

Water–Energy–Food Nexus Research in Africa

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The nexus of water, energy and food (hereafter WEF nexus) is undoubtedly complex, yet critical, for it mediates numerous issues that humankind faces today. These three resource systems are intimately interlinked and essential to the livelihoods of mankind, whereby actions in one sector are likely to have reciprocal impacts on other sectors, resulting in conflicts or competition.

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1. Introduction

The nexus of water, energy and food (hereafter WEF nexus) is undoubtedly complex, yet critical, for it mediates numerous issues that humankind faces today. These three resource systems are intimately interlinked and essential to the livelihoods of mankind ^[1], whereby actions in one sector are likely to have reciprocal impacts on other sectors, resulting in conflicts or competition ^[2]. It is widely recognised at the community level, and the national, regional and even global scale that WEF supplies are under strain and will soon be stressed to their limits. In particular, projections show that the demand for water, energy, and food resources is expected to rise significantly. This scenario is compounded by pressures arising from population growth, urbanisation, socioeconomic development, and climate variability and change ^[3]. In sub-Saharan Africa, for example, the demand will be much more substantial as countries face the difficult task to sustainably meet the growing demand for the increasingly scarce resources^[4]. Indeed, in many countries, particularly in the developing world, there is still demand and accessibility disparities, implying that millions of people lack such resources (e.g., water) ^{[3][5]}. In this regard, the impacts of climate variability and change as manifested in, e.g., the decreased rainfall reliability and increased water demand by the agriculture sector^{[6][7][8]}, are more pronounced in both agriculture and energy production—two industries that are key to several development agendas ^[9]. By the 2050s, the global energy demand is estimated to double, and water and food demand will increase by 50% with the drive to meet the needs of the anticipated 9 billion inhabitants^[10].

As worldwide demand for the WEF nexus resources grows, their sustainability becomes a vital concern. It is against this background that the WEF nexus research theme is expected to play an important role, considering that climate change impacts and responses are typically cross-sectoral^{[9][11]}. The WEF nexus framework, which came to the limelight at the World Economic Forum in 2008 ^[12] and was further developed during the 2011 Bonn Conference^[13], improves such cross-sectoral coordination and seeks to integrate resource management in support of sustainable development ^[1]. To this end, the WEF nexus framework's salient feature is the appraisal of the interconnections and interdependencies among water, energy and food systems^[11]. The WEF nexus advocates for

a structured methodology geared towards maximising the inherent synergies while minimising the trade-offs and improving the efficiency of using the resources and internalising the socio-environmental influences across a range of contexts and scales^{[13][14]}. Any lack of access to the inherently integrated systems constrains sustainable development and can have adverse effects on regional securities affecting the interrelated services needed to achieve human wellbeing, and preserve and strengthen livelihoods for generations to come. According to Olawuyi^[15], the “*WEF nexus provides a coherent, holistic, and integrated implementation of the Sustainable Development Goals (SDGs)*.” With just ten years remaining to achieve the 17 SDGs and their 169 targets, there is an urgent call for the effective and efficient work towards attaining multiple SDGs and avoiding isolated silo approaches^{[16][17]}. In this instance, the food (SDG 2), water (SDG 6) and energy (SDG 7) implementation through the WEF nexus lens becomes a priority. Notwithstanding the WEF nexus’ noble contribution towards attaining the SDGs, the WEF nexus implementation is nascent given that it has mostly remained theoretical^[18].

As a concept, the WEF nexus still needs to be translated from theory to practice^[19]. Research has shown that its implementation of the WEF nexus framework on the ground remains a challenge due to several factors including the lack of adequate funding, skilled personnel, equipment, politics and commitment from member countries, more so in Africa^{[19][20][21]}. Furthermore, the WEF nexus research scope—from the perspective of the spatial scale of implementation and assessment of implementation thereof—presents a significant barrier^[21] to the realisation of the full potential of WEF nexus applications. In addition, the lack of standardised methodologies requisite for enhancing the development and application of “nexus thinking” can impede implementation^[22]. In the study by Voelker et al.^[23], the lack of institutional logic comes out strong as an impediment to WEF nexus implementation. In addition, access to information systems and data from various observational platforms, including satellite, in situ, models and assimilation systems, as well as socioeconomic data, can also be a barrier^[20]. Furthermore, the lack of innovation may hinder the implementation of WEF nexus agendas^{[24][25]} that allow, for example, the production of more food with less water and energy resources to help attain SDGs on poverty eradication (Goal 1), zero hunger (Goal 2), availing water to all (Goal 6) and provision of clean energy (Goal 7).

Despite these limitations, adoption of the WEF nexus is paramount for Africa where, on the one hand, natural resource scarcities and socioeconomic vulnerabilities are at a peak^[26]. On the other hand, adaptation capacities are subtle due to population growth, low or declining economic growth, high poverty rates and a greater prevalence of food insecurities^[27]. It is against this backdrop that adopting a well-coordinated and integrated WEF nexus methodology will undoubtedly contribute to building resilient systems, minimising duplication of activities, increasing the opportunity for resource mobilisation, harmonising interventions, and managing and attaining trade-offs to support sustainability^[28].

This study provides a systematic review analysis of the WEF nexus body of research literature with a focus on the African continent. Thus, the present review aims to contribute to the advance of WEF nexus research through characterizing the intellectual and social structures, as well as the evolution of the WEF nexus research domain. In particular, the objectives of the review are: First, to conduct a systematic appraisal of the WEF nexus empirical research using bibliometric analysis in order to decipher the inherent intellectual patterns of WEF nexus research in the African continent. Specifically, the scientific mapping comprises trends, networks, keywords and thematic

analyses of the intellectual performance from the WEF nexus scientific community. Second, the review undertakes a detailed content analysis and synthesis of the African-based WEF nexus body of the literature. A detailed examination of the content of the empirical studies of the WEF nexus in the African continent will help identify and situate inherent paradigmatic perspectives (these are underpinned by the ontology, epistemology, and methodology and methods) in order to support inferences of the visualized intellectual structure and the changing patterns of the WEF nexus research.

2. Discussion: Salient Features of WEF Nexus Research Progression from Theory to Practice

The evolution of the WEF nexus as a scientific discipline can be viewed within the context of Shneider's theory of scientific change^[29]. The analysis presented in this review shows that research on the WEF nexus has gained traction in Africa since 2013. At a global scale, the need to understand this research trajectory has been linked to the WEF resource crises in 2008 and growing concerns to move away from sector-driven management strategies^[30]. The literature review points to the WEF nexus research domain transitioning through the four stages of scientific evolution, i.e., conceptualisation, the development of research tools/instruments, application of the tools to advance WEF nexus research, and accumulation of domain knowledge through scientific publications. This confirms that the research to date has been mostly theoretical. Notwithstanding the available scholarship of the WEF nexus, traditional academic research has a limited capacity for transitioning to practice. However, such transitioning to practice will entail a greater focus on socio-economic changes and human wellbeing through policies and decision-making; thus, completing the science–policy–practice interface. In order to achieve this, a more transdisciplinary research framework capable of addressing complex nexus issues is desired.

2.1. Institutional Support for the WEF Nexus Research across Africa

Since its inception, the WEF nexus research has enjoyed global, continental, regional, national and institutional support. For instance, the Southern African Development Community(SADC) region used the SADC 6th Multi-stakeholder Water Dialogue to raise awareness and create a shared understanding of the WEF nexus^[31]. The subsequent workshops in SADC highlighted the knowledge gaps, stakeholders and their role at various levels required to support the nexus in meeting the water, energy and food needs of the people, and effective utilization of resources to meet the SDGs ^[25].

In North Africa, initiatives such as the Arab League's Nexus Dialogue Programme and the Arab Coordination Group played a crucial role in developing WEF nexus research. They informed the development of policies that address WEF challenges. In East and Central Africa, the transboundary basin of Lake Kivu and the Ruzizi River, which are shared by the Democratic Republic of the Congo (DRC), Rwanda and Burundi, is a variety of ecosystem services. Research work in the Lake Kivu and the Ruzizi River basin by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) gmbH focused on understanding the trade-offs between competing users of water, land and energy, improving natural resource efficiency to sustain human livelihoods and ecosystem integrity of the basin using the WEF nexus approach.

In West and Central Africa, the WEF nexus has been driven by institutions such as the Niger Basin Nexus Dialogue, with the role being to advise and support the Niger Basin Authority (NBA) and its member states, as well as to mainstream the WEF Nexus approach into the management of the basin. The WEF nexus has been pushed forth in the region to support integrated transboundary management of the basin and to design policies to holistically attain the development objectives by seeking efficiency of resources to address pressing developmental challenges such as food insecurity, poverty, unreliable rain and highly variable inter-and intra-annual river flows^[32]. WEF-related research is still minimal in east Africa. Still, there have been initiatives by UNESCO in collaboration with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) gmbH, Strathmore University, and the Kenya Climate Innovation Centre to highlight the interdependencies between water, energy, and food in meeting global and regional goals such as the Agenda 2063^[33]. The WEF nexus is also expected to address such problems as energy-efficient production, agriculture productivity, climate change, water management practices, the impact of global oil and food prices, and the marginalisation of the poor and refugees^[34].

2.2. Challenges, Opportunities and Antecedents of Transitioning WEF Nexus from Theory to Practice

Owing to the potential contribution towards the effective management of WEF resources, the WEF nexus research (this includes consideration for the inherent interdependencies and interlinkages of the intrinsic elements) has continued to gain much traction^{[1][35][36]} to both scholars and practitioners. In this regard, the policymakers' understanding of the nexus methodology's complexity and the practical application for WEF resources management is boosted mainly by the rapid development of analysis tools and models^[37]. Based on the review conducted, e.g., by Shannak ^[38], the practical implementation of the WEF nexus is confronted with some of the following challenges: (a) The limited number of duly suited optimised and scalable WEF nexus modelling frameworks, (b) insufficient relevant input data (at appropriate spatial-temporal scales), (c) lack of requisite knowledge and skillset required to operationalise the WEF nexus, and (d) limited application of transdisciplinary research approach that bring scholars, practitioners and society as co-creators of WEF nexus knowledge. Although the literature highlights a growing trend in Africa's WEF nexus research, the nexus concept still needs to be translated from the theoretical domain to practice^[19]. Currently, the practical implementation of the WEF nexus in Africa remains a challenge due to, e.g., a lack of funding, skilled personnel, equipment and regional actors' commitment to managing transboundary resources ^{[19][20][21]}.

An analysis of key themes above presents some of the more established and emerging nexus themes—antecedents that can support the practical application of the WEF nexus in Africa. Hot themes such as climate change, sustainable development, water resources and socio-economic livelihood are increasingly being catapult into the WEF nexus research domain. These themes' societal values are dependent on their contribution to the practical solutions derived, which integrate actors' needs and values in policy and decision-making across the affected and interested stakeholders. In this regard, coordinated and transdisciplinary efforts are needed to implement and operationalise what has been, to date, a mostly theoretical exercise. Given that there are inherent differences in concepts across the natural and social sciences, knowledge integration is often a challenging task. If not facilitated well, they will fail to co-create a shared understanding of the varied factors that modulate the social-

ecological systems [39]. There is a need to formulate innovative approaches that are beneficial to the three nexus domains, and which are capable of addressing the salient features of each domain and their inherent challenges [40].

Studies by Pittock et al. [41] averred that the sectoral approaches to policy and decision-making have resulted in fragmented policy responses with limited understanding of the complex linkages between resource systems and sectors. For instance, policies that created unintended consequences have been put in place that impact sustainable livelihood [42]. In this regard, the interdependencies among the nexus components present decision-makers with synergistic problems, tensions and potential trade-offs between nexus emerging issues at spatio-temporal scales [43]. On the other hand, the established themes such as water management, agriculture and ecology provide a framework that can support the transition from theory to practice.

Opportunities that can support the transition from theory to practice include co-developing adequate resource assessment and visualization tools, expertise and institutional capacity to support the nexus dialogue. In addition, further development and application of modelling tools, technology innovation, especially during the fourth industrial revolution, encouraging broader market participation, and advanced governance to support integrated decision making [41][44] will be required. In addition, the nexus also presents opportunities to strengthen public-private partnerships and governance, as well as institutional mechanisms, to operationalise key nexus ideas. Therefore, transitioning from theory to practice in the WEF nexus requires multi-sectoral stakeholder capacity building to manage the interlinkages between resources, cost-effective policies and technological innovations. Furthermore, improving the understanding of the nexus approach through practical demonstration is key to the nexus implementation and informs planning and decision making for policymakers and other stakeholders.

2.3. Some Theories Underpinning the WEF Nexus Transition from Theory to Practice

Using the results of the scientific mapping and synthesis of the WEF nexus literature, we opine that for WEF nexus science solutions to be operationalized in the African continent, they need to take advantage of the inherent underpinnings of the science-policy-practice interface. We contend that microeconomic theory can be applied to explain how the user-inspired WEF nexus research efforts can meet societal objectives by reconciling the demand (societal need for WEF nexus knowledge) and supply (WEF nexus research). Additionally, the reviewed WEF nexus literature uncovered that there exists an inherent disconnect between WEF nexus output and governance processes. In order to respond to these governance gaps, the Integrative Environmental Governance (IEG) reported in, e.g., [46], is considered a suitable governance theory. If the societal needs are to be realised, it is natural that the scale/unit of operation of the WEF nexus ought to be framed at the local level and dynamically scaled up to macro or mega-scales. However, the WEF nexus scholarly community and practitioners are challenged to advance beyond the status quo and seek a new stand toward transdisciplinary research. This should include: (a) A reconciled demand and supply for WEF nexus scholarships informed by research agendas developed and assessed by the users, and (b) robust sensitivity analysis of how specific WEF nexus issues are prioritised under changing global environment changes.

Overall, from a philosophical viewpoint, the evolution of WEF nexus research espouses how the ontological and epistemological positions are embedded within the WEF nexus scholarly enterprise. The present review analysis illustrates evidence of shifts in the ontology-epistemology boundaries of WEF nexus research in respect of the shifts:

- (a) From the unconnected silo paradigms that focus on nexus resources (security concerns) to interconnected (and sometimes interdependent or nested) linkages or systems incorporating environmental, social-economic and political drivers in a bid to holistically support the SDGs.
- (b) In the evaluation of the WEF nexus scholarship based on novel analytical approaches that are (i) *innovative*—the methods are capable of quantifying and delineating WEF nexus linkages and system boundaries; (ii) *content specific*—while scalable, the methods are increasingly attuned to include multi-scalar socio-physical networks, as well as locally contextualized, (iii) *collaborative and participatory*—this enables the WEF nexus methodology to be aligned to stakeholder needs (while promoting advocacy and co-production of WEF nexus research), as well as enhancing data sharing (vital for improved model parameterization), and (iv) *supportive of the ultimate transition of research outputs to practice*, i.e., operationalizing the WEF nexus outputs.

It is against this background that for the WEF nexus research in Africa to transition from theory to practice, the philosophical positions situated in these models (ontology, epistemology, and methodology and methods) serve to be informed by transdisciplinary approaches. This clarion call requires that members of the WEF nexus scholarly and practitioner community in Africa, and elsewhere, ought to transition from the high ground of theory and descend to the swampy lowlands of practice.

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