A Share Response to Water Scarcity: Moving Beyond the Volumetric[1].

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Introduction

This chapter examines water scarcity through a facilitative ‘share’ response, arguing that scarcity is too often seen as volumetric imbalance to be dealt with by saving, storing and delivering more water. However, these may be responses that only partially recognize how water is shared and that therefore continue to exacerbate scarcity and inequity. In emphasizing a ‘para-volumetric’ response to scarcity, the chapter contains a framework of supply, demand and share responses and argues that, alongside demand and supply solutions, the allocation of water between users[1] increases in significance. An additional dimension of scarcity beyond the volumetric shortage occurs in dynamically supplied environments where water is variably apportioned between users semi-automatically or semi-consciously as a result of existing institutions and infrastructure. The chapter concludes that while scarcity might indeed be a universal backdrop, it is society’s experimentations with water interventions under conditions of rapid hydrological change that are the acid tests of how scarcity is understood.

For the purposes of political expediency, water scarcity, seen as limited or decreasing water supply in the face of existing or increasing demands,[2] proves to be useful in two ways. First, it is easier to blame a natural shortage of water than to accept the full liabilities related to the sharing of limited amounts. Second, ‘lack of water’ allows for policies that are not so much related to how water can be managed and shared but more to concerns about how to fix or solve the lack of supply (see also Chapter 13, this volume). A concern with volumetric shortages rather than with the details of water management, particularly the distribution of water between users, is nurtured by the material realities of water politics and policies; budgets to be spent, a desire to ‘keep things simple’[3] and a political milieu of lobbying, ballot intentions, donor-client agendas and public accountability (Chapter 4, this volume, also makes similar arguments in the concluding section). By drawing on a case study in Tanzania, particularly ideas developed in Lankford and Beale (2007), this chapter attempts to show differences between the volumetric logics of redressing demand-and-supply balances and approaches that facilitate the sharing of water under conditions of a highly varying supply.

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[1] Lankford, B.A., 2010.. Responding to water scarcity – beyond the volumetric. In, Mehta, L. (ed) The Limits of Scarcity. Earthscan, London. Pp 211-230.

Whether users face relative temporary or semi-permanent water scarcity in comparison to periods of water abundance is not disputed here because water supply in nature is inherently variable. Furthermore, the objective is not to comment on the efficacy of demand and supply solutions as others have done admirably (Mehta, 2006; Molle and Berkhoff, 2007). I move beyond the *volumetric* supply, demand and allocative origins and solutions of scarcity. Thus while Mehta (2001 and 2005) has focused on anthropogenic influences on water scarcity (such as over-exploitation of groundwater and devegetation) as well as the constructed nature of scarcity and its naturalization, these are volumetric commentaries on supply and demand. By contrast, I highlight the exacerbation of natural and social scarcity by anthropogenic structures inappropriately designed to share out water.

As well as shortages of water and degrees of access to water supplies, inequitable allocation of water is identified in the water scarcity literature as a ‘crisis’ (Clarke, 1991; Gleick, 1993; Brown, 2001). For example, the causes of the crisis of the Aral Sea (Micklin, 2007) are attributed to upstream irrigation. While allocation is acknowledged to play a role in scarcity in such writings, this tends to be couched in a volumetric analysis of which sectors are provided with water using long-term window sum-balances. I seek to go beyond ‘sum-balance’ allocation perspectives to the contemporaneous sharing of water in certain environments.

Share management is defined here as a set of interventions designed to propagate proportions of available supply through a hierarchy of competing users, taking into account variability of supply, the number of users and their demands. This proportional distribution of water occurs over different scales, levels and time windows. As a theoretical framework, it supersedes and incorporates water allocation because of the need to accept the paradigmatic challenges of water distribution in highly dynamic environments – the latter defined by semi-arid conditions or rapid climate change particularly in closed river basins – where variable intensities of scarcity and insufficiency occur rapidly and unpredictably both in time and space. The particularities of such environments may not be served by either current models of integrated water resources management or adaptive water resources management where both models undertake a normative regulatory approach to water allocation. In other words, allocating water from one user to another via regulation of the former’s demand may not be enough – in highly transient situations water sharing is mediated by a number of other means.

Water Scarcity

A brief overview of commentaries on the construction of scarcity is provided before moving on to an examination of the tendency towards volumetric thinking. From a seemingly neutral definition of a mathematical conception of balance between supply and demand, scarcity is undergoing an increasingly sophisticated level of analysis.

In disciplinary terms one might distinguish between scientists who study water balances as hydrologists might, technical instrumentalists who reflect on the role of the built environment (e.g. lack of storage) in determining scarcity, social scientists concerned with relationships between society, power over and access to and distribution of water and economists who endeavour to understand water scarcity as an expression of financial scarcity and market behaviour.

In addition, scholars have considered other forms of deficit (e.g. financial or political will) that drive water shortages. Turton and Ohlsson (1999) termed a focus on water shortages a first-order analysis of scarcity and other types of capabilities as second-order analyses. Mehta (2006) explored four types of resources, primary to quaternary, physical, economic, adaptive and political. Mehta’s capability and well-being approach to scarcity is an example of a multi-strand examination of scarcity, and argues for a detailed look at underlying capabilities, moving beyond first-order resource solutions that often propose ‘more water’ via supply technologies to help solve water imbalances. Ohlsson (1998) argued for a social water stress index to reflect adaptive capacity. Furthermore, our understanding is not simply a product of the range of incorporated perspectives as suggested by Turton, Mehta and others but is also a result of the depth and breadth within those disciplines and perspectives.

Scarcity is commonly analysed from a supply side or a demand side (or conservation), or in terms of how water is shared between sectors, termed here ‘share management’.[4] Although I draw on the literature on allocation within an integrated water resources management (IWRM) framework and particularly on Homer-Dixon’s third category (which he termed ‘structural’) (Homer-Dixon, 1999) and the use of ‘water allocation’ by the Comprehensive Assessment of Water Management in Agriculture (Molle, 2003; Molle et al, 2007), I make a special case for the term ‘share management’ alongside demand and supply management.

The bias towards supply management (e.g. building dams) or demand management (e.g. fixing leaks) is revealing not only of trends amongst donor thinking but also of how ‘scarcity response’ narratives are constructed. Of late, the International Water Management Institute (IWMI) and the World Bank have argued that per capita storage is low in sub-Saharan Africa and that additional storage is required; a reflection of the economic scarcity of investment (World Bank, 2007; Rosegrant et al, 2002). The ambivalent treatment of share management in these literatures suggests that a more profound look at the technical management of scarcity adds to demand and supply thinking, enhances the outcomes of additional storage and enriches our engagement with the political construction of scarcity. It should be said that this chapter does not take issue with the *how* and *whether* water is ‘saved’ in one sector – a debate where precise communication is required (Perry, 2007).

Tending Towards Volumetric Responses to Water Scarcity

A volumetric response to water scarcity is a natural logic. The evolution of this logic to scarcity can be seen in the last 40–50 years, with the supplanting of supply management (‘if water is scarce, increase supply’) by demand management (‘if water is scarce, reduce demand’). Evolution has continued with both supply and demand management promulgated, combined with the emergence of allocation within an IWRM framework (GWP, 2000), a central tenet of which is regulation via pricing water volumetrically or licensing water provision. These tend to be expressed volumetrically either as annual volumes (cubic metres) and discharges (litres or cubic metres per second) rather than in proportions or percentages of available flow.

As indicated above and in the chapter to follow by Jairath, the quality of scarcity thinking is most revealed when indicators of scarcity or recommendations are promulgated. The water stress index, one of the most widely adopted (Falkenmark, 1989), proposes a threshold of 1700m^3 of renewable water resources per capita annually, below which countries are said to be water-stressed (see also Rijsberman, 2006). This index functions when boundaries are carefully defined (e.g. basin, country level) but cannot express the extent to which water is shared between a unit’s population or users (see also Chapter 13, this volume, for a discussion of supply and demand management issues). The same omission applies to the Water Poverty

Index (WPI) (Sullivan, 2002), constructed from five main indicators (water availability, access to water, capacity for sustaining access, the use of water and the environmental factors that impact on water). Although WPI moves away from being a volumetric measure it does not describe how water is shared between users in a given area.

An Introduction to Supply and Demand Management

A careful framing of responses to scarcity is predicated on a specification of the concepts of demand and supply management guided by Tables 12.1 and 12.2, and Figure 12.1. In this analysis, water supply is taken as the amount of water extraneous to a user, while water demand is the amount of water utilized and managed 'within' a user from the point of abstraction. We can describe the 'amount' of water supplied, used or saved in three ways; *volumetrically* which includes three sub-types of depth (in millimetres), total volume (cubic metres) and discharge (litres/second); as an *intensity* calculated as a specific or tertiary ratio, a common one being the hydromodule in litres per second per hectare; and as a *proportion* (percentage) of total supply or total demand. Without formulating water use as 'intensity', or recasting demand as a proportion of supply or total demand, water wastage and overuse is difficult to judge accurately.

'Supply management' suggests the augmentation of water to sectors or a sector, while 'demand management' describes the reduction in demand for water via the improved management of water within a sector to fit the available supply (Radif, 1999). Supply management can be understood as increasing the amount of water either by extending access to existing flows, or by increasing the reserve volume (or buffer) by capturing flows that otherwise would have been lost to beneficial use. Examples include reservoirs and groundwater recharge systems. Conceptually, supply management shifts existing water either spatially, temporally or through changing quality and phase. Thus, storage of wet season flow to the dry season is an intra-annual shift in the hydrograph. Accessing groundwater comprises a shift on longer, even geological, timescales. Desalinization gives more water via improving water quality, while pollution, representing a decline in water quality, reduces water availability. Condensation technologies for drinking water are a phase shift from vapour to liquid, and may become increasingly important supply side solutions (Lindblom and Nordella, 2007). See also Molle (2003) for four types of water sources; rainwater, streamwater, controlled, and potential controlled.

Multiple concepts of demand management also require careful unpacking. Much work has been done by the IWMI (Molden et al, 2003). Table 12.3 identifies 10 dimensions to demand management. There are three components to water use and savings; net, tare and gross. Net is the component of gross water use that generates benefits to the user, and arises from consumptive or non-consumptive use (consumption is equivalent to depletion). Tare is the 'inefficiency' component arising from delivering water to provide the net requirement and gross is the combination of net and tare and leads to a gross requirement at the point of abstraction. Water demand in a user can be expressed from the point of view of the resource whereby returned water (and therefore net demand from the point of view of the hydrological cycle) can be computed.

Table 12.1 Framework of supply management as a scarcity response

Scarcity response	**Sub-type**	**Definition**
Amount descriptors	Volumetric (depth, volume or discharge)	Water supply, usage or saving within a sector expressed as a depth equivalent (mm), volume (cubic metres), or discharge (litres/second)
	Intensity or specific	Water supply, usage or saving expressed as a ratio to a field or person (litres/second/hectare)
	Proportion	Water supply, usage or saving within a sector expressed as a percentage of total water supply
Supply management Includes five types of shifts	Access	Establishing infrastructure that *extends access* to existing freshwater, for example a deeper borehole
	Buffer (or capital)	Establishing or managing infrastructure to store or create freshwater, for example a reservoir
	'Mining' – long time shifts	Acquiring and accessing geological water that moves slowly within the hydrological cycle
	Storage – short time shift	Acquiring water that represents a shift of water within the hydrological cycle over a short time-span
	Place shift	Managing water that entails a move of the resource; e.g. inter-catchment transfer
	Quality shift	Cleaning up or improving otherwise unusable water; e.g. desalinization
	Phase shift	Rain cloud-seeding and condensation technologies to provide drinking water from vapour

Two drivers reduce demand; the first is that demand reductions are driven by the availability of water, meaning that a reduced supply, either from natural variation or growing competition, forces a reduced demand. The second, less likely option, is that savings (or reductions in non-beneficial use) are made within the sector without reference to the external supply of water. In keeping with IWMI's framework, demand management should refer to, amongst other dimensions, consumptive, non-consumptive, beneficial and non-beneficial components.

Mental agility is required because demand management within one user frees up water for another user, and could be seen as a supply solution. Another confusion arises from a literal perspective; visible alterations to the 'supply' such as exchanging an open channel for a pipe to save water are 'demand' solutions (Merrett, 2004 has an example of this confusion).

Table 12.2 Framework of demand management as a scarcity response

Amount descriptors	Volumetric (depth, volume or discharge)	Water supply, usage or saving within a sector expressed as a depth equivalent (mm), volume (cubic metres), or discharge (litres/second)
	Intensity or specific	Water supply, usage or saving expressed as a ratio to a field or person (litres/second/hectare)
	Proportion	Water supply, usage or saving within a sector expressed as a percentage of total water supply
Demand management – requires reductions in one or more of these 'fractions'	Withdrawal (gross or cap)	Total amount of water required by a sector at the point of diverted supply including the 'inefficient' or non-beneficial (tare) part
	Consumptive use (beneficial and non-beneficial)	Water is depleted from the hydrological cycle during usage – irrigation is an example. This describes the amount of water removed by a user after recoverable return flows have been computed. From the source's point of view, this can be seen as a net depletion. Beneficial water is when it is consumed or used to produce societal benefits (e.g. crops or environmental goods)
	Non-consumptive	Water is minimally depleted but its quality might be changed during usage (industrial use is an example)
	Recoverable fraction	Water is returned to the hydrological cycle
	Non-recoverable fraction	Non-consumed water cannot be used for beneficial use within the hydrological cycle
	Supply-driven	Demand fluctuates as a result of short- or long-term changes in the availability of supply
	User-driven	Demand adjusts as a result of purposive measures taken by a user to reduce water consumption

A Facilitative Response – Water Share Management

For this analysis of scarcity, a third option exists, outlined in Table 12.3 and depicted in Figures 12.1, 12.2, 12.3 and 12.4. 'Share' determines how a stable or varying supply is apportioned between users resulting in currently supplied proportions of water and in future changes in proportions in either short or long timescales. Timescale and spatial scale are critical to our understanding of how share management functions and where a normal understanding of ‘allocation’ sits (Figure 12.1). Following Table 12.3, changes in apportionment of water between users occur via five mechanisms:

Table 12.3 Framework of share management

Amount descriptors	Volumetric (depth, volume or discharge)	Water supply, usage or saving within a sector expressed as a depth equivalent (mm), volume (cubic metres), or discharge (litres/second)
	Intensity or specific	Water supply, usage or saving expressed as a ratio to a field or person (litres/second/hectare)
	Proportion	Water supply, usage or saving within a sector expressed as a percentage of total water supply
Share management (determining both current and future division of water)	Appropriation	Share of current and future water over the longer term [bl]** external regulatory and dialogue environment ** demand management within one user ** growth over time of favoured user
	Allocation	[tx]Allocation of water between sectors or users by using allocation and regulation tools via IWRM framework
	Translation	Inter-seasonal change in share of controlled water between sectors or users as a result of new or altered institutions or infrastructure
	Modification	Intra-seasonal contemporaneous change in share of water between users or sectors as a result of an ongoing changing supply mediated by existing institutions and infrastructure
	Scheduling	Time period management of water distribution between users and sectors within proportions determined by allocation of water to users and sectors
Three types of water movement between users	Surface	Movement of water via channels, pipes and rivers
	Sub-surface	Movement via soil water and geological water
	Vapour	Movement of water via atmosphere

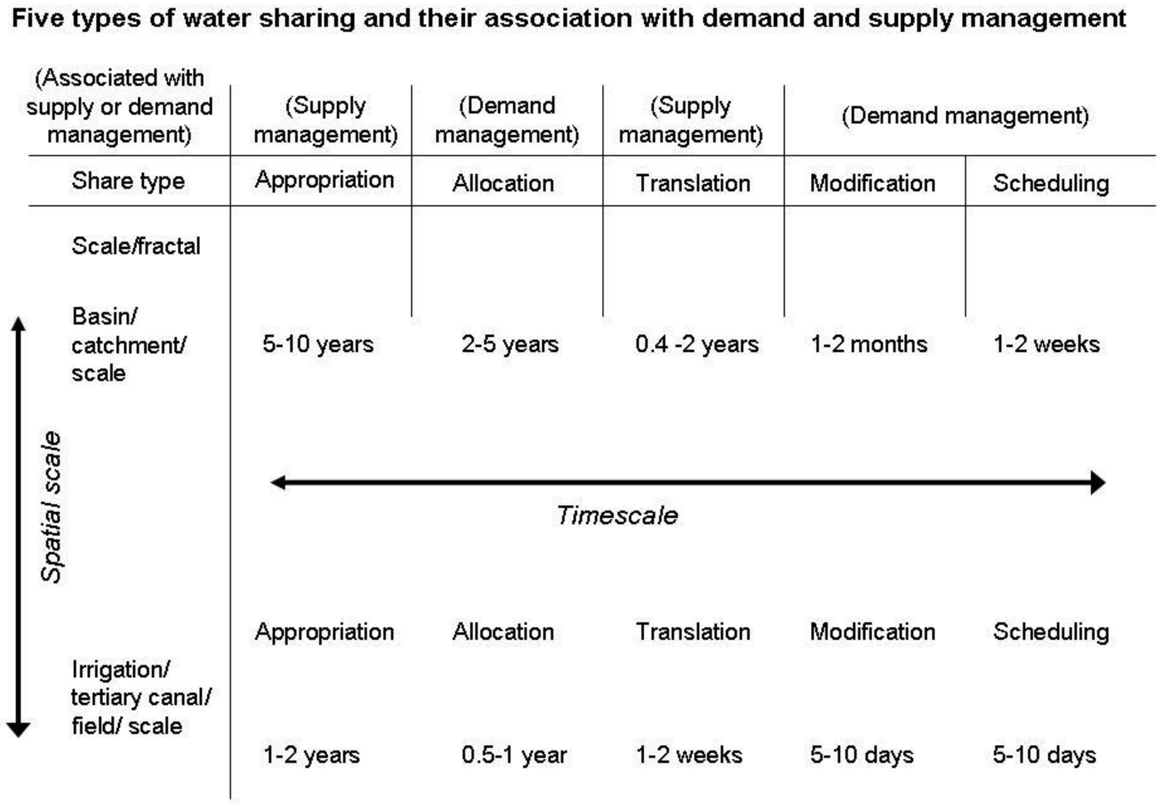
1 The first, *appropriation*, is the implicit and unforeseen shift in shares enabled by the growth of one user that then *ceteris paribus* reduces water for other users. This is most visible over timescales of 5–10 years and is seen more clearly in Figure 12.2 as a rising share of water accruing to user D1.

2 The second is the *allocation*[5] of water between users by using decision-making tools and devices (markets, licences) within a regulatory IWRM framework. This is how most commentators perceive water sharing alongside demand and supply management. Associated with allocation is the parallel application of demand management to a ‘donating’ sector (this is depicted towards the right-hand side of Figure 12.2)

3 *Translation* covers the (often implicit and unintended) change in shares of water between users as a result of new or altered supply side infrastructure integrated over a longer time (seasonal) period of the hydrograph. For example, surplus water stored in a dam during the wet season takes environmental water and holds it back for another user, perhaps irrigation. Translation implies a temporal inter-seasonal shift in water usage with a concomitant shift in apportionment between sectors (see Figure 12.3)

4 *Modification* describes contemporaneous changes in the share of water between users as a result of a changing extraneous supply being altered by existing infrastructural architecture. This is significant in environments with highly varying flows. In brief, the flow characteristics of abstractions determine the amount of water taken by users at any given time as a discharge – yet when expressed as a percentage of the total supply, shares between users alter. For example, two neighbouring irrigation intakes might both take 200 litres per second, amounting to 5 per cent of a river discharge of 8000 litres per second. When the river flow declines to 400 litres per second, they would then take an equal share of 50 per cent each of a river flow. As the dry season progresses, and the river flow falls to 200 litres per second, this gives unequal shares of 100 per cent to the first intake and 0 per cent to the second intake. See Lankford and Mwaruvanda (2007) for more on the implications of intake design for water distribution and basin governance

5 *Scheduling* is concerned with the short time period movement of water between users but within shares determined by the allocation of water to users. Scheduling does not result in any net long-term changes, but can critically resolve inter- and intra-sectoral water shortages where timing of delivery is important. For example, water flows can be scheduled between an irrigation system and a downstream wetland to sustain their respective ecologies. Scheduling is important where decisions about water sharing between users are best taken at a devolved level.



Five types of water sharing and their association with demand and supply management

(Associated with supply or demand management)	(Supply management)	(Demand management)	(Supply management)	(Demand management)	
Share type	Appropriation	Allocation	Translation	Modification	Scheduling
Scale/fractal					
Basin/ catchment/ scale	5-10 years	2-5 years	0.4 -2 years	1-2 months	1-2 weeks
	Appropriation	Allocation	Translation	Modification	Scheduling
Irrigation/ tertiary canal/ field/ scale	1-2 years	0.5-1 year	1-2 weeks	5-10 days	5-10 days

Figure 12.1 Scale and time acting on water sharing options

The five options describe *how* water is moved between users and sectors, distinguishing ‘sharing processes’ from ‘sharing claimants’. As presented in Figure 12.1, the five definitions are to some extent ‘fractal’. In other words, they apply to different levels of spatial scale and at different timescales, for example to the allotment of water between irrigation, industry and the environment on the same river or to a series of irrigation intakes on a river or to canals within an irrigation system.

Categorized with share management are the three ways in which water moves between users; surface, sub-surface and vapour. This hints at the likelihood of saved water being made available to another sector, or whether it may be captured by the same sector, depending on the spatial and hydrological route the water takes (see Molle et al, 2004). The route that water takes affects notions of certainty and timing, in that water moving via groundwater flow is slow and difficult to gauge while water moving between users as atmospheric vapour is even less ‘knowable’.

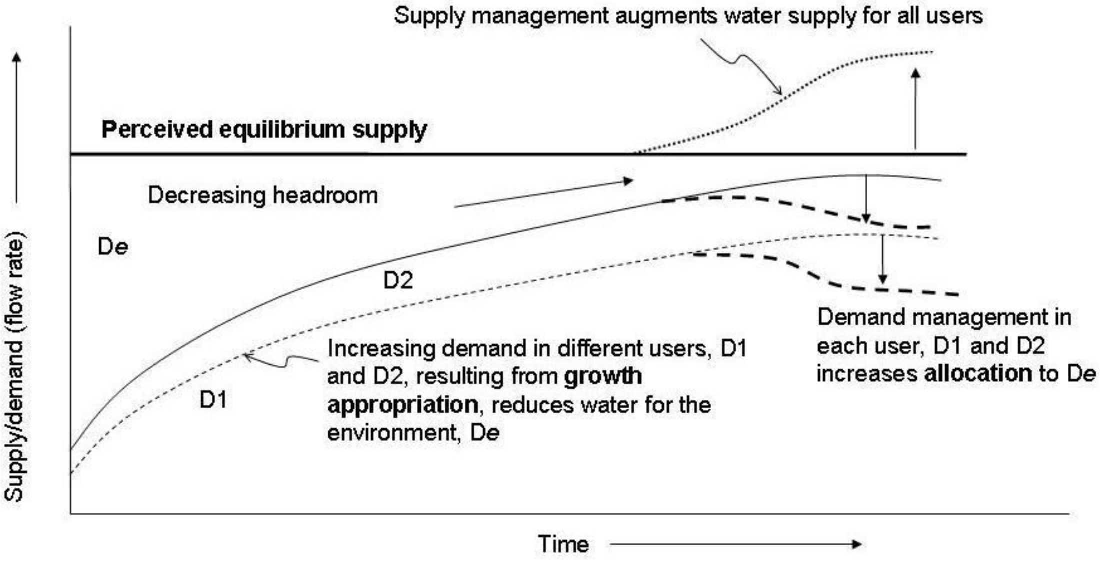


Figure 12.2 Supply and demand curves deemed to be in broad equilibria

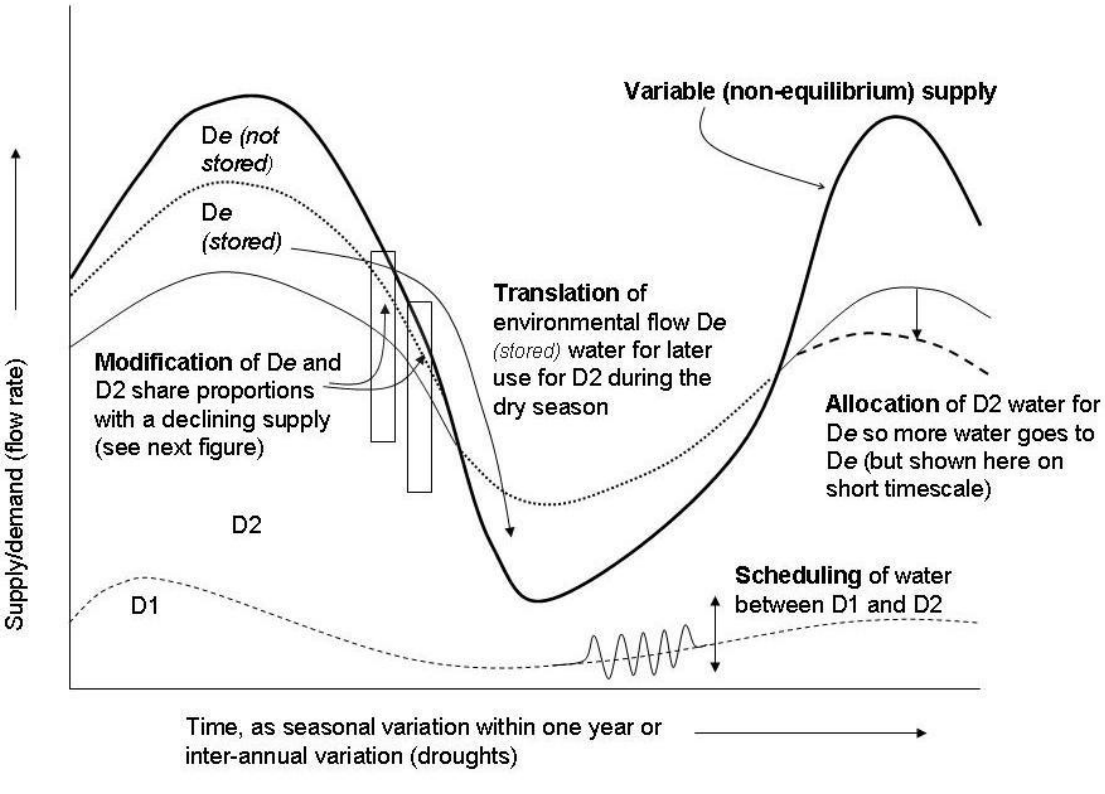
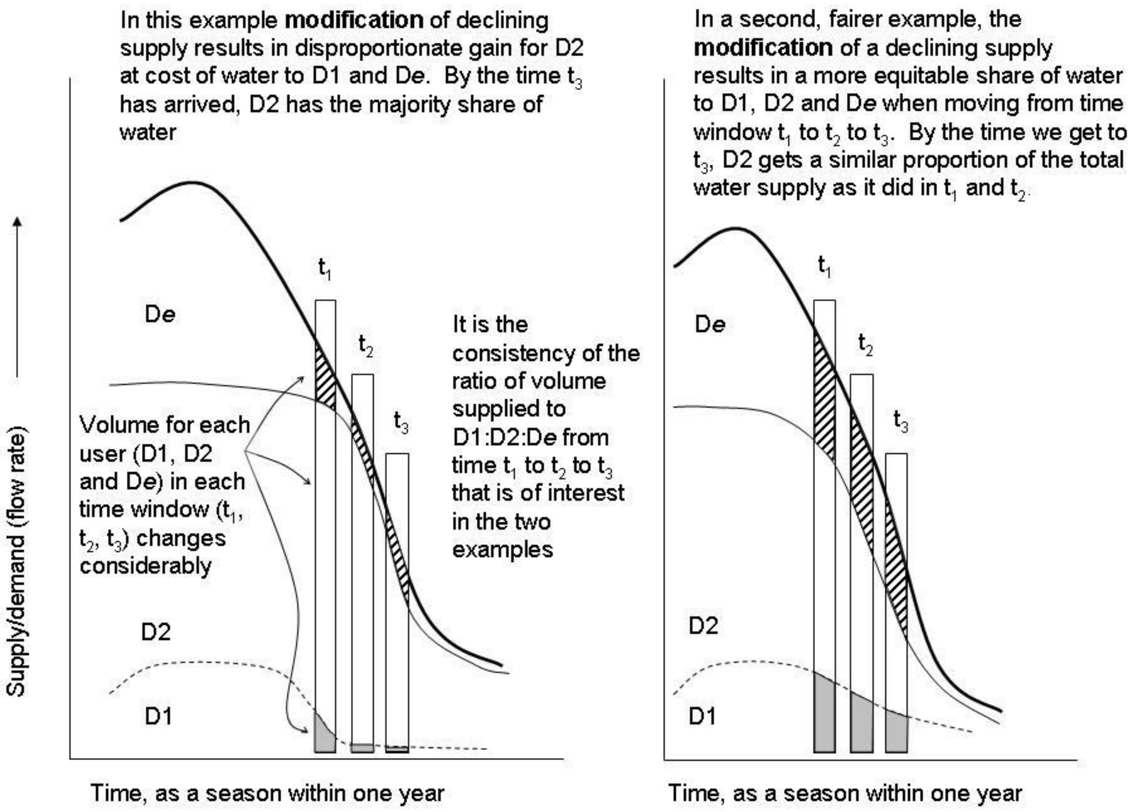


Figure 12.3 Varying supply, demand and share management under a variable climate


In this example **modification** of declining supply results in disproportionate gain for D2 at cost of water to D1 and D*e*. By the time t_3 has arrived, D2 has the majority share of water

In a second, fairer example, the **modification** of a declining supply results in a more equitable share of water to D1, D2 and D*e* when moving from time window t_1 to t_2 to t_3. By the time we get to t_3, D2 gets a similar proportion of the total water supply as it did in t_1 and t_2.

Volume for each user (D1, D2 and D*e*) in each time window (t_1, t_2, t_3) changes considerably

It is the consistency of the ratio of volume supplied to D1:D2:D*e* from time t_1 to t_2 to t_3 that is of interest in the two examples

Figure 12.4 Detail demonstrating modification of shares in a declining supply

Note that a change in water apportionment via allocation and scheduling arises from active management and governance, while a change in water apportionment arising from translation and modification occurs primarily from a variable supply interacting with existing infrastructural architecture and is therefore more passive (although these are subject to change as well).

The five types of share management apply to different river basin conditions with profound implications for how water is governed. Setting aside the first, appropriation, I contend that in an equilibrium climate (e.g. oceanic, temperate) where the supply of water varies relatively little, shares between users are determined by purposive demand or supply management in one or more sectors linked with allocation share management. Thus water saving in irrigation, cascaded up to a cap on abstraction, adds water to other sectors.

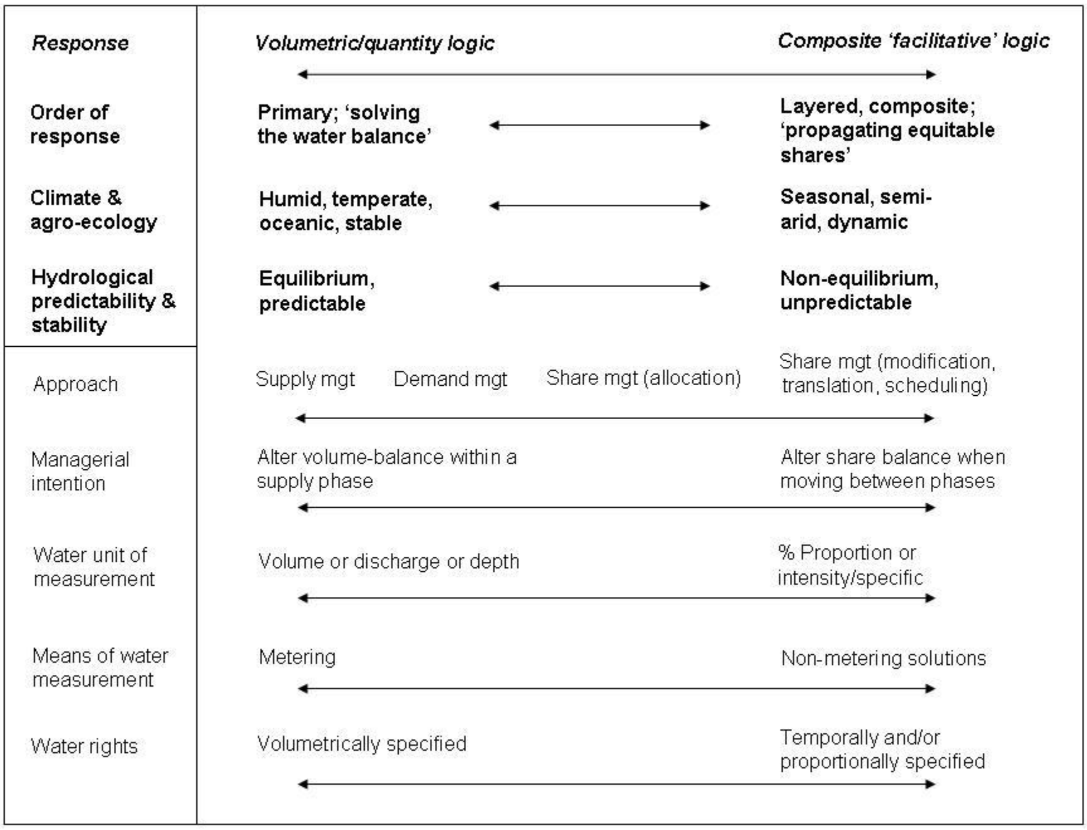
However, with greater amplitude of hydrological variability associated with pulse-driven semi-arid environments or climate change, translation and modification share management becomes more important (Figures 12.3 and 12.4). When supply increases or decreases over orders of magnitude within relatively short periods of time (rivers might vary from 0.1 cumecs during a dry season to 100 cumecs during a wet season), this imposes shifts in demand but disproportionally upon different sectors, depending on how users differentially access an increasing or decreasing rate of supply.[6] This can be seen as a modification of the supply variability upon demand variability, and therefore of the share proportions of users. At times of very low water supply in such arid environments, scheduling becomes more important too.

A Conceptual Framework of Scarcity Logic

Moving beyond a volumetric mission for balancing supply and demand opens up space for considering how inter-user shares can be managed, particularly in dividing water to users contemporaneously in the face of a variable supply. Figure 12.5 schematically expresses a single-axis concept of contrasting responses to scarcity. The left hand side tends towards tackling scarcity volumetrically, while the right side proposes a share response that recognizes – in the face of a dynamic supply – the allocative dimensions of scarcity, the facilitative nature of providing shares, and the need to propagate shares down levels of use. The middle territory suggests a mixed approach.

It is worth noting that water metrics are integral to the approach chosen. Thus supply and demand management, associated with ‘quantity-balance’ logics, primarily considers volume (cubic metres) or discharge (litres per second). The facilitative and composite approaches are inherently concerned with managing existing shares as proportions and/or specific flows expressed as an intensity (e.g. litres per second per hectare).

The framework comments on water responses to scarcity utilizing an equilibrium and non-equilibrium lens (Lankford and Beale, 2007) – drawn in turn from ecological theories of natural resource and ecological governance recognizing parallel challenges of meeting demand and supply at the local and landscape scales (Behnke and Scoones, 1993; Sullivan, 2003). Thus, when water scarcity is primarily held to be a problem of volumetric scarcity arising out of an imbalance of supply and demand linked under conditions of *perceived* average ‘equilibria’, analysts favour a response logic tending towards supply side or demand side solutions (see also Chapter 13, this volume). Apart from the risks of whether such technologies materially boost supply or reduce net demand, the key risk is that the interpretation of the environment is incorrect – hence the term ‘perceived’.



Response	*Volumetric/quantity logic*	*Composite ‘facilitative’ logic*
Order of response	**Primary; ‘solving the water balance’**	**Layered, composite; ‘propagating equitable shares’**
Climate & agro-ecology	**Humid, temperate, oceanic, stable**	**Seasonal, semi-arid, dynamic**
Hydrological predictability & stability	**Equilibrium, predictable**	**Non-equilibrium, unpredictable**
Approach	Supply mgt Demand mgt Share mgt (allocation)	Share mgt (modification, translation, scheduling)
Managerial intention	Alter volume-balance within a supply phase	Alter share balance when moving between phases
Water unit of measurement	Volume or discharge or depth	% Proportion or intensity/specific
Means of water measurement	Metering	Non-metering solutions
Water rights	Volumetrically specified	Temporally and/or proportionally specified

Figure 12.5 A conceptual framework of scarcity response logic

A ‘quantity-balance’ logic, while important, is not necessarily complete or accurate enough in semi-arid environments – seen as non-equilibrium environments marked by considerable fluxes of scarcity. For two reasons, pulse-driven environments require additional thinking. First, supply and demand are not in step with each other either inter- or intra-seasonally, and second they are not moving towards a broad equilibrium over time. The additional thinking is that we are not able or obliged to balance supply and demand in the same way, but to give emphasis to propagating shares between users in ways that are locally transparent and beneficial and facilitating user communities to transit from wet to dry periods.

This framework throws light on supply side solutions for non-equilibrium semi-arid environments. Given a new reservoir, the manner in which that additional water volume is shared within the locality becomes significant, recognizing the paramount importance of timeliness of water arrival for ecological functioning in semi-arid climates. How this takes place, with implications for guarding against unplanned appropriation, for purposive water allocation (setting the broad limits on water apportionment for domestic, productive or environmental purposes during dry and wet seasons), for translation (proportions changed through the presence of the dam), for modification (the interference of other infrastructure on the intended outcome of reservoir releases) and for scheduling (switching the dam's water between users) has to be critically addressed.

How society *shares* a variable supply between different users rather than attempts to climate-proof such an environment by boosting supply is a fundamental question. This is particularly so as we recognize differences between types of users and stakeholders characterized by their proximity to a secure supply (e.g. powerful top-enders versus impoverished tail-enders) and dependence on small, timely amounts of clean water (contrasting irrigators with domestic users). Moreover, it is the relative lack of political voice of the less advantaged that diminishes society's obligations to consistently prioritize a more equitable sharing of limited, varying supplies. It is posited that this water scarcity framework, while nevertheless subject to claims for water by socially differentiated groups, puts into the hands of water managers a more explicit tool for interpreting intended and unintended impacts of water interventions.

Case Study Example of the Framework

The differences between volumetric and facilitative approaches to scarcity are now briefly explored, exemplified by work conducted by the author in Tanzania during the period 1999–2005.[7] The case study is the basin of the Usangu wetland forming the headwaters of the Great Ruaha River, which is a major tributary of the Rufiji River. The area covers 20,800km^2, of which 23 per cent is alluvial plains at an elevation of 1000 to 1100masl, and the remaining 77 per cent forms the high catchment, ranging in altitude from 1100 to just under 3000masl. The high catchment receives 900–1500mm of rainfall annually while the plains receive 650–800mm. Rainfall is highly seasonal, occurring mainly between December and April. A long dry season occurs between May and November.

The Usangu basin contains a number of water resource subsystems. The relatively wet high catchment on the southern and western boundary of the area forms the source for a number of perennial and seasonal rivers which flow into the Usangu Plains. The plains consist of alluvial fans forming an almost continuous band around the margins of the central plains, and seasonally flooded open grassland and perennial swamp towards the centre.

Irrigated agriculture is situated on the middle to lower parts of alluvial fans on the southern margin of the Usangu wetland, consisting of large state-owned rice farms and separate informal smallholder areas. Irrigation using diverted river water is the greatest source of demand for water within Usangu. Paddy rice is irrigated in the wet season, while maize and vegetables are irrigated in the dry season. Below the irrigation systems are grasslands and wetlands – the latter expanding and contracting depending on inflows. Water exits the north end of the Usangu wetland over a natural rock sill which acts as a spillway. The outflow supplies the Great Ruaha River which flows northeastwards through the Ruaha National Park forming an important source of water for wildlife. Downstream of the Park, the river flows into the Mtera and Kidatu hydropower reservoirs that provide approximately 50 per cent of Tanzania's electricity supply.

A World Bank project 'River Basin Management and Smallholder Irrigation Improvement Project' (RBMSIIP), funded in Tanzania to support river basin management (World Bank, 1996), sought to allocate water in the Usangu basin via the implementation of a formal regulatory approach. The main aim was to reduce irrigation abstraction so that more water remained in the Great Ruaha River supporting the Usangu wetland, the Ruaha National Park and hydropower. This utilized new water rights sold in litres per second, combined with changes to intake design where an 'improvement' from traditional designs was deemed necessary (Lankford, 2004). One rationale for introducing water rights was to attach fees as an incentive for water conservation.

Research in the area by van Koppen et al (2004) demonstrated that the new volumetric water rights were poorly matched to the problems encountered. The water rights did not recognize existing customary water rights; they failed to accommodate swings in water supply due to rainfall and seasonality; could not be tied to actual water taken because no flow measuring structures were in place; and in many cases were not related to the discharge capacities of new intakes or to the demand of irrigation systems.[8] Furthermore, the rights were not, when cumulatively added to other water rights, related to the overall supply in the river systems (which varied by several orders of magnitude from wet to dry seasons) and were difficult to update in a constantly changing situation.

The design of irrigation rights and intakes by RBMSIIP influenced water allocation materially and in unintended ways. Downstream users were subjected to extreme low flows in the dry season as a result of upstream full crest (‘blocking’) weirs taking all the water. These conventionally designed types of irrigation intake aggravated a delicate situation where dry season flows of only 100–200l per second had to be shared between intakes and instream users along a catchment. The intakes did not increase irrigation efficiency in the ways intended because it was mainly affected by in-field water management and reuse of drain water by peripheral irrigators (Machibya, 2003). Thus a volumetric solution of water rights and intake ‘improvements’ based on equilibrium thinking exacerbated downstream water scarcity once the wet season was over and flows declined during the dry season.

A facilitative alternative (see Table 12.4) is provided in the legal infrastructure framework of Lankford and Mwaruvanda (2007) for managing formal and informal rights and river basin infrastructure. It rationalizes the interface between formal volumetric water rights (where the capped abstraction determines allocation between users in the wet season) and customary agreements (that relate to shares of instream water during the dry season). The framework demonstrates how, if strengthened and supported, local customary negotiations, combined with formal water management interventions, apportion water during both wet and dry seasons. The framework argues that the current design of irrigation intakes, in terms of maximum capacity, adjustability and any proportional capability, needs to be re-thought so that the intakes fit and help support their associated, seasonally-relevant, sharing arrangements.

On the left hand side of Table 12.4, with a volumetric bias, water rights require water measurement to charge users for the amount of water used (an economic incentive for demand management). Therefore, the logic runs, water discharges should be volumetrically measured.[8] Yet, water can be ‘measured’ in three other ways: by proportional division, by time measures (with off/on gate settings) and by modular gate technology, all of which establish transparent means of satisfying managerial gaps in apportionment of water.

Table 12.4 Comparing approaches for managing dynamic supply in sub-catchments

Water governance dimension	**RBMSIIP approach**	**Alternative 'facilitative' approach**
Seasonal change reflected in intake design	Weir and orifice intake has to be manually adjusted in dry season to reduce inflows	Proportional flume design embeds sharing of water during dry season
Intake component most closely associated with this change in design	Users rely on Q max rather than on throttling. Gate is usually opened to maximum setting. The focus here is litres/second	Design to allow passive proportional abstraction of available river flow with maximum intake capacity being the volumetric cap. The main focus is percentage of division
Type of rights most closely associated with wet and dry season	Formal water permit (volumetric) with no recognition of informal shares or rights	Formal water permit (volumetric) is the maximum cap during wet season while customary agreements are proportional during dry season (or time schedule basis)
Water measurement	If to support volumetric rights, then a measuring structure is necessary (yet open channel variable flow measurement is problematic)	No measurement necessary, volumetric cap designed into the intake, and proportional rights aided by proportional design
Role of intake improvement from traditional to 'improved'	To improve irrigation efficiency via regulation designed using normative irrigation engineering procedures	To help share water between users intra- and inter-sectorally within and below the catchment. Focus is on the catchment sharing of water

In summary, contemporary water rights issuance in Tanzania was a volumetric response to scarcity. RBMSIIP hoped that these volumetric rights would ensure demand management and therefore bring about reduced upstream demand thereby effecting inter-sectoral allocation from upstream irrigation to downstream hydropower. The framework proposed by Lankford and Mwaruvanda (2007) suggests a need to distinguish between the wet and dry season sharing of water, between paper 'rights' and concrete structures, and between proportional as well as volumetric division of water. As well as local power interests, one obstacle to the implementation of the approach in Table 12.4 is current momentum towards normative irrigation intake design. If implemented, the success of the framework would rely on ongoing efforts to socially explore water apportionment between water rich top-enders and water poor tail-enders combined with experimentation of gate dimensions, adjustments and flows.

Conclusions

In presenting a wider framework of supply, demand and share management responses to scarcity, I propose a number of conclusions. First, with regards to scarcity responses, clarity is required, not simply in definitional terms but in terms of intentions and material outcomes; what aims to boost supply can then increase demand and what can seem to be demand management may not affect total abstraction. More particularly, in highly dynamic environments, imperfectly considered interventions regarding demand or supply management might exacerbate unfair water apportionment and not alleviate scarcity for some. Within highly politicized debates about water scarcity, particularly to address scarcity under climate change, the need to define meanings, causalities, quantities, intentions and outcomes is paramount.

Second, I argue that a supply-and-demand ‘volumetric’ logic runs the risk of being a partial response to water scarcity, occluding dimensions of water management that address the sharing and scheduling of limited and varying water supplies. A composite framework that examines the supply, demand and share of water is proposed, emphasizing in particular modification and translation dimensions of sharing water during transitions from high to low water sufficiency and back again. Pursued to outputs, this approach might nevertheless require additional storage or water-saving technologies – but they would be encapsulated within a prioritized set of ideas regarding water apportionment contrasted against dominant volumetric scarcity narratives.

Drawing from political ecology approaches, we might observe that crises and technical responses are framed by those who have an ability to shape policy narratives (e.g. Sullivan, 2000). Thus, orthodoxies of supply and demand management that appear to have a *straightforward* and *sensible* technical basis should nevertheless be thoroughly contested. One example of this is that irrigation efficiency can be addressed by shifts to micro-irrigation or canal lining. While this is technically generalizable, it omits a definition of boundaries that define whether savings actually result in a reduction of net irrigation abstraction and the extent to which such interventions address how small amounts of water are apportioned to needy users during periods of drought or aridity at the landscape scale.

Third, the chapter elevates irrigation abstraction technology (mostly neutral in the demand and supply management debate, or potentially mistaken as a technology to improve irrigation efficiency) to being critical for considering how share management functions contemporaneously in the face of a varying supply. Seeing intakes and other abstraction points as technologies for flow switching or dividing a river flow might be a useful way of re-imagining these as representing share infrastructure, just as storage is supply infrastructure.

Fourth, the appropriate selection of supply, demand and share management responses represents a matter of water governance – and does so in two ways. First, share and demand management requires an effort of governance over and above providing the capital and infrastructural elements of storage. Second, governance theory must be in a position to comment on the inter-linkages between, and respective relevance of, supply, demand and share management, thus shaping a policy response to a particular context.

Fifth, the framework has critical implications for equilibrium and non-equilibrium theories of water apportionment between users. Under equilibrium conditions where water is perceived to be predictable and knowable in terms of supply and amount, the regulatory ‘allocation’ of averaged volumes via IWRM may be the most appropriate response to water sharing. However in semi-arid conditions where water supply is unpredictable and highly variable over short timescales, ‘translation’, ‘scheduling’ and ‘modification’ become more significant as mediating mechanisms for water sharing between users. In addition, under such conditions, regulators might entertain water rights expressed as proportions (percentage) of the available supply.

To conclude: we may too often underestimate the interplay between demand, supply and share management in different types of landscapes and environments. Put simply, if water systems and management are held to be manifold, composite and complex, then approaches change from being direct and volumetric to being composite and ‘para-volumetric’. Share management, together with demand and supply management, describes a tripartite view of scarcity management, underpinning an objective of facilitating a water-using society to transit to different states of water sufficiency during wet and dry periods by organizing resources at a locally and temporally relevant scale. It is about adaptive guises – society tends to default to volumetric adaptations to shortages rather than adaptations to shortages that accommodate the nature of water management (high variability, continuous flows, poor transparency, timeliness). This returns to an underlying adaptive or ‘knowledge scarcity’ which suggests that we do not critically unpack scarcity, particularly when scarcity responses are reinforced politically and materially by programmes that spend on storage infrastructure without making good the potential benefits of that extra storage through enhanced water apportionment, especially transiting from wet to dry periods.

Notes

1 The term ‘user’ covers all types of water sectors, stakeholders, individuals and groups.

2 As several authors in this volume note, water scarcity is something that is usually socially constructed. The term ‘water sufficiency’ could be explored as an alternative to encompass a decrease in the volume of water available per capita or to an area over time. However, it is beyond the scope of this chapter to deal with the social meanings of water scarcity or sufficiency.

3 The author has commonly heard this refrain at water workshops and meetings attended by policy-makers and scientists, particularly when dealing with IWRM.

4 ‘Share’ is preferred to the word ‘allocation’, which has already acquired other meanings in IWRM, and for its tonal and grammatical verbal similarities to the words ‘demand’ and ‘supply’.

5‘Allocation’ covers re-allocation; both are purposive, utilizing the same devices.

6 The Tanzanian case study saw irrigation intakes sequentially abstract water upstream to downstream. Upstream intakes received disproportionally more water during low flow periods.

7 This work provided the inspiration for non-equilibrium and facilitative approaches to water apportionment. A number of publications can be referred to as background reading (Lankford, 2004; Lankford et al, 2004; Lankford et al, 2007; McCartney et al, 2007; SMUWC, 2001).

8 I refer to emails with the World Bank in November 2003 on their long-term aims of RBMSIIP to support water measurement so fees could be set volumetrically.

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