Usangu	Water sharing	Local solution theory applied to Usangu – mainly to solve dry-season shortages	Water sharing
Slopes, rangeland & rainfed maize	Evapotranspiration for vegetative growth				
Domestic users in villages in sub-catchments	In-stream needs for cooking, drinking, etc	To provide minor needs here in those areas below irrigation intakes		Boreholes added to provide clean, timely water	
Irrigated agriculture, rice	Evapotranspiration, seepage for vegetative growth and open water evaporation	Water savings required here		Irrigation expansion of dry season crops via some storage. Release some water to wetland and for in-stream needs	
Permanent & seasonal wetland	Evapotranspiration/evaporation & in-stream consumption (for livestock keeping, fisheries, wildlife, wetland ecology; domestic needs for inhabitants)	To provide water here		Some allocation during dry season or build a raised weir at exit to keep water within wetland at a higher level?	
Ruaha National Park	In-stream needs for wildlife ecology and drinking needs	To provide water here		Local storage for Park; reservoir or boreholes	
Mtera/Kidatu HEP stations	Evaporation and release for hydro-electricity power	To provide water here		Manage reservoir draw-down according to guidelines	
Urban power users	Light, power, heat, cooling	To provide electricity here		Commission new HEP stations	

Source: Authors

Fig. 3. Contrasts between basin-wide water re-allocation versus local water development in the Upper Ruaha Basin.

large-scale reallocation of water based on raising irrigation productivity, precisely the rationale behind the RBMSIIP project, may be limited.

It is possible to argue that a combination of factors came together in Ruaha to create a difficult environment in which to progress towards a more nuanced and tailored understanding of problems. The science was sufficient—but only for the project investigators who also recognised acceptable confidence limits, time and resources available. Thus for a small group of specialists, the causes of the drying up were *sufficiently* understood, but for a wider constituency, some of whom strongly held other beliefs, the science-to-policy efforts were not convincing. The authors propose five key principles to address the roles of advisers and scientists in policy formulation aimed at large-scale environmental change.

Firstly, strategic engagement with influential stakeholders and elites is essential. This applies to partner donor organisations as well as to client ministries, established scientists and policy advisers, and other important players. For example, although the World Bank funded RBMSIIP was responsible for policy generated under the programme, it remained somewhat isolated from the debates raised by SMUWC and RIPARWIN. The end effect, it would seem, was that by abstaining from the debate, World Bank advisers held sway over the policy-makers. They were more influential because they combined donor/financial influence with definitive and clear arguments about the logic of water management early in the nineties and made direct inputs into policy-making without wider consultation among peers. Financial power, the directness of advice of the World Bank and a lack of alternative water perspectives amongst prominent institutions in Tanzania resulted in effective dominance by the Bank over water policy.

Secondly, time is required to address issues that combine science, policy advice and implementation. Time is required to work on a number of fronts; to work with entrenched viewpoints; to generate longitudinal studies; and to build capacity of national and international scientists and decision-makers. SMUWC was completed in 2.5 years, although it was originally envisaged to run for 4 years at the minimum. Mills and Clark (2001) describe a nine-month river basin study expanded to 5 years 'as complexity of the issues became clearer'. Winstanley et al. (1998) argue time is also required to allow for peer evaluation of work at time-scales set by various peer groups.

Thirdly, scientists should examine possible causes of environmental change other than those commonly or historically associated with change. Lubchenco (1998) argues that; "all too many of our current environmental policies and much of the street lore about the environment are based on the science of the 1950s, 1960s, and 1970s, not the science of the 1990s" (p. 495). One example from Usangu was the defence by scientists of the role of deforestation in hydrological change in Tanzania, a treasured connection based on years of study linking these two. Yet the SMUWC findings showed these to be unconnected because there had been little deforestation. Some scientists treated this conclusion with derision, a response that gave policy-makers further latitude for discounting other results of the study.

Fourthly, scientists should consider the nature of 'certainty' in the relationship between policy-crafting and scientific studies that inform policy. Policy-crafting tends to proceed with a clarity and certainty that is not always supported by underlying certainty because of 'error' in scientific methodologies and theorising. On the other hand, policy-advice is often required to be relatively direct and clear, distilled from qualifications, nuances and options. We argue that three points help address this difficulty; firstly building capacity is required to minimise the worst excesses of emphatic policy formulated on sketchy science. Secondly, acknowledging that policy often builds on inappropriate research, we argue that parallel research and monitoring is a requisite. Thirdly, parallel research then needs to feed back into regular policy reform. These three points are nothing new but we argue that in the case of Usangu it is the scientists and consultants that need to 'manage upwards' so that these three issues are adequately incorporated by decision-makers.

Fifthly, as Farrell et al. (2001) points out, science is more effective if it is demand led. "One of the most important parts of this interface are that quantitative modelling efforts must be designed to answer the questions that decision-makers ask" (p. 329). Letey (1999) also suggests that scientists need to respond to issues of greatest value to policy-makers. Yet these arguments assume that policy-makers know what to ask for, which is not always the case with complex environmental issues. Part of the policy-advising process is to appreciate this lacuna and to nurture relevant questions from clients. The challenge for RIPARWIN when building its decision-aid will be to encourage the client to have real input to the model in terms of framing questions that the model needs to answer.

8. Conclusions

The applicability of these lessons to other river basins depends on the socio-economics, institutions dealing with, and hydrology and environmental configuration of rivers within in those basins. For example, in Tanzania, these lessons apply to the Pangani River Basin which has closed, closing and open sub-catchments and is the focus of similar Ministry of Water and Livestock projects. These lessons might apply to other sub-Saharan rivers with comparable characteristics, such as a contrasting wet and dry season hydrology, for example, the Kafue sub-basin of the Zambezi. Internationally, cases with contested hydrological interpretations and those requiring inter-disciplinary, multi-faceted solutions could draw on the lessons outlined here.

These approaches show ways in which scientists can work within difficult circumstances to influence policy. These reflections are more conditional than the positivist conclusions of Mills and Clark (2001) that good science well disseminated will improve decision-making. Instead, context, strategy and multiple paths of collaboration are important. While Mills and Clark place responsibilities for establishing how science can affect policy at the door of policy-makers (making scientists neutral in this role), authors of this paper believe that dual or even multiple roles for scientists are possible, and indeed are already with us (Perry, 1998). This specially applies to interdisciplinary scientists carrying out action research in integrated water resources.

Thus, arguably, IWRM scientists need to work on two key fronts; 'action research' and 'action advising'. Action research involves various aspects of the research spectrum; conducting studies and assessments; advising on the research framework including time schedules involved to encompass scale-related issues; and resetting research questions in the light of new knowledge. Action advising might encompass various dimensions of policy work; identifying key influential stakeholders; challenging peers on the knowledge-system of IWRM; assisting policy-makers in framing appropriate policy aims; recommending policy advice; promoting policy reform; managing policy reception, demand and uptake;

encouraging further research and monitoring; and altering advice in the light of new experience. These multiple, reflective roles are described by Norse and Tschirley (2000) and by Lubchenco (1998, p. 495): "there is a concomitant requirement to train interdisciplinary scientists and to provide the skills and savvy to work at the policy–science or management–science interface". Building such skills and savvy will not only come from training; but from the design of donor-funded research, projects and programmes, which, if these skills are to be maximised, should mirror the nature of the underlying problems and their resolution, and therefore be long-term, explore many dimensions, involve stakeholders and foster feedback.

Acknowledgements

This work was funded by a combination of DFID for the SMUWC project (involving the first and third authors) and DFID and IWMI for RIPARWIN (involving first two and fourth authors). Full recognition is given to the SMUWC team and consulting companies in their role as investigators. Thanks also to the two referees whose comments helped in further editing and making clarifications.

References

Baur, P., Mandeville, N., Lankford, B., Boake, R., 2000. Upstream/downstream competition for water in the Usangu Basin, Tanzania. In: Proceedings of the British Hydrological Symposium, Seventh National Hydrology Symposium, University of Newcastle, 6–8 September 2000. BHS National Hydrology Symposium Series.

Bolin, B., 1994. Science and policy making. Ambio 23, 25–29.

Chambers, R., 1988. Managing Canal Irrigation: Practical Analysis from South Asia. The Wye Studies in Agricultural and Rural Development, vol. xxviii. Cambridge University Press, Cambridge, 279 pp.

Chopyak, J., Levesque, P., 2002. Public participation in science and technology decision making: trends for the future. Technol. Soc. 24, 155–166.

Collingridge, D., Reeve, C., 1986. Science Speaks to Power: The Role of Experts in Policy-Making. St. Martin's Press, New York, 175 pp.

DFID, 1998. Project memorandum. Sustainable Management of the Usangu Wetland and its Catchment (SMUWC); for the River Basin Management and Smallholder Irrigation Improvement Project (RBMSIIP) and Ministry of Water. Water Resources Department, Government of Tanzania, Department for International Development, London.

Edgar, B., Schofield, N., Campbell, A., 2001. Informing river management policies and programs with science. Water Sci. Technol. 43, 185–195.

Faraji, S.A.S., Masenza, I.A., 1992. Hydrological study for the Usangu Plains with particular reference to flow entering the Mtera Reservoir and Water Abstractions for Irrigation. Working paper, Insitutional support for Irrigation development, Ministry of Agriculture and Livestock, Tanzania, Dar es Salaam.

Farrell, A., Van Deveer, S.D., Jager, J., 2001. Environmental assessments: four under-appreciated elements of design. Global Environ. Change 11, 311–333.

Franks, T., Lankford, B., Mdemu, M., 2004. Managing water amongst competing uses: the Usangu Wetland in Tanzania. Irrigation Drainage 53, 1–10.

Garin, P., Rinaudo, J.D., Ruhlmann, J., 2002. Linking expert evaluations with public consultation to design water policy at the watershed level. Water Sci. Technol. 46, 263–271.

Herrick, C., Jamieson, D., 1995. The social construction of acid rain: some implications for science/policy assessment. Global Environ. Change 5, 105–112.

HTS Ltd., 1998. Sustainable management of the Usangu wetlands and its catchment, Tanzania. Proposal: Appendix A—General and Technical, Department for International Development, UK.

Joss, S., 1999. Public participation in science and technology policy- and decision-making—ephemeral phenomenon or lasting change? Sci. Public Policy 26, 290–293.

Kikula, I.S., Charnley, S., Yanda, P., 1996. Ecological changes in the Usangu Plains and their implications on the down stream flow of the Great Ruaha River in Tanzania. Research Report No. 99, Institute of Resource Assessment, University of Dar es Salaam, Dar es Salaam, Tanzania.

Lankford, B., Franks, T., 2000. The Sustainable coexistence of wetlands and rice irrigation: a case study from Tanzania. J. Environ. Dev. 9, 119–137.

Lankford, B.A., 2001. Red routes on Blue Rivers: strategic water management for the Ruaha River Basin, Tanzania. Water Resources Dev. 17, 427–444.

Lankford, B.A., 2004. Irrigation improvement projects in Tanzania; scale impacts and policy implications. Water Policy 6, 89–102.

Letey, J., 1999. Science and policy in integrated watershed management: a case study. J. Am. Water Resources Assoc. 35, 603–607.

Lubchenco, J., 1998. Entering the century of the environment: a new social contract for science. Science 279, 491–497.

Mills, T.J., Clark, R.N., 2001. Roles of research scientists in natural resource decision-making. Forest Ecol. Manage. 153, 189–198.

Norse, D., Tschirley, J.B., 2000. Links between science and policy making. Agric. Ecosyst. Environ. 82, 15–26.

Perry, D.A., 1998. The scientific basis of forestry. Annu. Rev. Ecol. Syst. 29, 435–466.

SMUWC, 2001. Final Project Reports. Directorate of Water Resources, Ministry of Water, Government of Tanzania., Dar es Salaam.

Winstanley, D., Lackey, R.T., et al., 1998. Acid rain: science and policy making. Environ. Sci. Policy 1, 51–57.

World Bank, 1996. River Basin Management and Smallholder Irrigation Improvement Project (RBMSIIP). Staff Appraisal Report, Washington, DC.