Stockholm Environment Institute

Where is the added value?

A review of the water-energy-food nexus literature

SEI working paper. June 2018

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Contents

Abstract

The water-energy-food nexus concept recognizes the complex interdependencies between the named sectors and seeks to analyse them as a single system to promote resource sustainability and effective governance. We review 63 self-identified empirical nexus studies to evaluate consistency, added value and transferability of nexus applications. Our synthesis of the scholarship includes insights regarding a working definition of the WEF nexus, the primary motivations for empirical nexus studies, the role of economics and governance in nexus analyses, and the nexus' dependence on socio-political and physical constructs. However, we find no clear boundaries to constrain the WEF nexus applications, and the resulting diversity of scholarship limits the synoptic conclusions that can be derived from it. The empirical WEF nexus research has not produced a discernible intellectual toolkit, nor has it validated claims that nexus approaches can improve resource management and governance outcomes. The lack of evidence for improving outcomes is a serious challenge that must be addressed if empirical WEF nexus research is to realize its promise.

Acknowledgements

Research for this paper was funded in part by the Stockholm Environment Institute's Nexus Initiative and core funding from the Stockholm Environment Institute US Center.

1. Introduction

The idea that water, energy and food systems are linked is not new, but the concept gained particular prominence in 2011 when the Bonn conference on Water, Energy and Food Security and the World Economic Forum focused on the *water-energy-food (WEF) nexus*. Advocates asserted that accounting for linkages between WEF systems can support sustainable development and optimize resource management (Hoff 2011). The conference inaugurated a period of increased interest and support of nexus research from international donors. Since then, the nexus has been featured in numerous articles, reports and journal special editions, and has motivated conferences all over the world (see list in Leck et al. 2015). The scholarship promises to provide novel insights into complex problems and support resource conservation, sustainability, and efficient and effective governance.

The Nam Gnouang Dam on a tributary of the Nam Theun River in Laos. © FLICKR / WORLDFISH

Though the nexus has produced many theoretical investigations, only a subset of empirical studies has applied the WEF nexus to specific regions to demonstrate its ability to structure analysis. We first examine what methodologies, framings or findings unite the nexus literature. Then we ask whether the identified studies demonstrate consistency in nexus applications that can serve as a toolkit for other studies. Finally, we examine to what extent nexus applications have improved outcomes through WEF case studies. To our knowledge this has not been attempted for the empirical nexus literature, as defined in Section 2, although the field is now over half a decade old. Other authors have reviewed the nexus, but they examined water and energy only (Hamiche et al. 2016; Tan and Zhi 2016), did not conduct a general search of the scholarly literature (Endo et al. 2017), or used a broader definition for what constitutes nexus literature (Albrecht et al. 2018). In examining the articles, we find that the diversity in nexus applications is arguably more characteristic of the field than the similarities. Due to the flexibility of the nexus concept, its application in empirical studies has best served to expand, rather than direct, study scope. Insights tend to be high-level, while identified actionable management and policy proscriptions are not broadly applicable. We found no clear methodology uniting nexus studies, and a lack of improvement of resource management and governance outcomes.

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We begin by describing our literature search and summarising the publishers, dates of publication, geographic foci, research emphases, and sources of funding for the 63 studies we reviewed (Section 2). We then present insights and findings from a synthesis of the studies, and highlight commonalities between them (Section 3). This is followed by a critical discussion of the limitations of empirical WEF nexus research to date (Section 4) and conclusions about our review's implications (Section 5).

2. Methods and Data

We examined the research questions, analytical approaches and key insights of empirical nexus literature to seek similarities, uniting methodologies and outcomes. To identify the articles, we used the Web of Science search engine. Our search (conducted May 2016) produced roughly 200 relevant results, which we filtered based on several characteristics. First, we only examined studies published in or after 2011, the year of the Bonn conference on the WEF nexus. While we recognize that integrative work on WEF systems predates the Bonn conference (Hellegers et al. 2008; McCornick et al. 2008), we chose this filter to sharpen our focus on contemporary nexus scholarship. Second, we selected self-identified nexus studies: studies that describe themselves as WEF nexus research and contain some discussion of what the nexus is and its relevance to the reported work.[1]

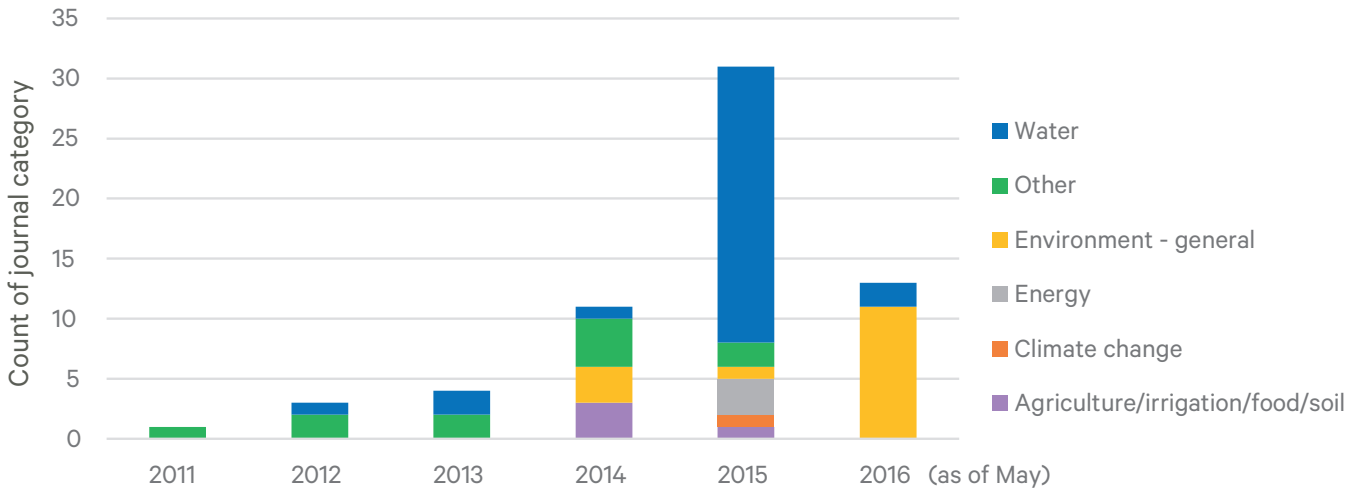
Third, we only considered studies that include all three components of the WEF nexus (water, energy, and food). Last, we selected empirical studies. These evaluations ranged from short descriptions to highly detailed case studies that illustrate specific nexus concepts. This filter excluded purely theoretical papers, which do not answer the question of how the WEF nexus has been applied in practice.

Our set of studies was further limited by which articles we were able to access through the Tufts University Library or its interlibrary loan network. We obtained 63 studies in total that matched all of our requirements. Figure 1 classifies these articles by publication year and journal/publication focus.

As Figure 1 shows, the rate of publication of empirical WEF nexus studies has been increasing, suggesting growing popularity of the nexus concept (note that the 2016 value includes only articles published before May). This distribution is also a direct result of which journals ran special issues: the journals *Water International* and *International Journal of Water Resources Development* each published a special issue examining the nexus in the autumn of 2015, and the *Journal of Environmental Studies and Sciences* and *Ecosystem Services* published a special issue and special section, respectively, about the WEF nexus in February 2016. We note that the majority of studies were published in water journals, which may indicate greater interest in the nexus among practitioners in the water sector.

As Figure 2 below illustrates, the studies took place in every continent except Antarctica, in both developed and developing countries, and in a wide variety of natural and socio-political environments. To provide an initial characterization of the studies' research emphases, Table 1 tallies the articles that included the modelling of physical WEF systems, that analysed governance and management systems surrounding the nexus, and that provided direct support to decision- or policy-making processes.

Figure 1. Count of empirical WEF nexus studies by publication topic



1 Studies that merely mentioned the nexus in passing in the article text (Cohen et al. 2016), abstract (Daccache et al. 2014), or title (Kraucunas et al. 2014) were excluded.

Table 1. Count of Studies by Research Emphasis

Research Emphasis	# of Studies
Modelling of physical systems	18 (29%)
Analysis of governance and management systems	23 (37%)
Direct support of decision or policy-making	5 (8%)
None of the above	24 (38%)

Note that some topics overlap; for example, all the studies that supported decision-making also modelled physical systems. The 24 studies that did not include any of these three aspects most frequently provided overviews of the nature of interactions between WEF sectors, such as a basin-wide study of water, energy and food demands and supplies. These overviews did not constitute critical analyses or decision support.

We also considered the studies' sources of funding. With the nexus increasingly serving as a framework for research funding (Cairns and Krzywoszynska 2016), this background information is instructive. While many of the studies do not identify their sources of funding (38 of 63, 60%), 19 of the studies (30%) received funding from government agencies, eight (13%) were funded by academic institutions, and three (5%) received foundation funding. Four of the studies were supported by funders from more than one of these categories – government agencies and academic institutions, foundations, or both.

A solar-powered system for pumping water for agriculture. © Getty / scalatore1959

3. Synthesis

Our review of the target studies revealed important commonalities in definitions and motivations for the empirical work undertaken. A few themes were also apparent in the studies' conclusions, although differences in the scope and applicability of conclusions seem at least as significant as any common ground. This section explores these synthesis findings of the review, highlighting examples from the 63 studies. Though we describe some commonalities, we also see a wide diversity in study approaches, insights, and conclusions.

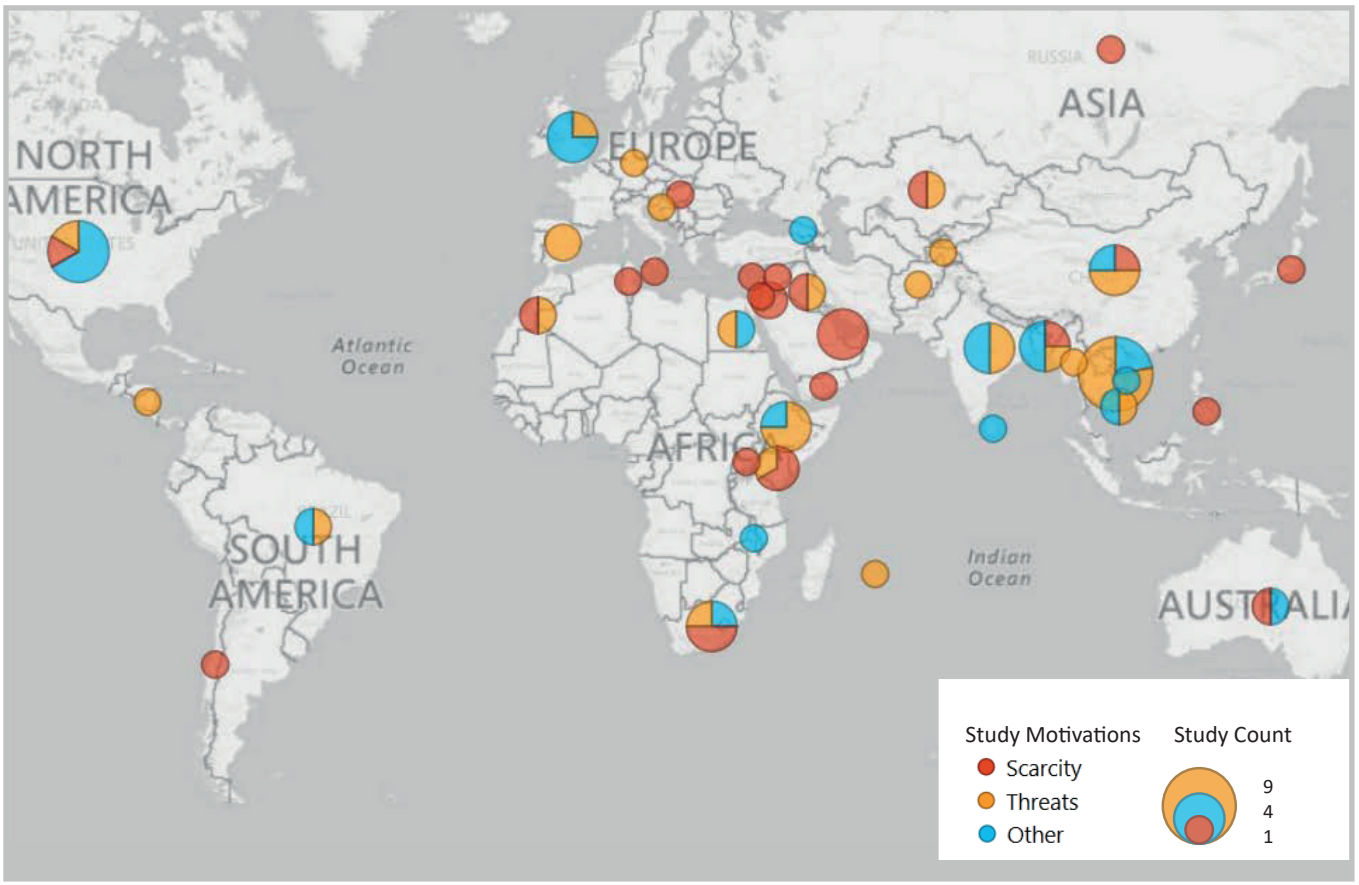
3.1 Definitions

Nexus studies often begin by defining their terms, which provides a useful opportunity to compare definitions of the WEF nexus. While some of the studies we examined define the nexus in quite different ways, most agree on a definition with these key elements: complex interdependencies and linkages between WEF sectors or systems, including trade-offs and feedbacks between them.

3.2 Study Motivations

Another notable pattern in the studies relates to motivation: why the empirical work was undertaken or what justifies it. The authors cite a variety of reasons, but two in particular characterize the primary motivation for most of the studies: 1) current scarcity of WEF resources; and 2) threats to WEF resource security due to large-scale infrastructure development, such as for hydropower or irrigation. Figure 2 maps the studies with color-coded primary motivations. As some articles examined multiple locations, the map depicts more than 63 data points.

Figure 2. Empirical WEF nexus studies by location and primary motivation. Circle sizes vary between 1 and 9 studies represented.



3.2.1 Resource Scarcity

Most of the studies motivated by resource scarcity focus on water scarcity, which explains the cluster in the arid Middle East North Africa (MENA) region (Hoff 2011; Jobbins et al. 2015; Keulertz and Woertz 2015; Kibaroglu and Gürsoy 2015; King and Jaafar 2015; Talozi et al. 2015). A Moroccan case study also mentions energy scarcity as a secondary motivation (Jobbins et al. 2015), and four studies examining water scarcity in Qatar reference concerns about food self-sufficiency (Al-Ansari et al. 2014; Daher and Mohtar 2015; Linke 2014; Mohtar and Daher 2014).

Water scarcity motivated studies elsewhere as well. In Southern Africa, the connection between water scarcity and food costs prompted the work by Gulati et al. (2013), while water scarcity for energy production was a primary motivation cited by Wong and Pecora (2015). In Chile, relative water scarcity was the entry point to examine competition between sectors (Meza et al. 2015). Endo et al. (2017) examines water scarcity in Japan and the Philippines, and the implications for groundwater, fisheries, agricultural demand, energy and more. In Central Asia, mismanagement of transboundary water raises concerns of water scarcity (Granit et al. 2012), while the lack of water in Cyprus (Halbe et al. 2015) and the Maldives (Borg et al. 2013) impacts agricultural production and creates reliance on desalination. Drought prompted a study of water scarcity in the United States (King and Carbajales-Dale 2016), and in Kenya, water scarcity justified the analysis of trade-offs between hydropower, agriculture, drinking water and environmental flows (Hurford and Harou 2014). Karabulut et al. (2015) sought to mitigate water scarcity risks by mapping and modelling water provisioning services in the Danube basin. Food security is the chief motivator behind Mukuve and Fenner's (2015) analysis of the nexus in Uganda, but water scarcity is identified as a major contributor to this problem. Since water is a necessary input for food or energy production, scarcity for all three WEF sectors can manifest as water scarcity.

3.2.2 Development Threats

Several studies also cited development threats to WEF resources as a motivation, particularly threats from hydropower development. This theme emerges especially in the Mekong region and elsewhere in Southeast Asia (Bach et al. 2012; Belinskij 2015; Matthews and Motta 2015; Smajgl et al. 2016; Smajgl and Ward 2013; Biba 2015; Gain et al. 2015; Kattelus et al. 2014; Keskinen et al. 2015; Lele et al. 2013; Middleton et al. 2015; Yang et al. 2016). In the Mekong region, hydropower development can compound other threats such as unequal access to resources (Middleton et al. 2015) and uncertainties about food security, livelihoods, land use change and mining (Smajgl and Ward 2013).

Outside the Mekong region, motivating threats include hydropower expansion on the Amu Darya (Bekchanov et al. 2015) and Syr Darya in Central Asia and on the Sava river in Europe (de Strasser et al. 2016). Hydropower and irrigation development together threaten resource balances in Ethiopia (Hoff 2011; Stein et al. 2014). Economic growth in Morocco requires increased irrigation, which raises energy demands (Rachid Doukkali and Lejars 2015) Elsewhere in the Middle East, transitions to irrigation require more water and energy (King and Jaafar 2015). Irrigation also affects water and energy supply in Spain, Germany, Kenya and India (Villamayor-Tomas et al. 2015). Social change and deteriorating infrastructure in the United States threaten urban access to resources (Treemore-Spears et al. 2016). Nations developing policies for low-carbon transitions can subsequently face competing demands for land and resources (Sharmina et al. 2016). Failure to recognize ecosystem services may enable developments that compromise the supply of WEF resources (Rasul 2014).

3.2.3 Other

A number of studies mention motives besides scarcity and development threats, or do not explicitly describe their motivation. The stated motivations vary widely: a desire to increase the availability of resources for current and future generations prompted Tidwell (2016) to analyse forests' role in the WEF nexus in the United States. In the Himalayas, farmers must grow more food with the same land, less water, and increased energy prices (Rasul 2012). Vlotman and Ballard (2014) are motivated by inefficiencies in WEF supply chains, particularly food waste, while Walker et al. (2014) seek to maximize the benefits of alternative waste management technologies in London.

Impacts of phosphorous on water quality and crop production underpin the analysis in Jarvie et al. (2015). The use of chemical pesticides and their impacts on water quality and ecosystems justified a nexus study of Vietnam and Cambodia (Bell et al. 2016).

In Spain, Mayor et al. (2015) were motivated by suboptimal planning in WEF sectors. Similarly, in Southern Africa, researchers aimed to inform resource management with nexus insights and thus improve security in the face of climate change (Conway et al. 2015). A study in Mauritius examined opportunities for win-win outcomes of shifting from sugar production to bioethanol production (Hoff 2011). On the Alazani/Ganykh river in Georgia and Azerbaijan, a WEF study was prompted by flooding, land stability, and the potential for hydropower development (de Strasser et al. 2016). Loss of topsoil following harvests was a motivating factor in a Malawi study (Bell et al. 2016).

Some geographic regions had unique circumstances that supported a nexus study. Sri Lanka was chosen as a case study because its WEF resources are relatively self-contained within the island state (Perrone and Hornberger 2016). A Darfur case study was a response to the impact of conflict and humanitarian aid on WEF resources (Bromwich 2015). Nicaragua was selected for a nexus study because of its progressive legislation on integrated water management and its pilot initiatives for ecosystem services payments (Hack 2015). WEF linkages within Ethiopia's state-building agenda and the influence of nexus resources on Egypt's political history invited Verhoeven's inquiries (2015 and 2013, respectively).

Although studies motivated by scarcity or threat concerns account for large portions of the literature, the remaining studies resist categorization, due in part to a diversity in starting points for a study around water, energy or food.

3.3 Study Insights and Results

Three themes emerged in the studies' findings and conclusions: the importance of economic forces in the WEF nexus, the role of governance in determining WEF outcomes, and the contribution of both social and physical factors to nexus interdependencies. At the same time, the studies also reported a wide array of specific technical findings and recommendations that are not readily generalizable. The pronounced diversity of these conclusions is arguably as important as the identifiable themes in assessing the impact of empirical nexus scholarship. The descriptions below are meant to characterize the studies as well as demonstrate the broad variety of aims and approaches even for the studies within the same discipline.

3.3.1 Economics

Many authors examined economic phenomena or the effects of economic forces in WEF systems. These studies demonstrated that economic considerations are interwoven into the nexus (and, indeed, give rise to many nexus interdependencies); and that economic incentives are a critical tool in managing WEF resources. Economic growth raises demand for WEF resources, especially energy, while accompanying resource depletion can encumber economic prosperity (Ozturk 2015). Hack (2015) explores incentives for ecosystem services payments. Gulati et al. (2013) identify a link between energy and water prices, food prices, and food security; and Rasul (2014) argues for financial incentives to promote efficient use of water and energy in agriculture and effective management in critical upstream headwater ecosystems. A Pareto optimization analysis of reservoir operation and irrigation schemes in Hurford and Harou (2014) considers both monetized and non-monetized WEF objectives and assesses trade-offs between them. Ringler et al. (2016) cite fossil fuel taxes as a greenhouse gas mitigation strategy that can simultaneously improve global food security. Matthews and Motta (2015) show how economic factors – including foreign exchange reserves, trade packages, and dependency on foreign direct investment – drive Chinese investments in hydropower in the Mekong Basin.

3.3.2 Governance

The role of governance also emerged in several studies' discussions and conclusions, with authors identifying it as both a current limitation and an opportunity. Lele et al. (2013) write that "governance challenges are at the heart of the nexus" (p. 44), while Villamayor-Tomas et al. (2015) show the influences of institutional arrangements and governance systems on physical WEF linkages. Keulertz and Woertz

(2015) caution that the world is not run by resource managers, but by individuals charged with state affairs and public finance; they argue that the WEF nexus can only be addressed while accounting for these roles.

The studies offer a variety of recommendations related to governance. Kibaroglu and Gürsoy (2015) suggest strengthening transboundary governance institutions in the Euphrates-Tigris basin to integrate WEF management. Bach et al. (Bach et al. 2012) recommend governance processes that engage WEF stakeholders on an equal footing in analyses and management decisions; this point is echoed by Treemore-Spears et al. (2016), who highlight the importance of addressing power imbalances and supporting innovative management practices. Benson et al. (2015) contend that optimal governance from a nexus perspective involves multi-level institutions and efforts at policy integration/coherence. Responding to the complexities of the nexus and uncertainties such as climate change, Allouche et al. (2014) propose a shift in WEF governance towards approaches that acknowledge and hedge against limits to the physical control of resources.

Many recommendations emphasise raising awareness of the nexus among decision-makers and other actors in governance systems (Biba 2015; Gain et al. 2015). These steps are posited to improve governance outcomes (e.g., resource security and sustainability innovations), with empirical nexus scholarship playing a key role in developing the information to be shared (Conway et al. 2015; Halbe et al. 2015). Conversely, a lack of information or poorly distributed information can contribute to inadequate governance, which could be exacerbated by failures of strategic vision and disparities in stakeholder power and resources (Lele et al. 2013). Weak resource governance can enable actors to pursue narrow interests at the expense of nexus approaches (Meza et al. 2015), and contribute to and be amplified by conflict (Bromwich 2015).

Weitz et al. (2017) connect the theoretical nexus governance literature to integrative environmental governance literature, and suggest ways to position the nexus within decision-making processes.

3.3.3. Social and Physical Construction of the Nexus

As noted earlier, most of the authors we reviewed conceive of the nexus as a web of linkages and interdependencies between WEF systems. In addition to physical WEF linkages, the studies identify important social linkages, such as the economic and governance relationships just discussed. Several studies also reveal the key role of one aspect of social relations – power dynamics – in determining WEF connections. By shaping institutions, governance processes, technology and development choices and norms, the distribution of power and competition between actors can cause particular configurations of the nexus (Foran 2015; Allouche et al. 2014). In this sense, nexus interconnections are “contested and contestable outcomes” (Verhoeven 2015).

3.3.4. Findings and Solutions: A Nexus Toolbox?

Notwithstanding the commonalities profiled above, the reviewed studies provide diverse findings and proposed technical and non-technical solutions to resource management challenges. Recommendations include plural water-storage systems (Allouche et al. 2014), energy efficiency, wild-capture fisheries, diversified smallholder agriculture (Foran 2015), solar drip irrigation, seawater cooling for thermal power plants, upgrades of existing infrastructure (Wong 2015), ending waste and minimizing losses (Bach et al. 2012), regional integration of upstream and downstream areas (Rasul 2014), restoration of natural water storage capacity, development of climate smart and socially sound infrastructure, strengthening institutions and instruments of trade of agricultural products with embedded water (Conway et al. 2015), green agricultural water management (King and Jaafar 2015), and increased solar electricity (Talozi et al. 2015).

Conclusions also provided overviews of the systems. Using a combined water system-economy model, Yang et al. (2016) link insufficient precipitation and, to a lesser extent, upstream diversions to conflict in the Brahmaputra River basin; neither, however, would impact hydropower generation. Jobbins et al. (2015) report that water and energy efficiency do not necessarily reduce consumption of these resources among Moroccan farmers. Keskinen et al. (2015) conclude that the impacts of hydropower development are likely to be much more severe than those from a changing climate in the Tonlé Sap region.

4. Discussion

Our review of the empirical nexus literature revealed a substantial amount of work – in many regions, by many actors, and on a variety of subjects. However, it is the diversity and flexibility of the nexus concept that has produced important limitations in the contemporary empirical nexus research. Cohesion is an inherent challenge owing to the breadth of the nexus concept. The WEF nexus encompasses three sectors that are critical to human and natural systems and are foundational to all life. Each sector is itself complex, and the complexities are multiplied by cross-sector linkages and place specificity. What results is a topic with myriad points of entry and connections to a vast array of questions in the social and natural sciences.

To illustrate the nexus's ability to accommodate topics, Table 2 summarises diagrams of the WEF nexus from both empirical and theoretical nexus papers, as structured by the nexus' key constraints, intervention points and potential outcomes.

Table 2. Compilation of Nexus Diagrams – Nexus Interventions

Key Constraints	Intervention Points	Potential Outcomes
• Climate change and variability • Crop productivity • Demand • Economic growth and inequality • Environmental limits and planetary boundaries • Global governance failures • Land use change • Population growth • Technological change • Urbanization	• Culture and society • Economy • Environment • Finance • GHG emissions • Governance and institutions • Innovation • Natural and built systems • Politics • Regulation • Society • Trade/business • Waste	• Adaptive capacity • Avoidance of geopolitical conflict • Enhanced livelihoods • Enhanced resource efficiency • Equitable and sustainable growth • Human wellbeing • Improved health • Resilient, productive environment • Social justice • Water/energy/food security

Sources: Bazilian et al. 2011, Bizikova et al. 2013; Conway et al. 2015; Gulati et al. 2013; Hoff 2011; Mayor et al. 2015; Mohtar and Daher 2014; Rasul 2012; Ringler et al. 2013; Scott et al. 2015; Vanham 2016

This view of the nexus exemplifies the topic's range, a characteristic that in practice produces widely varying research objectives, methods, and conclusions that resist generalization and seem to be wholly unconfined to anything more precise than sustainable development generally. Posing a nexus question does not illuminate a pathway towards resolution, but rather helps expand the scope of the analysis.

We do not question the validity of considering interchanges between water, energy and food within policy planning mechanisms, but we assert that the boundaries of three sectors are too easily stretched or constricted to create a workable framework for either research or policy implementation.

While it could be argued that such diversity and flexibility are a strength, our review suggests that commonalities and synoptic insights from the empirical nexus research tend to be high-level. At the same time, actionable resource management and policy prescriptions from the work are fragmented, making it difficult to draw overarching lessons from them.

The nexus concept does not seem to be a precondition for the empirical studies we evaluated.[2] The specificity of the explorations suggest that the role of the nexus in structuring them may be minor compared to that of pre-existing research interests. There is no clear nexus methodology, the concept does not provide researchers a significant set of initial assumptions or definitions, and the boundaries and

2 But it is worth mentioning that the nexus may be a precondition from a practical standpoint – that is, as a way of mobilizing research funding. This raises questions about funding priorities and trade-offs, which are beyond the scope of this paper.

A vegetable farm being irrigated by a solar pump in the Indonesian village of Lewa. © FLICKR / ASIAN DEVELOPMENT BANK

goals of nexus analyses vary from case to case. In terms of methods, for example, the studies comprise such disparate approaches as quantitative hydro-economic modelling (Bekchanov et al. 2015), value chain analysis (Villamayor-Tomas et al. 2015), stakeholder engagement through workshops (Howarth and Monasterolo 2016), and qualitative resource accounting (King and Jaafar 2015). The most frequent approach is a descriptive overview of the nexus in a geographic area that gathers and presents information on the three nexus sectors to demonstrate the complexity of the overall system (Rasul 2014). However, none of these methods is particular to the nexus or owes its existence to it. For resource managers, then, the literature does not seem to offer a toolbox of generally applicable solutions or actionable cross-cutting insights.

Perhaps most critically, we do not find evidence in the literature that the intended benefits of nexus approaches – that they can improve resource management and governance outcomes – have been realized. This is consistent with the findings of Albrecht et al. (2018). A key aspect of the framing of the nexus is improving outcomes, with aims ranging from increased resource productivity to sustainable economic development, equity, and avoided negative externalities. While we did find that a small minority of the reviewed studies (five of 63) provided direct support to WEF decision-making processes (such as involving decision-makers in the co-production of knowledge), it is not clear that even these studies tangibly affected resource management and governance outcomes. The lack of evidence for the claims about outcomes may simply be a question of time (i.e., more is needed for the growing body of empirical nexus work to have an impact) or forum (workshops may be better posed to support decision-making than peer-reviewed articles). But it could also be related to incongruities between empirical nexus findings and current governance structures, inadequate dissemination of nexus knowledge, or other factors. It appears that if nexus applications are contributing to improved outcomes, the processes are not yet documented in the literature.

5. Conclusions

This literature review examined the application of the WEF nexus concept following its rise to prominence in 2011. We found a considerable body of empirical WEF nexus work published from 2011 to mid-2016 that covers a wide range of research questions and locations. The evidence indicates that the pace of empirical nexus research is increasing, that the topic may have greatest traction among water resources practitioners, and that government agencies (particularly in the United Kingdom and United States) are key sources of funding. It may also signal that the implementation of the nexus has not been as balanced between sectors as perhaps initially envisioned.

The great breadth of the WEF nexus provides an intellectual home for an expansive array of research objectives, methods, and conclusions. This has produced some valuable scholarship but simultaneously limits overall insights and lessons that can be drawn from empirical nexus work. Our review identified some high-level insights and commonalities related to the definition of the WEF nexus (centring on linkages between WEF systems), the motivations for empirical nexus study, the importance of economics and governance in the nexus and nexus analyses, and the role of social and physical factors in constructing nexus interdependencies. Beyond these, however, the findings and specific technical and policy solutions proposed in the reviewed studies are difficult to synthesize as they lack coherence.

To date, empirical nexus research has not produced a well-defined intellectual toolkit (with methods, research inputs, conventions), and it has not demonstrated a clear link to the improved resource management and governance outcomes that underlie the value of a nexus approach. These issues are troubling given the resources dedicated to nexus study. We suggest that future efforts in original empirical nexus research should focus on bridging this "outcome gap" – perhaps by better connecting with decision-makers and resource managers, emphasizing participatory approaches, and contributing to capacity building.

The merits of systems analyses for natural resources have long been debated. Rogers and Fiering (1986), who sought evidence of optimization as a defining feature of a system analysis, concluded that the water resources literature did not provide "reliable generalizations concerning the stability of the systems approach to a given problem." A 2004 review of Integrated Water Resources Management (IWRM) alleges that the concept existed some 60 years prior to the 1990s, but had never been critically assessed and offered a dubious record of implementation. The assessment found that contemporary publications promoting IWRM did not demonstrate the concept's meaning in operational terms or identify an implementable process for integration (Biswas 2004). The author attributed this to an "almost universal popularity of a vague, indefinable, and un-implementable concept." The WEF nexus seems to be struggling with the same issues of coherence. Time will tell if it surmounts these challenges, or if it too falls prey to the weaknesses that plagued previous integrated systems approaches.

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