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Water security: Debating an emerging paradigm

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ABSTRACT

This paper presents a comprehensive review of the concept of water security, including both academic and policy literatures. The analysis indicates that the use of the term water security has increased significantly in the past decade, across multiple disciplines. The paper presents a comparison of definitions of, and analytical approaches to, water security across the natural and social sciences, which indicates that distinct, and at times incommensurable, methods and scales of analysis are being used. We consider the advantages and disadvantages of narrow versus broad and integrative framings of water security, and explore their utility with reference to integrated water resources management. In conclusion, we argue that an integrative approach to water security brings issues of good governance to the fore, and thus holds promise as a new approach to water management.

1. Introduction

The concept of water security has received increased attention over the past decade, in both policy and academic debates. Multiple definitions of this concept exist, promoted by a range of international organisations—notably the Global Water Partnership and the World Economic Forum.[2] Other groups identifying the importance of water security include UNESCO's Institute for Water Education, which has made water security one of its research themes (UNESCO-IHE, 2009) and the Asia-Pacific Water Forum that, in 2007, held its first summit entitled "Water Security: Leadership and Commitment" (Asia Pacific Water Forum, 2007). Water security has also come to the fore of some domestic water management agendas in the past decade, particularly associated with (bio-) terrorism concerns, leading some to characterise it as "a key objective of a range of governmental and nongovernmental agencies across the spectrum of governance levels" (Jansky et al., 2008, p. 289). Moreover, as we explore below, there has been a significant increase in the employment of 'water security' within the academic community over the past decade.

This paper presents a comprehensive review of the concept of water security in academic and policy debates. Despite the necessarily exploratory nature of this analysis (given that 'water security' is—at best—an emerging paradigm), this analysis is merited given that a growing number of scholars and policy makers have adopted the term, while an increasing number of international organisations are employing the concept of water security to frame water-related issues. Simultaneously, the divergence between different framings of water security has become apparent, sparking debate over analytical approaches to, and definitions of, water security.

We contribute to this debate through critically analysing the differences and commonalities in approaches to water security across academic disciplines. In Section 2, we provide a comprehensive review of water security-related research. We identify distinct differences in methods, scale, and framing of water security in the different disciplines surveyed and discuss the implications of these differences. We also show that framings of water security have become more diverse, expanding from an initial focus on quantity and availability of water for human uses to include water quality, human health, and ecological concerns. In Section 3, we argue in support of a broad and integrative conceptualisation of water security, and explore the utility of this approach in water governance, while recognising constraints that arise in the context of implementation and management. In Section 4, we conclude with a discussion of the implications for policymakers and academics. Before beginning the analysis, we should note that this paper does not present a water security framework. Rather, it is a critical review intended to identify different approaches to water security across the natural and social sciences, and to stimulate dialogue about the need for convergence on framing the concept of water security.

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[2] At its Summit on the Global Agenda in Dubai in November 2008 the Network of Global Agenda Councils of the World Economic Forum discussed water security extensively (World Economic Forum Network of Global Agenda Councils, 2008).

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2. Framings of water security across the physical and social sciences

We conducted a comprehensive review of the English-language academic literature, covering all publications on water security and cognate concepts.[3] In order to analyse the trends in the academic literature we used a subset of our findings: articles in peer-reviewed journals on the topic of "water security" across all years in the Web of Science database. The compiled water security database (including policy reports but not including news articles) of 418 references prepared first in October 2008 and updated in November 2010 was the basis for the literature review. The literature search results were analysed quantitatively and qualitatively. We believe the review presented here is the first of its kind.

2.1. Increasing use of the term "water security" across disciplines

The quantitative review of the Web of Science database search results indicated that use of the term water security has increased across a wide range of disciplines in the last decade. Fig. 1 illustrates the trend of steadily increasing frequency of use of the term "water security" in academic, peer-reviewed journals. In total, the Web of Science database returned 95 articles containing the term "water security" from all years in the database. (Our review of the policy literature indicated a similar trend.) Empirical and modelling studies dominate the academic literature on water security. We classified the 95 Web of Science articles into four main categories: empirical,[4] modelling, conceptual, and lab-based. Nearly half of the studies were empirical (44) and nearly one third were modelling (30). The remaining studies were mostly conceptual (15), with a small number of lab-based studies (4).

Our analysis also illustrates the diversity of disciplinary approaches currently characterising academic research on water security. Fig. 2 indicates that a wide range of disciplines use the term "water security" (although it is important to note that Web of Science offers patchy coverage of the social sciences and humanities, which may thus be under-represented). Using the Web of Science database "subject areas" analysis tool, we sorted the 95 articles into disciplinary groups, amalgamating complementary subject areas to produce combined categories of cognate disciplines.[5] Notably, each of the top five most-cited articles as at November 2010 containing the term "water security" in the Web of Science database (including both social science and natural science journals) is based in a different discipline. In descending order of citation frequency, the articles are from fisheries science, hydrology, public health, environmental studies, and water management/policy (Ashton, 2002; Döll et al., 2003; Hrudey et al., 2003; Schindler, 2001; Shuval, 1992). As explored below, these different disciplinary perspectives offer distinct framings and methodologies for the analysis of water security.

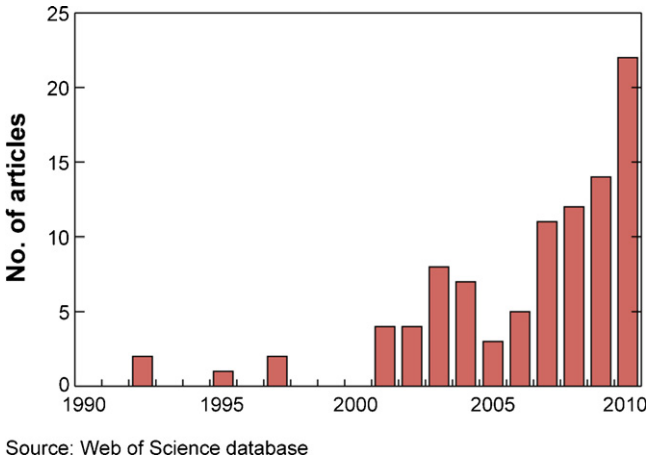

Fig. 1. Articles containing the term "water security" in the academic literature (1990–2010).
Source: Web of Science database.

Another salient finding of our analysis is the variability of scales at which water security is defined and measured. Scale is critical in assessing water security because of the scalar variability of hydrology, as illustrated by a recent study (Vorosmarty et al., 2010). The global focus of that study is useful for inter-country comparisons; however, the relatively coarse spatial resolution of the study hides significant variability in water security. In Canada, for example, which is classified as "water secure", decreasing water availability in the Prairie region is a growing concern, and

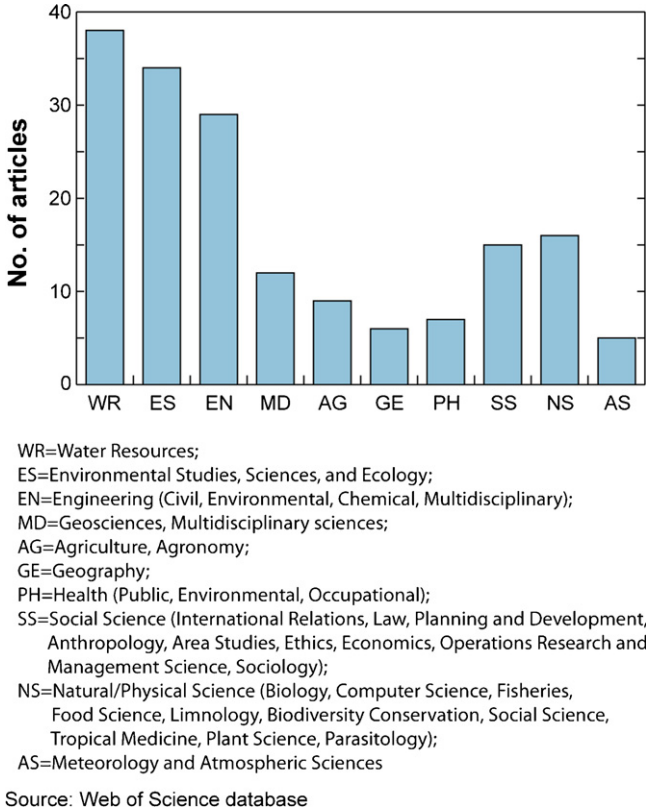

Fig. 2. Disciplinary grouping of articles containing the term "water security" (1990–2010).
Source: Web of Science database.

[3] The following search terms were used: "water security", "water vulnerability", "water stress", "water index/ices", "water frameworks", "water sustainability", and "secure water". Given the widespread use of the term water security, it was necessary to review a variety of databases covering a broad range of disciplines. We searched the following databases: Geobase/GeoRef, PAIS, EconLit, Worldwide Political Science Abstracts, International Political Science Abstracts, JSTOR, Web of Science, and LegalTrac. In addition, policy references were gathered via Internet [Google] searches for "water security".

[4] Non lab-based.

[5] The articles were sorted into ten subject areas, based on the Web of Science primary categorisation: WR, water resources; ES, environmental studies, sciences, and ecology; EN, engineering (civil, environmental, chemical, multidisciplinary); MD, geosciences, multidisciplinary sciences; AG, agriculture, agronomy; GE, geography; PH, health (public, environmental, occupational); SS, social science (international relations, law, planning and development, anthropology, area studies, ethics, economics, operations research and management science, sociology); NS, natural/physical science (biology, computer science, fisheries, food science, limnology, biodiversity conservation, social science, tropical medicine, plant science, parasitology); and AS, meteorology and atmospheric sciences.

Table 1
Articles containing the term "water security" in the academic literature (1990–2010) sorted into type and scale of study.

Type of study	Scale of study	Total no. of articles
Empirical	No specific scale	0
	Community/municipal/hydraulic infrastructure	4
	Subnational watershed/drainage basin	9
	Regional (province/state/subnational)	9
	Nation-state	10
	Supranational (two or more countries)	12
Modelling	No specific scale	10
	Community/municipal/hydraulic infrastructure	0
	Subnational watershed/drainage basin watershed	6
	Regional (province/state/subnational)	0
	Nation-state	11
	Supranational (two or more countries)	5
Conceptual		15
Lab-based		4
	Total no. of articles	95

Source: Web of Science database.

long-term water quality issues in Aboriginal communities have been well documented (Phare, 2009).

Our analysis confirms that different disciplines have a tendency to focus on different scales. Development studies tend to use national scales, hydrologists often focus on watershed scales from the regional to the national, and social scientists regularly work at the community scale. The fact that disciplinary toolkits and frameworks imply that water security analyses use different scales complicates and, we would suggest, confounds a meta-analysis of water security across the disciplines. Table 1 illustrates that political boundaries are used more frequently than hydrologic boundaries for empirical and modelling studies. This is interesting to note given that many of the studies are based in subject areas (such as water resources and environmental science and studies) that tend to privilege the watershed.

Table 2, below, provides an overview of the framings of water security found in the academic and policy literature. Drawing from our water security database, we selected examples of water security framings and sorted them into the subject areas used in Fig. 2. Table 2 illustrates the degree of differentiation in scope, and

Fig. 3. Water security content cloud.
Source: Web of Science database using TagCrowd.com.

variables of analysis, used by different disciplines and organisations.

Fig. 3 presents a content cloud providing an indication of the key concepts of interest across the academic community (for a discussion of content clouds as a method for qualitative data analysis, see Cidell, 2010). The content cloud provides an assessment of the relative frequency of words used in the 95 academic articles in our sub-database of Web of Science results (including the title, abstracts, and keywords) and suggests convergence around a set of core concepts: "areas", "basin", "change", "development", "food", "irrigation", "management", "model", "resources", and "river".

This analysis indicates that a diversity of definitions of and approaches to analysing water security are deployed across the natural and social sciences. Below, we identify key themes and compare and contrast the usage of the term in different disciplines.

2.2. Evolving and competing framings of water security

As indicated in Section 2.1, the widespread uptake of the term 'water security' is relatively recent. Contemporary framings of water security are highly diverse and include issues other than water quantity (or water as hazard). Indeed, framings of water security are by no means consistent and (as we discuss below) tend to vary with context and disciplinary perspectives on water use.

Table 2
Scope of approaches to water security, selected examples.

CODE	Subject area	Water security focus or definition
AG	Agriculture	•Input to agricultural production and food security
EN	Engineering	•Protection against water related hazards (floods, droughts, contamination, and terrorism) •Supply security (percentage of demand satisfied)
ES	Environmental science, environmental studies	•Access to water functions and services for humans and the environment •Water availability in terms of quality *and* quantity •Minimizing impacts of hydrological variability
NS	Fisheries, geology/geosciences, hydrology	•Hydrologic (groundwater) variability •Security of the entire hydrological cycle
PH	Public health	•Supply security and access to safe water •Prevention and assessment of contamination of water in distribution systems
SS	Anthropology, economics, geography, history, law, management, political science	•Drinking water infrastructure security •Input to food production and human health/wellbeing •Armed/violent conflict (motivator for occupation or barrier to cooperation and/or peace) •Minimising (household) vulnerability to hydrological variability
	Policy	•Interdisciplinary linkages (food, climate, energy, economy and human security) •Sustainable development •Protection against water-related hazards •Protection of water systems and against floods and droughts; sustainable development of water resources to ensure access to water functions and services
WR	Water resources	•Water scarcity •Supply security (demand management) •"Green" (versus "blue") water security – the return flow of vapour

Source: Prepared by the authors.

For example, from a legal perspective, water security has generally been associated with allocation rules that seek to secure entitlements to desired quantities of water (Tarlock and Wouters, 2009, p. 54). In contrast, from an agricultural perspective, protection from flood and drought risk is generally considered a key determinant of water security. Framings of water security are thus dependent upon one's perspective, as reflected in the diversity of framings put forth in the academic and policy literature.

Within this diversity, some common themes and trends can be identified. In general, the definitions of water security used in the 1990s were linked to specific human security issues, such as military security, food security and (more rarely) environmental security. Then, at the Second World Forum in 2000, the Global Water Partnership introduced an integrative definition of water security that considered access and affordability of water as well as human needs and ecological health. Since then, a variety of a scholars and policymakers have taken up the term and given it various meanings, with some developing discipline-based definitions and others advancing an integrative, interdisciplinary approach. Within this diverse literature, four interrelated themes dominate the published research on water security: water availability; human vulnerability to hazards; human needs (development-related, with an emphasis on food security); and sustainability.

First, framings of water security that focus on quantity and availability of water are often linked to water security assessment tools. Perhaps the most well known assessment tool to date combines two indices—for water stress and water shortage—in the measurement of water scarcity (Falkenmark et al., 2007; Falkenmark and Molden, 2008). The first index of water stress evaluates the ratio of water use to availability and estimates demand-driven apparent scarcity by measuring how much water is withdrawn from rivers and aquifers—the blue water resources. The second index of water crowding or water shortage estimates population-driven real water shortages by measuring the number of people that have to share each unit of blue water resource (Falkenmark et al., 2007; Falkenmark and Molden, 2008). From this perspective, sufficiency of water supply for humans is the primary gauge of water security. For an individual, water security exists when she has access to sufficient safe and affordable water to satisfy her needs for drinking, washing, and livelihood (Rijsberman, 2006).

A second theme of the academic literature on water security is the issue of water-related hazards and vulnerability. For example, the UNESCO – Institute for Water Education advocates an infrastructure and systems approach to water security which "involves protection of vulnerable water systems, protection against water related hazards such as floods and droughts, sustainable development of water resources and safeguarding access to water functions and services" (UNESCO-IHE, 2009). The US Environmental Protection Agency defines water security as prevention and protection against contamination and terrorism (Crisologo, 2008; Minamyer, 2008; Morley et al., 2007). Of course, this is directly linked to broader concerns over state or "homeland" security; indeed, United States federal law has made "drinking water infrastructure security…' a cornerstone of homeland security"' (Shermer, 2005, p. 359). In implementing this concept, water engineers have developed an understanding of water security as "guns, gates, and guards" to ensure potable water and drinking water infrastructure security (see especially the *Journal American Water Works Association*; Staudinger et al., 2006).

A third dimension of water security literature is "human needs", a term which covers a broad range of issues, including access, food security, and human development-related concerns. For example, one framing of water security from the 1990s focusses on the human need for water: "[W]ater security is a condition where there is a sufficient quantity of water at a quality necessary, at an affordable price, to meet both the short-term and long-term needs to protect the health, safety, welfare and productive capacity of position (households, communities, neighborhoods [*sic*], or nation)" (Witter and Whiteford, 1999, p. 2). The United Nations Development Program's approach to human security underpins many of these definitions (UNDP, 1994); for example, Janksy et al. defined water security as "all aspects of human security pertaining to the use and management of water" (Jansky et al., 2008, p. 289). Of course, the anthropocentrism of such a framing of water security risks neglecting the importance of the ecosystem as an integral component of both human and water security.

Within the human needs approach, there is a tendency to frame water security as a component or subset of food security (Biswas, 1999; FAO Land Division Water Development, 2000; White et al., 2007). The Food and Agricultural Organization (FAO) linked the concept of water security to food security, in which water security was the ability to provide adequate and reliable water supplies for populations living in the world's drier areas to meet agricultural production needs (Clarke, 1993). The FAO has maintained an agricultural focus of water security—"crop water security"—where water quantity is highly relevant (FAO Land Division Water Development, 2000). In many countries, reservoir storage for the purposes of irrigation is the salient feature of water security (El Saliby et al., 2009). This focus on water quantity also holds true for framings that widen concern from reservoir storage to consider the entire hydrological cycle (Johansson et al., 1999; Oki and Kanae, 2006; Tuinhof et al., 2005). From this perspective, water security is threatened by either water scarcity or risk of inundation that can be attributed to an inability to manage water.

A fourth theme in the water security literature is that of sustainability. According to the Global Water Partnership, for example, "[W]ater security at any level from the household to the global means that every person has access to enough safe water at affordable cost to lead a clean, healthy and productive life, while ensuring that the natural environment is protected and enhanced" (Global Water Partnership, 2000, p. 1). This broad framing includes seven variables: meeting basic needs, securing the food supply, protecting ecosystems, sharing water resources, managing risks, valuing water, and governing water wisely. This, the GWP argues, implies the need for baseline requirements for water resources management in a watershed on a continuous basis—for "life"—and demands access to adequate quantities of acceptable quality of water for both humans and the environment.

Framings of water security used by academic scholars often cite the GWP definition (or offer a similar definition that includes human and ecosystem needs, accessibility, continuity, and affordability). For example, researchers in Canada define water security as "a multi-dimensional concept that recognises that sufficient good quality water is needed for social, economic and cultural uses while, at the same time, adequate water is required to sustain and enhance important ecosystem functions" (de Loë et al., 2007, p. 1). Another group of Canadian researchers defines water security as "sustainable access, on a watershed basis, to adequate quantities of water, of acceptable quality, to ensure human and ecosystem health" (Dunn and Bakker, 2009, p. 11; Norman et al., 2010, p. 14). A framing that draws on the GWP's report states water security "involves the availability of water in adequate quantity and quality in perpetuity to meet domestic, agricultural, industrial and ecosystem needs" (Swaminathan, 2001, p. 35).

Somewhat surprisingly (given the attention paid to 'water wars' in popular media), there is relatively little emphasis in the water security literature on military security or on the concept of environmental security ('green wars'), which emerged in the 1990s to refer to the links between violent conflict and environmental degradation (Kaplan, 1994; Homer-Dixon, 1999; Stern, 1999). Of

course, these issues have received significant scrutiny from academics (Giordano et al., 2002; Gleick, 1993; Wolf, 1999). But these scholars do not appear to have adopted the term 'water security', even where their nuanced approach to the integrative nature of environmental issues leads them to voice parallel issues, such as the links between multiple scales, or the importance of good governance[6] (e.g. Dalby, 2002). The one exception is the Middle East and North Africa, where early uses of the term water security explicitly focussed on geopolitical security concerns (Anderson, 1992; Savage, 1991; Shuval, 1992; Starr, 1991).

3. Discussion: critiquing approaches to water security

The review of the literature presented above indicates that approaches to water security are diverse and evolving. The potential compatibility (and incommensurability) between these approaches raises a series of questions, which are considered here. We begin by considering the relationship between water security and integrated water resources management (IWRM). We then explore the tension between conceptual and operational framings of water security and suggest that holistic approaches might best be deployed at a conceptual (paradigmatic) rather than at an operational (programmatic) level. Finally, we consider the claim that water security is deployed as a discursive strategy and explore key issues that may arise, focussing on questions of governance.

3.1. Water security and IWRM: complementary paradigms?

The increasing use of the term water security raises an important conceptual issue for water analysts and managers: how does water security overlap with IWRM and to what extent are they complementary paradigms? This is particularly important given that IWRM has emerged as a dominant water management paradigm in the discursive framing of international water policy over the past 20 years (Conca, 2006).

Like IWRM, water security—at least in its broad, integrative framings—offers a paradigmatic approach to the analysis of water systems, which integrates across scales (from the local to the global) and incorporates both quality and quantity concerns (including hazards and water access). For example, consider the degree to which the well known Global Water Partnership definition of IWRM incorporates the four themes of water security identified in Section 2.1, "a process which promotes the coordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital eco-systems" (Global Water Partnership, 2000, 2008). The coordinated management of water would address the four water security themes—water availability; human vulnerability; human needs; and sustainability—through a balancing of resource use and development with ecosystem needs. The GWP definition of IWRM shares much in common with integrative approaches to water management that have become increasingly widespread over the past few decades, in which the need to meet both human and ecosystem needs (while recognising their interdependencies) is paramount (Gleick, 2000; Pahl-Wöstl et al., 2008; Savenije and Van der Zaag, 2008, p. 295).

To the extent that framings of IWRM and water security display similarity, the two concepts appear to be complementary; however, perhaps no definition is broad enough to capture the complexity of water-related issues. For example, one critique of the GWP definition of water security is its focus "on individual water users in an environmental context, without considering other users such as agriculture and industries" (van Hofwegen, 2009, p. 201). To date, groundwater and atmospheric water have received little attention within water security analyses. Thus, despite a broad approach, it may not be possible to capture fully the complex dimensions of security throughout the hydrological cycle, particularly given the desire to integrate human and ecosystem health concerns.

Moreover, an integrative framing does not necessarily make water security easier to apply; the need to balance competing demands becomes increasingly salient as more components are incorporated into the concept (Norman et al., 2010). Indeed, a broad and integrative framing has a significant potential pitfall: multiple variables tend to increase the technical complexity of water security assessment and raise the risk of conflating water status (e.g. ecosystem health) with stressors (e.g. the quality of good governance regimes).

Indeed, we note that some of the challenges related to implementing IWRM (Biswas, 2004; Jonker, 2007; Watson, 2007) will also affect water security-related agendas. Since the 2006 World Water Forum, where water management professionals stressed that there is no single blueprint for moving towards IWRM (Martinez Austria and van Hofwegen, 2006) critiques have included the difficulty of IWRM implementation (Watson, 2007), its over-reliance on a regulatory regime, and its developed world policy prescriptions (Lankford and Hepworth, 2010). A further critique of IWRM centres on its expert-driven agenda (Conca, 2006). Others have commented on the perceived utopian nature of IWRM (Molle, 2008) arguing that it, in practice, IWRM "has rarely, if ever, been achieved in reality" (Watson, 2007, p. 34). The failure to implement IWRM has been attributed to insufficient capacity and financial support of the water sector, conceptual and theoretical fuzziness of IWRM, and reticence of policy makers to integrate issues (Jonker, 2007). A broad, integrative concept of water security will share these implementation challenges. As we argue in the next section, a narrowed framing will be a necessary (although arguably not sufficient) condition to operationalise water security.

Nonetheless, we argue in favour of an integrative and broad framing of water security for four reasons. First, a broad framing of water security is complementary to IWRM, as both imply the need to integrate water quantity and quality, in addition to ecosystem and human health concerns. 'Narrow' approaches to water security may move away from the integrative approach central to IWRM, which implies the need for robust governance processes to mediate the trade-offs between different stakeholders, scales, and uses of water. Second, a broad and integrative approach may be more analytically robust, because they are more comprehensive. Definitions of water security that focus solely on water quality, for example, are likely to miss water quantity-related concerns, which also affect secure access to water. Third, water security provides a means to respond to recent calls for a "clear vision or direction about a desired end state for a catchment or river basin" (Mitchell, 2006, p. 52). In other words, water security provides a framework, which lends itself to a 'vision', which is normatively goal-oriented (insofar as security implies a particular state). We suggest this is positive because it focusses attention on the end goal (water security) rather than the process of "integrated management" (as has been the case with IWRM). Fourth, the use of the term 'security' implies thresholds (below which water is insecure)—which may be of use in situations where monitoring and enforcement have been lacking. With thresholds in place, stakeholders and regulators must ensure water meets some agreed upon minimum standard, and water security may lend (at least discursively) greater priority to doing so (as explored below).

[6] According to UNESCAP good governance "has 8 major characteristics. It is participatory, consensus oriented, accountable, transparent, responsive, effective and efficient, equitable and inclusive and follows the rule of law. It assures that corruption is minimised, the views of minorities are taken into account and that the voices of the most vulnerable in society are heard in decision-making. It is also responsive to the present and future needs of society" (UNESCAP, 2011).

3.2. Operationalising water security: narrowing a broad framing

Water security is an overarching conceptual framework that articulates the desirability of balancing competing land and water use practices, much like IWRM. The challenges of IWRM sound a cautionary note that broad concepts are most usefully engaged in governance processes and must be narrowed to facilitate operationalisation.

As suggested by the review of the literature presented in Section 2, one of the most significant challenges in operationalising the concept of water security is the diversity of potential variables and methods. The "operationalisation challenge" is also a potential criticism of a broad and integrative framing of water security. We suggest that broad and integrative framings of water security are best viewed as conceptual and paradigmatic; and, as such, a useful complement to narrow framings, which are more likely to be operational—linked to policy, modelling, empirical research, and/or lab-based studies.

To give a concrete example, consider the approach adopted in one of the most influential papers on water security to date. In this study, which originates in the discipline of development studies, water security is framed broadly as "the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments, and economies" (Grey and Sadoff, 2007, p. 545). However, when operationalised, the framing is narrowed to the ability of a country to harness the productive potential of water and to limit its destructive impact. Grey and Sadoff (2007) separate countries into three categories: those that have harnessed hydrology; those that are hampered by hydrology; and those that are hostage to hydrology. This allows a conclusion that countries, such as Canada, that have successfully harnessed hydrology have achieved water security.[7] Of course, Canada is among the water-rich nation-states of the world, but there are regions of the country that suffer significant water scarcity. Indeed, water security assessment at the national scale can mask significant variations in security at the local scale (Vorosmarty et al., 2010). A true picture of country water security requires assessment at multiple scales—from the local to the national—for both human and ecosystem needs.

A recent article on national water security cites Grey and Sadoff's (2007) framing of water security as a generally accepted one and notes the concept "is normally defined and thought of in narrow terms limited to the water resources themselves" (Zeitoun et al., 2010, p. 230). The authors argue that water security requires a broader approach—especially when applied in the Nile basin—that "account[s] for the political and socio-economic factors related to the river's freshwater resources" (Zeitoun et al., 2010, p. 230). Yet Zeitoun et al.'s approach remains focussed on national water security. It is unclear how a focus on national water security with a framing broad enough to include political and socio-economic factors might be operationalised. Here, although the nation-state scale of analysis enables important and useful conclusions to be drawn, it precludes a fine-grained analysis of sub-national spatial and social variation of water security. This observation is not intended to imply that we seek to privilege the local (or indeed any) scale, or argue that all analyses must be multi-scalar. Rather, and more modestly, we simply observe that the choice of analytical scale implies analytical trade-offs, which is particularly relevant in the integrated study of water, insofar as different disciplines tend to prefer different scales of analysis.

We suggest that the advantage inherent in narrower framings of water security is that they enable precise identification and assessment of specific issues of concern. When managers try to implement a concept, they necessarily must narrow it, focussing on the primary concerns in the management area. An obvious critique of these narrow framings is the failure to recognise or integrate the multiple stressors that affect water security. We suggest that narrow framings would be usefully allied with broader, integrative framings of water security—such that these over-arching issues (such as the political and socio-economic factors identified by Zeitoun) are also taken into account.

Operational definitions of water security are also, our analysis indicates, likely to vary geographically. Specific definitions of water security have emerged in regions where particular water security concerns are acute. Our review of research on water security in Australia, China, and the Middle East and North Africa illustrates these regional specificities where disciplinary framings have taken a particular focus. In Australia, well-known as the world's most arid continent, water security has been defined predominantly as a concern of water availability (quantity) to be addressed by the national and state governments through a variety of mechanisms, as detailed in *A National Plan for Water Security* (Government of Australia, 2007, 2010). Australia has four priorities for water security—taking action on climate change, using water wisely, securing water supplies and supporting healthy rivers and wetlands (Government of Australia, 2010). Considerable research has focussed on making sustainable use of the country's major water resources found in the Murray–Darling Basin (e.g. Dijk et al., 2007). Water markets as a tool for sustainability, especially in irrigation have been studied (Khan et al., 2009), as well as the different approaches taken for reforming urban and agriculture water use (Crase, 2010; Crase et al., 2008).

In China, the industrial and populous north is considered highly water insecure (Xia et al., 2007). Here, water security research often has a combined focus on both availability and pollution, drawing on definitions from the World Water Forum 2000, either the Global Water Partnership (Zhao et al., 2009) or the Ministerial Declaration (Dong et al., 2010; Zhou et al., 2007). For example, "[W]ater security means the ability to supply water, according to a specified quality, to homes and industry under conditions satisfactory to the environment and at an acceptable price" (Xia et al., 2007, p. 242). Another definition suggests water security is "based on analysis of the relationship between environment [*sic*] changes and security issues considering not only the situation of water resources, but the related factors of environment, ecology, society, politics, and economy" (Ma et al., 2010, p. 541). While definitions of water security in the context of China are variable, most of the articles we reviewed were engineering studies focussed on building models to assess water security at the urban (Tong and Dong, 2009; Zhao et al., 2009) or regional scale (Huang et al., 2009; Ren and Dong, 2009).

In the Middle East and North Africa (MENA) region, the focus is on sharing a scarce resource amid increasing demand in an unstable geopolitical climate. One article defines water security as having "[A]vailable and secured enough quantities of fresh water to meet normal/rationing demand under emergency situations until water production facilities are constructed or rehabilitated" (Al-Otaibi and Abdel-Jawad, 2007, p. 301). The authors go on to state that water security is critical to "the stability, continuity and sustainable development of the states located in the arid realm" (Al-Otaibi and Abdel-Jawad, 2007, p. 305). Unsurprisingly, studies based on the MENA region often view water security at the national scale (Omer, 2003; Zeidan, 2005; Zeitoun et al., 2010). The concept of virtual water has been explored to address national water security in the MENA region (Allan, 1996; Nassar, 2007; Zeitoun et al., 2010) since it is effective in addressing water deficits

[7] For an exploration of Grey and Sadoff's (2007) thesis that water security is necessary for rapid economic development see Merrey (2009) Will future water professionals sink under received wisdom, or swim to a new paradigm? Irrigation and Drainage 58, S168–S176.

while being economically invisible and politically silent (Allan, 2003).

From a legal perspective, Mekonnen (2010) critiques the introduction of the "destructively elastic and indeterminate concept of 'water security'" into the Cooperative Framework Agreement for the Nile Basin" (Nile CFA) (Mekonnen, 2010, p. 439). Citing the Grey and Sadoff (2007) definition of water security, Mekonnen notes the inappropriateness of the "cornucopian illusion [of the definition] belied by the hydrologic environment of the river"—despite its length, the Nile River's annual discharge is meagre about equivalent to 2% of the Amazon's (Mekonnen, 2010, p. 438). Mekonnen disputes the purported usefulness of the "constructive ambiguity" that water security offers for the Nile CFA in a river basin characterised by a hydro-political hegemony that resists water reallocation. He concludes that in the Nile basin, water security only promotes the existing stalemate by reifying the status quo and securitisation of water (Mekonnen, 2010, p. 440).

These regional examples illustrate the significant variation in framings of water security to suit particular geographies. Some—but not all—of the regions we surveyed have linked their definitions to geopolitical concerns. The interrelationship between water quantity and quality varies in significance. And, the debate engendered by the concept of water security varies greatly between regions, stimulating the most critical commentary in the Nile region. These observations indicate that narrowing the framing of water security is essential to operationalising it. Nonetheless, we still consider a broad and integrative water security concept is useful and complementary to governance processes.

In summary, 'narrow' and 'broad' framings of water security are complementary rather than mutually exclusive. Operationalising water security at the management level will likely require specific and sometimes narrow framings of water security; in this context, these will be both useful and may be necessary. However, integrative framing of water security still needs to happen at the policy level, and in governance processes, in which priorities are established and decisions made between competing uses and users.

The extent to which policy makers and water managers can mobilise these two sets of approaches synergistically depends, to some extent, on the discursive mediation of water security. A broad and integrative framing of water security operates at the level of discourse. As with other environmental issues, it facilitates the establishment of "discourse coalitions" around shared goals (Hajer, 1995; Smith and Florian, 2009). For example, discursively framing their goals in terms of water security-related thresholds may be productive for water managers, because this implies setting thresholds, which are actionable in governance processes (e.g. via indicators). Nonetheless, the literature on the use of discourses in the context of environmental crisis also suggests that we must be sceptical, insofar as discourses of water security (and associated 'crises') may be strategically leveraged to further the advancement of other (usually pre-existing) goals (Kaika, 2005; Nevarez, 1996; Otero et al., 2009; Wilhite, 1986).

4. Conclusions

The critical review provided in this paper indicates that the concept of water security emerged in the 1990s and has evolved significantly since then. Two decades ago, the term was variously linked to military security, food security, and (more rarely) environmental security. In 2000, at the Second World Forum, the Global Water Partnership introduced an integrative definition of water security that considered access and affordability of water as well as human needs and ecological health. Since then, a variety of a scholars and policymakers have taken up the term and given it various meanings. Some have developed discipline-based definitions, and others have advanced an integrative, interdisciplinary approach.

Above, we reviewed these approaches and then argued for a broad and integrative conceptual framing of water security, while acknowledging the challenges this would entail. Indeed, we noted that debates over water security (like those over IWRM) illustrate the tension between broad and narrow framings. Nonetheless, we have argued that an integrative concept of water security is desirable, given the lessons of debates over environmental security (namely, that broader environmental goals can be sidelined in the absence of a broad and integrative framing of water security). Thus, our analysis might be understood as responding to recent calls emerging from the debate over IWRM; McDonnell (2008) notes, for example, that IWRM "is without question a desirable framework for water management, but ... there should be parallel moves to develop other ideas which bring the same returns of equity, efficiency and sustainability" (McDonnell, 2008, p. 142). Water security is, we suggest, one such 'parallel move' that shows promise.

Yet, scepticism regarding the uptake of water security as a concept is merited. In particular, those interested in operationalising the water security concept would do well to reflect on the reasons why this term has become popular and on the agendas it might serve. For example, it might be appropriate to examine the links between an increased uptake of the term water security and recent reforms in water governance, notably decentralisation, devolution and/or greater participation of communities in water governance (Blomquist and Schlager, 2005; Conca, 2006; Irvin and Stansbury, 2004; Leach and Pelkey, 2001; Reed and Bruyneel, 2010; Sabatier et al., 2005; Singleton, 2002). These changes in water governance have occurred for several reasons: shifting views over the role and mandate of governments; new legal requirements; increased desire for public participation; a desire to draw on expertise available outside of government; concern regarding low efficiency of water use, associated with ineffective management of resources and supply systems; and increased emphasis on integrated management of environmental issues (Brick et al., 2001; Gleick, 2000; Sabatier et al., 2005; UNWWAP, 2006, 2009).[8]

In turn, these changes have led to an emphasis on good governance, a point central to IWRM, but less of a focus in much of the water security literature to date (with some exceptions, e.g. Mirumachi, 2008). We argue one of the key reasons to favour a broad, integrative framing of water security is because it brings governance issues to the fore, whereas narrow and discipline-specific approaches often fail to broach governance issues. Of course, governance is critical to the effective implementation of water security, we would argue, not only because of the broad scope of threats, but also because good governance is an imperative for the successful management of multiple stressors on water environments (UNWWAP, 2006, 2009). In other words, a broad concept of water security and good water governance may be symbiotic, in the sense that each facilitates the other: water security sets goals for good water governance, and good water governance is necessary to move towards water security at an operational level. This is particularly the case at the global scale: without improved governance (and what Falkenmark terms 'hydrosolidarity'), we can expect greater divergence in the water security of low- and high-income countries (Falkenmark, 1999, 2001; Vorosmarty et al., 2010). From this perspective, water security is a promising framework but only if defined in a broad,

[8] These developments are articulated with, and to some extent illustrative of, a more general shift from 'government' to 'governance' in which non-governmental actors play a more significant role than in the past (Jessop, 2004; Pierre, 2000; Pierre and Peters, 2000; Rhodes, 1996; Strange, 1996).

integrative manner; aligned with well-established IWRM approaches; and embedded within good governance processes necessary for achieving secure water for all.

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