



# Nexus disrupted: Lived realities and the water-energy-food nexus from an infrastructure perspective

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## ABSTRACT

In recent years, the water-energy-food nexus gained traction in science and policy debates to address the relationships between water, energy and food sectors. Inspired by Political Ecology thinking, we advocate for a nexus understanding that acknowledges the political nature of the concept and points to lived and experienced nexus realities. We draw on literature from heterogeneous infrastructures, giving attention to the socio-material entanglements that configure a nexus dynamically over time and space. We substantiate our conceptual arguments based on three different cases from Sub-Saharan Africa, that reveal the ways in which people access, maintain or disrupt infrastructure that links water, energy, and food systems. This may occur through practice forms of tinkering or improvisation of infrastructural components, intermediate (decentralised) technologies, through theft, or through some form of self-empowerment. Methodologically, the role of practices is emphasized as they help to understand Nexus heterogeneity and disparate forms of agency to (re-)configure a nexus.

The findings demonstrate that *the* nexus is not just there but is constantly in-the-making. Practices stabilise, build, or alter differentiated nexus configurations within uneven nexus in/securities. Moreover, this article disrupts a “one-size-fits-all” nexus concept by offering a nuanced understanding of nexus realities that are more complex, heterogeneous, and plural than commonly described. Our analysis shows that re-thinking the nexus by focusing on people and practices draws the attention towards agency and change – and thus enables to identify leverage themes rendering a more just nexus.

## 1. Introduction

For more than a decade, the water-energy-food nexus (WEF-nexus or WEF) has been used as a conceptual approach, an analytical framework, and a governance perspective to address the relationships between water, energy and food supply within politics and academia (Keskinen et al., 2016; BMU & Bmz, 2012b; BMU & Bmz, 2012a). Originating from international discourses, nexus thinking centres on water, energy, and food as interlinked sectors that can neither be fully appreciated, nor indeed be governed independently of each other (Allouche et al., 2015; Foran, 2015). A milestone for the debate around the nexus was the so-

called Bonn Nexus Conference in 2011, where science and policy representatives came together to discuss “how a nexus approach can enhance water, energy and food security by increasing efficiency, reducing trade-offs, building synergies and improving governance across sectors” (Hoff, 2011p.4). The conference spurred the nexus debate and shaped the prevailing rationale of nexus thinking: resource scarcity and resource security are global threats that limit socio-economic development and stability (Hoff, 2011; BMU and BMZ, 2012a). With the aim of promoting the nexus, the World Economic Forum Global Water Initiative pointed to global risks of an economic growth slowdown resulting from higher prices of scarce commodities. At

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the same time, arguments were made for a structural linking of these resource systems to the global economy, purportedly to address and govern the interconnected nature of resource security (World Economic Forum, 2011).

In these early framings nexus thinking is introduced as a seemingly neutral frame to identify interlinkage between vital resource systems and to manage those interlinkages efficiently. This article, however, shows that the nexus is not an apolitical governance concept. Instead, the water-energy-food nexus is ultimately about resource systems and their governance. Therefore, any nexus thinking inevitably includes political questions, such as the securitisation of resources (Leese and Meisch, 2015), how resources are made scarce (Mehta, 2005), how inequalities are (re-)produced through neoliberal techno-politics, Eurocentric developmental politics (Allouche et al., 2015) and global financial networks (Schmidt and Matthews, 2018).

In an attempt to adopt a more critical reading of the nexus, our arguments build upon Political Ecology thinking to show how the nexus unequivocally is about resource systems and governance. We advocate for a nexus understanding that is sensitive to socio-political factors, inclusive of the historical features essential to understanding specific nexus configurations, and how to derive lessons for nexus governance (Foran, 2015; Albrecht et al., 2018). We propose embracing analytical and methodological insights from Political Ecology that engages with knowledge production and the framing of nexus governance (Allouche et al. 2015), infrastructures and the southern urban critique (Simone, 2004; Kooy and Bakker, 2008; Lawhon et al., 2013; Lawhon et al., 2018). This scholarship shares a common interest in (urban) resource and infrastructure politics, and in the production of infrastructural supply systems, including their uneven outcomes. From this, our empirical attention shifts towards the practices people employ to secure everyday needs. In doing so, we aim to situate and contextualise the nexus, an endeavour aligned with Political Ecology approaches and reasoning.

Building upon this body of Political Ecology work, we outline how we think systematically about the social and material processes that create linkages between water, energy, and the food sectors. This is done by using an analytical lens that focusses on infrastructure in-the-making, as well as in-the-use, in order to reveal the socio-material entanglements, which are characteristic of any given nexus. We reveal how and by which “matters of practices” (Shove, 2017) a particular nexus is crafted, how it is stabilised, and under what circumstances any type of nexus configuration evolves into another. In particular, we are interested in moments of disruption, potentially giving rise to action on the individual, local or regional level. We substantiate and illustrate our approach using three different cases drawn from Sub-Saharan Africa. In the first case, we observe Teshie, a fishing neighbourhood located in Accra, the shifting nexus configurations due to frequently occurring power shortages. The second case of a small community, GaManoke located in the town of Burgersfort in South Africa, showcases how marginalized people are affected by nexus insecurity. The third case is situated in the rural areas of Northern Ghana and Burkina Faso, where we discuss how distant factors alter nexus configurations on a regional scale. We conclude that learning from nexus realities – as they are lived and experienced in the South – enables us to rethink the nexus in some important ways.

## 2. The water-energy-food nexus

Nexus thinking has been introduced as a novel concept in an attempt to integrate separately managed resource systems. Building on Political Ecology scholarship, we provide a critique by asking different questions about socio-material interconnections of water, energy and food. In doing so, we foreground an alternative account of the nexus.

### 2.1. Emergence and framing of the nexus

Nexus thinking emerged around 2007 and 2008, when crude oil was achieving peak prices. This was interpreted by strategic analysts as foreshadowing the end of the fossil fuel era in which global resource scarcity is the new normal (Allouche et al., 2015; Leck et al., 2015). The oil price crisis was held responsible for the sharp increase in food prices and the resulting food crisis. Due to these developments in the commodity and resource markets, which threatened growth in the Global North, efforts to establish a new global resource governance concept was solidified at the international level (Allouche et al., 2015). During this time, the notion of nexus thinking was coined as the ‘perfect storm,’ and was the preferred solution to manage and identify interconnected resource security challenges (Cairns and Krzywoszyńska, 2016). Subsequently private actors, large multinational firms and international organizations took up the concept and drafted science-policy papers.

Many of these science-policy papers refer Hoff’s (2011) background document prepared for the 2011 Bonn Nexus Conference. This seminal publication provides typical examples for nexus thinking and terminologies, such as “improved water, energy and food security can be achieved through a nexus approach – an approach that integrates management and governance across sectors and scales. A nexus approach can also support the transition to a Green Economy, which aims, among other things, at resource use efficiency and greater policy coherence. Given the increasing interconnectedness across sectors and in space and time, a reduction of negative economic, social and environmental externalities can increase overall resource use efficiency, provide additional benefits and secure the human rights to water and food” (Hoff, 2011p. 7). This quote reflects the typical nexus framing and illustrates how ideas of ecological modernization are mobilized throughout nexus thinking: solutions to resource scarcity are seen in market instruments, efficiency measures and tools for policy integration (Cairns and Krzywoszyńska 2016). Yet, as Allouche et al. (2015, 613) critically argues, “the nexus has primarily been driven by international private actors, who see both the nexus – and subsequently also the concept of Green Economy – as an opportunity and a constraint to their business”. Despite these concerns, the nexus has been adopted and promoted by global sustainability discourses centred around the UN Sustainable Development Goals.

Although strong normative statements characterize typical nexus thinking, the nexus is used in science as a seemingly objective heuristic to study sector interdependencies. This is even more surprising since any additional theoretical and analytical work on the nature of the linkages between the resource systems is missing. This gives reason to consider how current nexus studies are conceptualised and executed. In reviewing nexus studies, we find that the typical nexus understanding is rooted in positivist thinking that rests on a binary view on society versus nature, whereby nature or resources can be assessed and monitored from above through remote sensing or statistical modelling at large scales (Wiegleb and Bruns, 2018). Accordingly, nexus studies tend to have a very strong bias towards a focus on accountable flows (omitting or ignoring unaccountable flows), formal networks (neglecting the fragmented nature of infrastructure) and state provision (overlooking all other forms of resource provisioning systems)(see Table 1). Therefore, we argue there is a need to engage with an account of the nexus, that takes closer attention to the lived and experienced water, energy and food realities at stake.

### 2.2. A Political Ecology perspective on the nexus

The thinking that underpins the nexus concept, as summarized above, has been vigorously opposed by scholars from critical social science, and most prominently from Political Ecology. While it is beyond the scope of this paper to discuss the vibrant research field of Political Ecology in detail, we find it worthwhile to refer to the following three defining characteristics of Political Ecology. First, Political Ecology

**Table 1**

Communities of Research on the WEF-nexus in an idealized comparison. Own compilation, inspired by [Wesselink et al., 2017](#) who used similar categories for a different topic.

Ways to study the nexus	Typical Approach (e.g. Socio-Ecological-Systems Approach)	Critical Approach (e.g. (Urban) Political Ecology Approach)
Research Paradigms	(Post)Positivist	Constructivist, critical theory
Ontology	Duality of Nature/Materiality and Culture/Society	Socio-nature, hybrid thinking
Problem Framing / Entry Point (Typical) Methods	Natural system: resource scarcity driven by population growth and global threats Quantitative research, statics, modelling, remote sensing	Society: power relations and the production of resource inequality and insecurity Qualitative Methods, ethnographic approaches, historical analysis
(Typical) Scale	“large scales”: national, river basins, city level	Uneven Geographies: intra-urban differences local and individual level
(Typical) Focus	<i>The</i> nexus; accountable flows; networked infrastructure	Multiple, co-existing nexuses; unaccountable flows; heterogeneous infrastructure
Knowledge	Neutral, objective	Situated, subjective and inter-subjective
Leverage Points	Efficiency, technocracy	Power imbalances and injustice

stems from an intellectual tradition that positions itself against a positivist, apolitical understanding of nature and the transformation of nature. It focuses on how various forms of political power shape human-environment relations, and how this results in uneven outcomes, such as resource insecurity or land dispossession ([Robbins, 2004](#)). Therefore, it is highly interested in how far different inequality dimensions, such as gender, class, or race, intersect at different geographical scales, and how this is shaped by historical-colonial power relations. Second, Political Ecology takes a reflexive stance on knowledge creation and its claims on authoritative expertise. Hence, political ecologists are in strong opposition to the scientific objectivism that set out to explain natural problems or frame solutions in techno-managerial realms ([Bridge et al., 2015](#)). Rather, Political Ecology takes an explicitly normative stance that is committed to structural inequalities and multiple forms of injustices. Third, the methods employed in Political Ecology are plural, serving the interest in profound understanding of multiple social realities ([Sultana, 2021](#)). Different qualitative methods are commonly applied, ranging range from interviews, observation, or document analysis, to creative tools, such as participative mapping or storytelling. Often political ecologists incorporate historical information in order to contextualize their work, and to disclose the often deeply colonial inequalities ([Kooy and Bakker, 2008](#)). The high degree of reflexivity in Political Ecology stems from the type of research questions asked, the conceptual frameworks applied, the framing of theoretical ideas and the modes of knowledge production. Thus, political ecologists carefully scrutinize their very own geography of knowledge production, and how it relates to theory-making (e.g. [Lawhon and Truelove \(2020\)](#) within the field of urban studies, or [Sultana \(2021\)](#) with feminist Political Ecology).

Building on Political Ecology scholarship, we sympathise with the following statements: one could question whether the WEF-nexus concept is genuinely novel from Benson et al. (2015); the concept is immature by [Keskinen et al. \(2016\)](#); the criticism that it is ahistorical made by [Foran \(2015\)](#); and those who refer to its depoliticising nature ([Allouche et al., 2015](#)). We do, however, acknowledge the need to look at the ways water, energy, and food are “interconnected, contingent and co-producing” ([Williams et al., 2019, p. 653](#)). Seeing these interconnections is even more important as the transformation of nature and depletion of resources unfolds rapidly – and this is putting more and more people at risk. Urbanisation in the Global South is a vital consideration in this respect, since it is often related to increasing resource needs, uneven resource access, and a fragmented urban infrastructure

([Coutard and Rutherford, 2015](#)). This not only makes WEF in/security an important field for resource politics, but we see the need to engage productively with interdependent resource security risks ([Romero-Lankao et al., 2018](#)), as well as what this implies for livelihoods ([Biggs et al., 2015](#); [Spiegelberg et al., 2017](#)). However, we must not end there, but rather instead as a starting point for examining the processes that render access to, and control over uneven resources ([Wiegleb and Bruns, 2018](#)), in order to address nexus securities in a socio-spatially differentiated manner, and to explore transformative options towards more just futures.

Hence, studying WEF security requires that we acknowledge and examine the uneven geographies of nexus security within and across societies and on different scales, within and between cities and rural regions, and between the Global North and Global South ([Allouche et al., 2015](#); [Wiegleb and Bruns, 2018](#)). In sharp contrast to this claim, the majority of nexus studies focus on countries, nations and administrative levels where statistical data is, in fact, available – or demand that such data be collected. This discrepancy renders informal metabolic flows of water, energy and food invisible and overemphasizes formal service delivery models. It also implies a lack of engagement with the people, practices, and possibilities that actually shape, configure, and even transform the nexus. A recent *meta*-analysis of nexus studies found that there is a severe lack of studies that include “local features” and “on-the-ground implementation” ([Albrecht et al., 2018, p. 10](#)). To date, only a few studies have examined the uneven patterns inherent to basic supply needs ([Biggs et al., 2015](#); [Foran, 2015](#); [Spiegelberg et al., 2017](#)). We argue that this misbalance results in one-sided and reductionist nexus understandings, as if there were only one single nexus (in a country, region, or city), and as if nexus outcomes were experienced equally across resource users, places, and times. In short, we see a disturbing trend toward universalising and stabilising the nexus and in overlooking the multiple lived nexus realities, which shapes our aim in this paper to address and stem this trend.

Political Ecology illustrates how resource policy concepts are never neutral, nor are resource and environmental analyses never objective. This also holds true for the WEF-nexus, which like any resource governance approach, that might serve vested interests and dedicated agendas ([Leese and Meisch, 2015](#); [Wiegleb and Bruns, 2018](#)). In light of a dominance of technical and managerial framings of resource scarcity and security challenges, we see the need to be critical of discursive strategies which infuse and legitimise managerial resource governance approaches. It is possibly the very normative and analytical vagueness of the nexus which makes way for this appropriation. Similarly, other sustainability-oriented governance concepts have been criticised for their arbitrariness. For instance, [Molle \(2008\)](#) calls Integrated Water Resources Management a “Nirvana” concept (i.e., something that cannot and will never be achieved, although everyone agrees to it in theory); again, [Luke \(2005\)](#) talks about sustainable development as an empty signifier that is “neither sustainable nor developmental” ([Luke, 2005, p. 229](#)). The same can be argued in the case of the nexus, and it is perhaps exactly this “relative emptiness of the concept” ([Luke, 2005, p. 229](#)) that allows its strategic mobilisation towards techno-managerial fixes, while having relatively little to offer (analytically or practically) to understand and secure everyday access to the interlinked water, energy and food needs any better. There is a tendency for the nexus concept to be appropriated by techno-managerial approaches that sustain business-as-usual strategies, or – even worse – legitimise the further financialisation of basic supply sectors ([Schmidt and Matthews, 2018](#)).

Moreover, the nexus is portrayed as having an *a priori* potential to translate academic knowledge of interlinked resource challenges, scarcities, and vulnerabilities into the formulation of integrated policies. It is claimed that nexus research is *per se* of societal and political relevance. Built into these nexus conceptualisations are strong assumptions about (neutral and objective) knowledge generation, their translation into policy (a linear process), their implementation (from knowledge to action) and their effectiveness of policies (assuming more integrated

policies enhance sustainability). All these assumptions have been discussed intensely as being overly simplistic, blind to structural barriers to system change, as well as the role of power in creating knowledge for resource governance (van Kerkhoff and Lebel, 2006). Questioning the normative power and knowledge base of the nexus raises our critique of precisely whose knowledge, norms, and practices are being articulated and represented in the WEF debate. Scholars from post-/decolonial studies have pointed to the dominance of Eurocentric understandings of the world (Chakrabarty, 2009), including their narrow understanding of societal relations to nature and pathways for transformations (Escobar, 2016). Critical social scientists, therefore, rightly advocate for global environmental change knowledge “that opens up multiple interpretations” helping “to extend the realm of the possible for environmental politics” (Löfbrand et al., 2015, p. 211). However, this is not a call to broaden the debate unnecessarily, but rather to delink it from a purely western understanding, to situate it and re-politicise it.

In its current form, the nexus concept depoliticises relationships between the material (biophysical) and the social, because they are reduced to something that is manageable and controllable (Wiegleb and Bruns, 2018). Therefore, we see the need to re-politicise the nexus to make it truly about people’s WEF in/security. Everyday practices and micro-politics that shape in/securities and inequalities are important aspects of governance that have so far been neglected. Giving attention to nexus realities as they are experienced and lived might well reveal contested ideas and ideals on resource governance, as well as the governance of resource supply, including on the provisioning infrastructure itself (Ahlers et al., 2014; Alba et al., 2019).

We outline a novel way of identifying and analysing linkages and interdependencies between water, energy, and food from still under-represented critical social sciences. Building on scholarly work from urban Political Ecology and related studies on infrastructures in-the-making, we look at lived and experienced nexus realities, and at the practices that configure and reconfigure the nexus at local and regional levels. We utilize an approach that is sensitive to the practices and the diverse forms of agency, which are important to informing governance, and vital to identifying appropriate leverage-points for more just, sustainable, and resilient water, energy, and food systems. Our agenda is to situate and democratise the nexus in order to develop a counter-narrative to managerial approaches that overemphasise the technological to the detriment of the social. It is therefore, our aim to shed light on the question neglected so far, as to how uneven nexus in/securities are experienced, and how and by whom they can be altered and transformed.

### 2.3. An alternative nexus understanding: The nexus as infrastructural configuration

Typical nexus studies fail to conceptualise the linkages between the resource systems systematically analytical rigorous ways (Albrecht et al., 2018; Wiegleb and Bruns 2018). Motivated by recent contributions and conceptual premises from political ecologists, we suggest looking at infrastructures to address this shortcoming. We find that scholarship on infrastructures (or more broadly: socio-technical systems) provide an intriguing way to think about and study conceptually and empirically linkages and interdependencies between water, energy, and food systems. Infrastructures not only shape resource flows, and connect people and places, but each infrastructural component may also enable or disable the functioning of the other by means of causal relationships, or co-constitution. Infrastructure systems are foundational for any socio-economic activity that can be understood “as a series of interconnecting life-support systems” (Gandy, 2005, p. 28). While the functioning of modern infrastructure is often taken for granted, it becomes visible in moments of failure or disruption, or in places characterised by the absence of certain infrastructural elements. Later in section 3, we indicate that moments of disruption are analytically useful in revealing that material objects are relational rather than fixed and

static (Shove, 2017).

Infrastructures “furnish the world” (Amin and Thrift, 2017, p. 2) and provide material and physical connections between water, energy and food systems, but also point to the importance of the social for the material world (Schatzki, 2010; Shove, 2017). We understand infrastructures as socio-technical systems that include, not only “a series of physical artefacts and technologies, but also the actors involved in providing and using the services” (Moss, 2014, p. 1435). As such, infrastructures are equally social and material. Schatzki recognises this in his article Materiality and Social Life as “any thing, property, or event can be at once both social and material-natural. Something is social if it is part of the nexus of practices and arrangements as part of which human coexistence inherently transpires. Something is material if it is physical, biological, or natural” (Schatzki, 2010, p. 133).

A socio-material perspective, thus, provides a way of considering the WEF-nexus as a web of relations between the social and material. Material artefacts, such as infrastructures, technologies, or indeed any devices, can be understood through the people who use or (re-)configure them, and people can be viewed as part of this infrastructure (Simone, 2004; Silver, 2013; Lawhon et al., 2018). Scholars particularly aligned with southern urban critique have pointed out the conjunction of people, practices, places, materialities, and technologies that are altogether more diverse than usually described. Different from how the networked infrastructural ideal of the Global North suggests – and resource governance approaches like the nexus take the North, both as analytical starting point and as normative reference – infrastructure is absent from many places in the world, or it is fragmented, messy, or failing<sup>1</sup>. Studying the practices people employ to get access to essential resources in such places brings into view many forms of self-built, incremental and ‘in-the-making’ infrastructures, coexisting with the infrastructures created and governed by the state. This then shifts the focus to the making and re-making of infrastructure (Simone, 2004)<sup>2</sup>, which consequently also serves to strengthen a processual and relational perspective of the nexus. As political ecologists have shown independently for the water sector (Jaglin, 2014), energy sector (Silver, 2013) as well as the food and agricultural sector (Kemerink-Seyoum et al., 2019), this understanding of infrastructure beyond the network opens up ways of studying how heterogeneous socio-material entanglements are created. Yet as long as theory is being “developed from a limited number of cases in the north” and as long as this results “in a tendency towards universalising theory” (Lawhon and Truelove, 2020, p. 5), the diversity of the world remains unacknowledged – or even deliberately obscured. Questioning uni-directional theory-making also fuels the problematization of the seemingly “given” infrastructural ideal (Kooy and Bakker, 2008; Jaglin, 2014). Against this background, we will discuss throughout our three cases in specific, the diverse ways to which infrastructures are interlinked through practices and materialities, yet varying, and heterogeneous ways. These heterogeneous infrastructures, thus, “produce” a nexus that is equally social and material, geographically situated and entangled in power relations.

A practice lens allows us to comprehend lived experienced nexus

<sup>1</sup> It is important to note, however, that engineered and networked infrastructures do not automatically provide universal and equal access to goods and services either (Lawhon et al. (2018)). On the contrary, scholars like Michelle Kooy have shown how splintered infrastructure leads to exclusions and inclusions and how this splintering is made from above and from below (Kooy and Bakker (2008)).

<sup>2</sup> Hence, infrastructure, like the natural world in general, does not just exist out there, but rather, “it is intrinsically social” as Noel Castree argues (Castree, 2001, p. 5). If we were to consider nature, natural resources, or the infrastructure that mediates their flows, “by definition [as] nonsocial and unchanging, [it] can lead not only to confusion but also the perpetuation of power and inequality in the wider world” (Castree (2001, p. 5)). This thinking is axiomatic for our understanding of nature as socio-nature and infrastructures as socio-technical systems.



realities in a people-centred way. Practices are a set of doings and sayings, that is empirically an intriguing unit when studying the social (Reckwitz, 2002; Everts et al., 2011). Describing and understanding the nexus as constantly being made and remade by doings and sayings, helps to reveal how the social world is entangled with objects or material artefacts (Nicolini, 2012). Practices build and rebuild technologies and infrastructure, thus, equally embrace infrastructures created by the state (i.e. networked infrastructure), or by individuals using a self-supply strategy. The latter is important to our situated nexus understanding, since many people in the Global South access and use informal, fragmented infrastructures. Nexus studies, however, tend to overlook those infrastructures leaving then not only the associated metabolic flows unaccounted for, as statistics are not usually available, but also neglect transformative possibilities embedded in heterogeneous infrastructures (Guibrunet and Broto, 2016). Because we see an undesired and reductionist tendency to focus only on the formal, accountable and quantifiable nexus, we advocate examining the informal infrastructure configurations and informal practices.

Building on these conceptual elements, we study the nexus through the lens of heterogeneous infrastructure configurations (HIC). This approach has been recently introduced to look at “the range of infrastructural options” people employ to secure everyday needs (Lawhon et al., 2018, p. 726). This perspective brings a view of infrastructure that is beyond formal, networked systems, and allows us to depart from any implicit understanding that the nexus (singular) is created around the interplay of modern, often large-scale infrastructure as governed by the state. Instead, other, more heterogeneous, flexible, transient, informal and unstable forms of nexuses (in the plural) come into view. Moreover, through the lens of lived experienced nexus realities, we see the myriad alternative, incremental, self-built and often decentralised ways of providing basic services (Simone, 2004; Alba and Bruns, 2016; Lawhon et al., 2018; Alba et al., 2019). Likewise, we see the in/securities and inequalities shaped by the infrastructure landscape that constitutes the nexus.

Our alternative account pays attention to the social-material entanglements that define a particular nexus. Against this background, we understand a nexus as neither universal, stable, homogeneous, nor centrally designed. Rather, the diverse forms of human and non-human agency configuring and altering nexuses emerge into focus. While state-centred forms of governance and service provision are primarily analysed in nexus studies, we find the micro-politics around WEF infrastructures of similar importance. Therefore, we suggest an understanding that pays attention to socio-technical tinkering in order to understand the “very visible manifestations of agency and change” and their “potential political spaces” (Kemerink-Seyoum et al., 2019, p. 12). What our Political Ecology inspired perspective thereby offers, is an alternative lens on the linkages between water, energy and food.

### 3. Studying nexus realities

#### 3.1. Methodological approach

Methodologically, we assemble insights into an instructive set of cases from Sub-Saharan Africa, providing a productive way to unsettle nexus research. We have chosen three cases because nexus thinking is closely related to developmental agendas that aims to provide solutions for a basic provision of needs. Using this as our starting point and applying a Political Ecology perspective, a one-week workshop was dedicated to these research aims<sup>3</sup> to elaborate and build upon our critique, and more importantly, find an alternative to mainstream nexus research that is centred on empirical knowledge and Political Ecology thinking. Against this background, we chose cases based on our own

<sup>3</sup> <sup>3</sup> March 25–29, 2019 organized by the main author and funded by the German Research Foundation (DFG).

research where we had existing qualitative and quantitative data from previous research. The empirical data consists mainly of abundant case descriptions (e.g. interviews, document analyses, roundtable discussions, and field observations), which have been re-analysed, in order to reveal how the nexus is configured and altered. To do so, we study practices as the “smallest unit of social analysis [...] which consists of several elements, interconnected to one other” (Reckwitz, 2002, pp. 249–250). In assembling technical artefacts, such as pipes or buckets, diesel generators or transformers, it is possible to identify how individual people carry out practices through which they make connections between water, energy and food. These practices have a bodily basis, and they require knowledge about specific “things”, therefore the case studies attempt to address the interplay of these socio-material elements and interactions.

In-depth discussions of the case-studies were guided by the following criteria: (i) comprehensive empirical data of practices that form, shape or alter nexus configurations, (ii) representation of diverse forms of nexus disruption to illustrate their change and dynamism, (iii) incorporation of varying degrees and forms of infrastructural linkages created through socio-material processes, and (iv) inclusion of diverse institutional settings and governance contexts. In addition to the selection criteria, our cases speak to different challenges of resource provisioning: Teshie, a fishing neighbourhood of Accra, unfolds in an urbanized context that is characterized by recurring power outages and a fragmented water infrastructure; GaManoke, a community in South Africa, shows how different inequality dimensions intersect of a rural community with poorly maintained municipal water supply systems; and Northern Ghana and Burkina Faso illustrate how climate mitigation policies of the global north negatively affect nexus security in the global south.

#### 3.2. Nexus disrupted – learning from nexus realities

Nexus Studies tend to start their analysis from the premise that resource provisioning systems are present and working in the form of networked infrastructure. By contrast, we become aware as to how infrastructural provisioning systems are always in-the-making, because failure and disruption is the norm in many regions.

We understand disruptions to be any socio-natural process that triggers a change in nexus configurations. A disruption may occur in the form of a failure of one specific item of infrastructure or technology, eliciting practices that reconfigure the nexus, thus, bringing about a different nexus configuration. Disruptive moments will most likely reveal the inequalities and injustices built into existing nexus configurations, or they may favour some actors while disadvantaging others. Sometimes a disruption may not result in any material re-arrangement – as a lack of agency, in which case the nexus is stuck or hindered, which will have impacts on the nexus in/securities experienced, and may also reinforce existing inequalities. Moments of disruption have the potential to open up political spaces, or create possible windows of opportunity for the social mobilization of alternative, that result in desirable nexus configurations. Yet, different people and groups have different abilities to navigate disruptions (Pelling and Dill, 2010; Silver, 2013). In moments of disruption, the inherently political nature of infrastructure that is often invisible or has been deliberately concealed (Meisch, 2019) becomes evident and then subject to public debate. Finally, a disruption may also expose the differentiated cooperativeness of water, energy or food in terms of governance mechanisms (Bakker, 2005).

In the following section we will draw on three different cases that illustrate and underpin the socio-material practices in the making of heterogeneous nexus configurations, and their agency, in the configuration of a nexus along with the scalar aspects of such nexuses. In this way, we will be able to identify differentiated nexus outcomes and acknowledge inequalities and insecurities embedded in, or reinforced by specific nexus configurations.

### 3.2.1. *Heterogeneous infrastructure and the making of an alternative nexus: A fishing village in Accra*

**3.2.1.1. Empirical interest.** Infrastructures and technologies are nodes, which create certain enabling or disabling conditions for basic supply. Material things, such as a poly-tank to store water, or a smoking rack to conserve fish, might become an important element of infrastructure within the WEF-nexus while its configuration is changing. We illustrate this process by looking at a shifting nexus configuration in a Ghanaian Fishing Community. We show how practices around infrastructures are produced by in/securities and inequalities and also productive of such in/securities and inequalities.

**3.2.1.2. Nexus disruption.** In Ghana, power cuts are frequent (Silver, 2015) that have severe effects on interlinked water, energy and food security. Hydropower is an important source of electricity, yet, everyday supply is disrupted due to a decrepit and fragmented energy infrastructure, and by fluctuations in water levels from the Volta Lake (Gyamfi et al., 2015). Equally important to understand, is that the frequent breakdowns are part of the historical colonial governance of energy, the power relations between different actors, World Bank interests in large-scale investments and neoliberal energy policies. These factors together account for the disruptions, as Jonathan Silver importantly illustrates (Silver, 2015), and, as we argue, they shape unique geographies in nexus in/securities.

Teshie, a fishing neighbourhood in Accra, the capital of Ghana, has a nexus configuration with significant implications for livelihoods: whenever the networked electricity supply is functioning, those fishing families connected to the grid use refrigerators for their catch. Fishing provides their income and main source of protein. In times of power cuts, the refrigerators do not work, and the fishermen are compelled to sell their fish as fast as possible owing to the tropical climate – and often must sell at a lower market price. Some fishing families smoke the fish as an alternative means of preservation, because this allows them to sell at a higher price to avoid any loss of income. For this altered livelihood practice (from refrigerating to smoking), the fish is cleaned thoroughly with water and is salted prior to smoking.

**3.2.1.3. Socio-material implications of the altered nexus.** These changing practices, triggered by energy insecurity, have material and social implications which are arguably related to WEF-nexus configurations. First, new physical artefacts for smoking are needed: either smoking racks that fishing families own already, or construct or rent one as an adaptation strategy. Biomass for smoking and a quantity of water for cleaning are needed as well. Although Teshie is connected to the Ghana Water supply network (which is regulated by the state through the Ghana Water Company Limited, GWCL), polytanks for storing the water are necessary, because piped water supply is equally fragmented, rationed, and insecure as the energy supply (Stoler et al., 2012; Fiasorgbor, 2013). When state supply of water is rationed, private water suppliers (e.g. water tankers) become an important element in meeting water needs (Alba et al., 2019). If we scale up our analysis from the household and neighbourhood perspective, to the regional level, we see implications beyond a place-based understanding of the nexus. Firewood and wood chips are imported from northern Ghana, creating tele-connected impacts elsewhere (Martey, 2019; Owusu et al., 2019). A change within a nexus configuration, thus, has a scalar dimension and might impact livelihoods elsewhere. Secondly, changing food preservation practices are associated with variations in the social domain, more precisely in gender relations: usually, it is the women who are responsible for smoking the fish, and the altered nexus configuration, thus, means that the gendered household labour is now shifted at the expense of women, whose workload increases. At the same time, however, the household income increases, which adds security.

Disruptions in the networked electricity flow change practices and

material entanglements in the WEF-nexus. The resulting energy insecurity has a direct impact on food security and is dependent on water security. This example reveals that some households have the agency to navigate around the changed nexus configuration to secure their household income, while others bear the risk of a reduced income, ultimately affecting livelihood resilience.

### 3.2.2. *Possibilities to (re)configure nexus security in a rural community in South Africa*

**3.2.2.1. Empirical interest.** The ability to adapt to, or transform nexus configurations is key when navigating the inequalities and insecurities resulting from a disruption. Therefore, we seek to know about the possibility of maintaining or repairing infrastructure that is vital for a particular nexus configuration. We do so by asking who is affected by failing nexus infrastructure, and how are the interests and concerns of marginalized communities addressed in moments of disruptions? We will discuss these aspects by looking at the neighbourhood GaManoke, located in the town Burgersfort in South Africa. Thereby we show, that in post-apartheid South Africa, nexus insecurities are still heavily shaped by historically established inequalities: economic advantage (for industries, urban areas or white irrigators) is prioritized over improving resource for the people (Bourblanc and Blanchon, 2019).

**3.2.2.2. Nexus disruption.** In GaManoke, located at the Steelpoort River, an electrical transformer of a purification plant had been stolen. Due to the interrupted electricity supply, the pumps and the water purification plant were not working, resulting in absolute water scarcity for community members. According to South African Statistics, GaManoke is characterised by its “poor infrastructure, major service delivery backlogs [...] and high poverty levels” (Statistics South Africa, 2018).

In South Africa, the state-owned electricity supplier ESKOM, is responsible for the generation and distribution of electricity, and the maintenance of the electricity distribution network. The provision and management of water services is the responsibility of municipalities. In GaManoke, a purification plant supplies water to the village for basic household needs, and the production of food in household and communal gardens. Due to frequent failures of the municipal water supply system, community members regularly rely on river water, though this water is contaminated with effluent from improperly functioning treatment works, as reported by Ntombela (2013). At the same time, the Steelpoort river is highly contaminated from industrial and agricultural sources (pesticides, fertilizers), and heavy metals from mining activities, and the water quality continuously is deteriorating (Stimie et al. 2001; Addo-Bediako et al. 2018).

Neglect of infrastructure maintenance and vandalism is an often reported problem in rural South Africa. Although 89% South Africans have access to water supply infrastructure, the actual reliability is very low because local municipalities are incentivized to maintain fragmented infrastructure, rather than to repair existing infrastructure (Lebek et al. 2021, p. 271). Against this background it is imperative to understand water, energy and food insecurity at the local or household level, instead of focussing solely on regional or scales, and to acknowledge the embodied inequalities (Truelove, 2019; Sultana, 2021).

**3.2.2.3. Socio-material implications of the altered nexus.** Following the interrupted water supply in GaManoke, community members requested ESKOM for more than three months to fit a new transformer (Meissner, 2015, p. 94). Due to the lack of piped water, community members resorted to buying water from informal water vendors at relatively high price for a poor rural community (R50 (US\$ 3) for 210 L). These additional water expenses affected the ability of households to spend money on other basic household requirements, including food. To reduce water expenditures, women did their laundry in the river and collected water at the river, where they were exposed to violent crime (e.g. rape and

armed robbery) and venomous insects and snakes (Meissner, 2015). In order to improve their situation, and because ESKOM did not react, community members were also in contact with the Tubatse Local Municipality, responsible for water supplies as the constitutionally mandated water service authority, to replace the transformer. When these interventions were unsuccessful, the community approached a research team from the Council for Scientific and Industrial Research (CSIR), conducting research in the community as part of their Water Sustainability Flagship Project. Shortly afterwards, CSIR team members intervened, and the stolen transformer was eventually replaced by ESKOM (Meissner, 2015).

This case shows that previously existing WEF insecurities are exacerbated when a single-supply system fails. Hence, the nexus is transmitting risks. This case, however, also reveals an embodied pattern of nexus insecurity, where again women are disproportionately affected in moments of nexus disruptions. In addition, the example of the stolen transformer emphasised how non-human actants, like technology, can act back to co-create “political configurations or *assemblages*” (emphasis in the original) (McCourt, 2016, p. 480). This example, therefore, also shows that the materiality of energy (electricity) and water differ, because the latter is not substitutable and somehow un-cooperative (Bakker, 2005). When the transformer was stolen, treated water could no longer be pumped to the people, and people had to travel to obtain water at high prices and poor quality.

### 3.2.3. Distant drivers and the nexus: Foreign Climate and Energy Policy meets local Agency in Northern Ghana

**3.2.3.1. Empirical interest.** We illustrate how comprehending nexus realities requires becoming aware of scalar dynamics, distant factors and unintended consequences of foreign policies. In particular, we show how international climate policies act as a driver for the globalisation of commodity markets and how this alters nexus realities at local and regional levels elsewhere.

**3.2.3.2. Nexus disruption.** Given the urgency of combatting climate change, a shift towards renewable energy has been induced in the form of political incentives in the European Union, and biofuels have become an attractive sector for direct foreign investment in many African countries (Schoneveld et al., 2011). In response to this trend, guided by expectations of modernisation and development, the government of Ghana introduced various policies, such as tax holidays, to attract large-scale land-based biofuel investments (Ahmed et al., 2017), without having a direct control over land transactions. In Ghana, land governance is characterized by customary land ownership, with local chiefs acting as custodians of land on behalf of their subjects. Motivated by development promises, a local chief in Northern Ghana entitled his land to an Italian investor, who had been enticed by the enabling market conditions and possibilities. The Italian company acquired 6,750 ha of farmland located in the *peri*-urban area of a small city along the Volta Lake, and five-years after the land acquisition, began commercial cultivation of *Jatropha* (physic nut) (Ahmed et al., 2017). Previously, the land had been used for dry season irrigation farming (irrigation water came from the Volta Lake), for firewood and charcoal (major sources of primary energy for cooking), and the harvest of wild fruits in the savannah vegetation, including shea, which is both a source of food and a major livelihood option for women. The land acquisition and the subsequent land conversion into a *jatropha* plantation profoundly limited people’s access to primary energy sources and food.

**3.2.3.3. Socio-material implications of the altered nexus.** Biofuel-driven land acquisitions in northern Ghana changed patterns of access, use, and control over land resulting to changing WEF security levels. Land use and land cover changes led to widespread land dispossession in the area (Ahmed et al., 2018), subsequently reducing food production at

household levels while increasing *Jatropha* production for foreign markets. The conversion of farmland to non-food energy crops manifested itself in a local food price rise affecting food security, especially of poor households that marginalised them further (Ahmed et al., 2019).

In addition, the labour-intensive nature of the plantation work put pressure on women, exposing them to health risks due to their contact with agrochemicals, while still being responsible for household care work. The community was alarmed and protested: farmers agitated against the *de facto* land dispossession (they were never compensated in any form for the loss of land and livelihood) in a series of local unrest, including demonstrations by young people deprived of their future. In an interview with the local Assemblyman of the Yeji area indicated that: “Farmers here have not supported the project because we cannot be cutting down shea trees just to make a *jatropha* farm. For us here, we cannot give our farmlands for fuel making” [interview, Assemblyman, Kadue, 2016]. Large-scale land transformations into a *Jatropha* monoculture in Northern Ghana brought widespread resistance and affected also other resource systems.

In the region, groundwater and surface water for commercial use is regulated by the state, represented through the Water Resource Commission and the Volta Basin Authority. However, many smallholders reported that the company illicitly extracts water from the Volta Lake, especially in the dry season. Indeed, a crosscheck in the water use register of the Water Resource Commission confirmed that the company was not permitted at that time to extract water from either the Volta Lake or groundwater sources. Local communities are of the opinion that, the original intention of the investor was first to grab land for fuel, and later grab water for irrigation (Adams et al., 2019). Following several agitations for dry season farmers, in 2018, the company acquired a license to extract ground water for irrigation (Water Resources Commission, 2018), and stopped water extraction from the Volta Lake.

The Italian company, however, failed to secure the necessary certification for exporting *Jatropha* to the EU market. *Jatropha* seeds were then exported to Burkina Faso, where they are in use as biodiesel for small generators (Favretto et al., 2014). These diesel generators are a widespread form of heterogeneous energy infrastructure in the absence of electricity mains. In addition, women use the *Jatropha* biodiesel to replace firewood to power small crusher machines for the production of shea butter (Contran et al., 2016). Income generated through employment in *Jatropha* production increased the adoption of modern energy sources (Moioli et al., 2018; Karanja and Gasparatos, 2019). Women alleged that by using the crusher machine, the amount of water and firewood needed for shea butter processing is reduced, so that these shifts in socio-materialities improved energy and water securities for women in this location.

This complex web of socio-ecological relations involved in *Jatropha* production reveals how European policies aim to enhance European energy security at the expense of altering WEF-nexus configurations in different places. The case shows how a foreign investor (i.e. an Italian company) co-produces in alliance with a powerful local actor (i.e. the chief) the alteration of resource flows for the worse. Yet, in a different place and political context (Burkina Faso), the very same biodiesel from *Jatropha* has been an enabling agent for positive change of livelihoods: by switching to Biodiesel from *Jatropha* as a new energy source, women have been empowered and their household WEF-nexus security has ultimately improved. The case is, hence, an example of the complex governance challenges of the nexus that is full of unintended effects and cross-scalar linkages. Governing the nexus requires in-depth knowledge of (sometimes distant) socio-ecological systems, including the governance of land, and it requires acknowledgement of the unaccounted resource systems that are foundational for nexus security.

## 4. Conclusion

Seeing the nexus through the lens of Political Ecology enables us to disrupt nexus thinking in several important ways. We move beyond an



understanding of the nexus as universal and homogeneous, static and given, purely material or a-political. Instead, we capture the nexus as a dynamic socio-material configuration that is embedded in power relations and altered over time and space. In our paper, we therefore propose a heuristic lens to comprehend better the diversity of nexuses and the socio-material processes that constitute them. Building on Political Ecology enables us to illustrate that *the* nexus does not exist by itself, but rather that nexuses are configured through practices and discourses.

Our study provided insight on different nexus configurations on individual, up to intra-regional scales and showed how – in moments of disruptions – usual forms of water, energy or food supply are intermitted. In these instances, other supply forms are brought to the fore. A focus on people and how they navigate the interlinked challenges of WEF security broadens, therefore, our analytical attention that is often too narrowly scrutinizing the formal service provision by state actors and, thereby, failing to acknowledge everyday forms of service provision. By drawing on the example of Teshie, a neighbourhood in Accra, we showed that water, energy and food circulate through heterogeneous infrastructures in which state supply and private forms of service provision are assembled. As people and households have different capabilities and options to manoeuvre in moments of service disruptions, lived experienced nexus realities unfold unevenly across places and between different people. We have demonstrated that nexus in/security is, thus, related to the infrastructural configuration of nexuses that are geographically uneven – especially so, in the Global South, where the centralised network is often absent or fragmented. Yet while we have examined and learned from the South, where WEF in/security is of high concern, we are nevertheless, aware that nexus insecurities and inequalities also manifest themselves in Northern cities and regions (Romero-Lankao et al., 2018).

By studying nexus realities, we extend the conceptual, methodological and empirical focus within nexus studies. Our people-centred approach draws attention to diverse practices that may create spaces of possibility to enhance nexus security. Hence, this perspective offers a widened and differentiated understanding of nexus politics, including its micro-politics, which is important for two reasons. Firstly, we also include informal, often invisible metabolic circulations (Guibrune et al., 2016), and the way they produce or mitigate nexus in/securities. As most nexus studies focus on accountable flows, formal networks and state provision, these other nexuses, created by processes of tinkering, usually remain invisible, inadequately analysed, and insufficiently incorporated into the governance of nexuses. Secondly, we make a counterproposal to managerial techno-politics and mainstream nexus approaches, as these tend to black-box social, political and humanitarian dimensions. Thereby, we showed that differentiated forms of agency are shifting and altering nexus inequalities and insecurities. A stolen transformer fundamentally disrupted the nexus in a South African community and undermined their water, energy, and food security. This case, like the other two cases revealed, that particularly women are affected. Therefore, an intersectional and gender perspective is crucial in apprehending nexus realities. In emphasising embodied experiences and gendered differences, we disclose power assemblages shaping everyday nexus security. Societal marginalisation and economic poverty often amplify nexus-related insecurities and inequalities, as they are formative of relatively low agency to mitigate risks. Since WEF-nexus studies usually self-identify as applied research that can inform resource governance, it is of even greater importance to understand and reveal where the everyday agency to mitigate insecurities is and how this agency is performed. Resource governance needs to learn from these empirical examples to identify spaces of possibility for more just futures.

Finally, we suggest devoting greater attention to the material properties of water, energy and food respectively, and how these properties interact in making up a nexus configuration. While water is non-substitutable, difficult to transport over longer distances and to store safely, energy has different material properties. These distinct properties

of energy resources allow, for instance, a shift from modern energy (electricity) to biomass in moments of disruption. This is because biomass can be obtained even from far distances (for instance from distant rural places), and stored for situations of energy insecurity. While it was beyond the scope of this paper to examine the key properties of the resources involved in the nexus, we see great potential in this field of study. In agreement with Karen Bakker and Gavin Bridge we acknowledge that, “matter matters because it is through grounded research that we encounter differences that make a difference” (Bakker and Bridge, 2006, p. 21). Nexus studies, thus far have tended to downplay or even neglect the diverse materialities of the resources involved. As resources have differential biophysical and spatial properties, they are embedded in different processes of resource mobilisation and commodification that need to be taken into account in future studies.

#### CRediT authorship contribution statement

**Antje Bruns:** Conceptualization, Methodology, Investigation, Funding acquisition, Workshop Organization. **Simon Meisch:** Conceptualization, Methodology, Writing. **Abubakari Ahmed:** Conceptualization, Investigation. **Richard Meissner:** Conceptualization, Investigation. **Patricia Romero-Lankao:** Conceptualization, Investigation.

#### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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#### References

- Adams, E.A., Kuusaana, E.D., Ahmed, A., Campion, B.B., 2019. Land dispossessions and water appropriations: political ecology of land and water grabs in Ghana. *Land Use Policy* 87, 104068. <https://doi.org/10.1016/j.landusepol.2019.104068>.
- Addo-Bediako, A., Matlou, K., Makushu, E., 2018. Heavy metal concentrations in water and sediment of the Steelpoort River, Olifants River System, South Africa. *Afr. J. Aquat. Sci.* 43 (4), 413–416.
- Ahlers, R., Cleaver, F., Rusca, M., Schwartz, K., 2014. Informal space in the urban waterscape: Disaggregation and co-production of water services. *Water Altern.* 7, 1–14.
- Ahmed, A., Campion, B.B., Gasparatos, A., 2017. Biofuel development in Ghana: policies of expansion and drivers of failure in the jatropha sector. *Renew. Sustain. Energy Rev.* 70, 133–149.
- Ahmed, A., Campion, B.B., Gasparatos, A., 2019. Towards a classification of the drivers of jatropha collapse in Ghana elicited from the perceptions of multiple stakeholders. *Sustain. Sci.* 14 (2), 315–339.
- Ahmed, A., Kuusaana, E.D., Gasparatos, A., 2018. The role of chiefs in large-scale land acquisitions for jatropha production in Ghana: insights from agrarian political economy. *Land Use Policy* 75, 570–582.
- Alba, R., Bruns, A., 2016. Beyond the pipe: Re-thinking urban water supply in African cities: Conference Paper. Southern African Cities Studies Conference, 2016, Durban, South Africa.
- Alba, R., Bruns, A., Kooy, M., Bartels, L., 2019. Water brokers: Exploring urban water governance through the practices of tanker water supply in Accra, Ghana. Special Issue: “Doing Water Provision, Distribution and Conservation: A Practice-Based Approach to Water Governance. *Water*.”



- Albrecht, T.R., Crootof, A., Scott, C.A., 2018. The water-energy-food nexus: a systematic review of methods for nexus assessment. *Environ. Res. Lett.* 13 (4), 043002. <https://doi.org/10.1088/1748-9326/aaa9c6>.
- Allouche, J., Middleton, C., Gyawali, D., 2015. Technical Veil. Interrogating the Power Linkages behind the Nexus. *Water Alternatives, Hidden Politics*, pp. 610–626.
- Amin, A., Thrift, N., 2017. *Seeing like a city*. John Wiley & Sons.
- Bakker, K., 2005. Neoliberalizing nature? market environmentalism in water supply in England and Wales. *Ann. Assoc. Am. Geogr.* 95 (3), 542–565.
- Bakker, K., Bridge, G., 2006. Material worlds? Resource geographies and the 'matter of nature'. *Prog. Hum. Geogr.* 30 (1), 5–27.
- Biggs, E.M., Bruce, E., Boruff, B., Duncan, J.M.A., Horsley, J., Pauli, N., McNeill, K., Neef, A., Van Ogtrop, F., Curnow, J., Haworth, B., Duce, S., Imanari, Y., 2015. Sustainable development and the water–energy–food nexus: a perspective on livelihoods. *Environ. Sci. Policy* 54, 389–397.
- BMU, BMZ, 2012b. *The Water, Energy and Food Security Nexus – Solutions for a Green Economy. Policy Recommendations*, Bonn, Berlin, 26 pp.
- BMU, BMZ, 2012a. *The Water, Energy and Food Security Nexus. Solutions for the Green Economy. Conference Synopsis*, Bonn, Berlin, 28 pp.
- Bourblanc, M., Blanchon, D., 2019. Political ecologies of water in South Africa: a literature review. *WIREs Water* 6 (5). <https://doi.org/10.1002/wat2.v6.510.1002/wat2.1371>.
- Bridge, G., McCarthy, J., Perreault, T. (Eds.), 2015. Editors Introduction. In: Perreault, T., Bridge, G., McCarthy, J. (Eds.). *The Routledge handbook of Political Ecology*, Routledge, London, New York, 646 pp.
- Cairns, R., Krzywoszyńska, A., 2016. Anatomy of a buzzword: the emergence of 'the water-energy-food nexus' in UK natural resource debates. *Environ. Sci. Policy* 64, 164–170.
- Castree, N., 2001. Socializing Nature: Theory, Practice, and Politics. In: Castree, N., Braun, B. (Eds.), *Social Nature: Theory, Practice, and Politics*. Blackwell Publishers, pp. 1–21.
- Chakrabarty, D., 2009. *Provincializing Europe: Postcolonial Thought and Historical Difference-New Edition*. Princeton University Press.
- Conran, N., Chessa, L., Lubino, M., Bellavite, D., Lobina, R., Sahanoon, O., Fuseini, S., Imoro, T.S., Roggero, P.P., Enne, G., 2016. Potentialities and limits of *Jatropha curcas* L. as alternative energy source to traditional energy sources in Northern Ghana. *Energy Sustain. Dev.* 31, 163–169.
- Coutard, R., Rutherford, J. (Eds.), 2015. *Beyond the Networked City: Infrastructure reconfigurations and urban change in the North and South*. Routledge.
- Escobar, A., 2016. Thinking-feeling with the Earth: Territorial Struggles and the Ontological Dimension of the Epistemologies of the South. *AIBR* 11 (1), 11–32.
- Everts, J., Lahr-Kurten, M., Watson, M., 2011. Practice matters! Geographical inquiry and theories of practice. *Erdkunde* 65 (4), 232–334.
- Favretto, N., Stringer, L.C., Dougill, A.J., 2014. Unpacking livelihood challenges and opportunities in energy crop cultivation: perspectives on *Jatropha curcas* projects in Mali. *Geogr. J.* 180 (4), 365–376.
- Fiasorgbor, A., 2013. Water and sanitation situation in Nima and Teshie, Greater Accra Region of Ghana. *J. Toxicol. Environ. Health Sci.* 5 (2), 23–28.
- Foran, T., 2015. Node and regime: interdisciplinary analysis of water-energy-food nexus in the Mekong Region 8, 655–674.
- Gandy, M., 2005. Cyborg urbanization: complexity and monstrosity in the contemporary city. *Int. J. Urban Regional* 29 (1), 26–49.
- Guibrunet, L., 2016. Towards an urban metabolic analysis of the informal city. In: Archer, K., Bezdecny, K. (Eds.), *Handbook of Cities and the Environment*. Edward Elgar Publishing, pp. 160–180. <https://doi.org/10.4337/9781784712266.00013>.
- Guibrunet, L., Sanzana Calvet, M., Castán Broto, V., 2016. Flows, system boundaries and the politics of urban metabolism: Waste management in Mexico City and Santiago de Chile. *Geoforum* 85, 353–367.
- Gyamfi, S., Modjinou, M., Djordjevic, S., 2015. Improving electricity supply security in Ghana—The potential of renewable energy. *Renew. Sustain. Energy Rev.* 43, 1035–1045.
- Hoff, H., 2011. Understanding the nexus: Background paper for the Bonn2011 Conference. Background Paper for the Bonn 2011 Conference: The Water, Energy and Food Security Nexus. Stockholm Environment Institute, Stockholm.
- Jaglin, S., 2014. Regulating service delivery in southern cities: rethinking urban heterogeneity. In: Susan Parnell, S.O. (Ed.), *The Routledge handbook on cities of the global south*. Routledge, pp. 456–469.
- Karanja, A., Gasparatos, A., 2019. Adoption and impacts of clean bioenergy cookstoves in Kenya. *Renew. Sustain. Energy Rev.* 102, 285–306.
- Kemerink-Seyoum, J.S., Chitata, T., Domínguez Guzmán, C., Novoa-Sanchez, L.M., Zwartveen, M.Z., 2019. Attention to Sociotechnical Tinkering with Irrigation Infrastructure as a Way to Rethink Water Governance. *Water* 11, 1670.
- Keskinen, M., Guillaume, J., Kattelus, M., Porkka, M., Räsänen, T., Varis, O., 2016. The water-energy-food nexus and the transboundary context: insights from Large Asian Rivers. *Water* 8 (5), 193. <https://doi.org/10.3390/w8050193>.
- Kooy, M., Bakker, K., 2008. Splintered networks: The colonial and contemporary waters of Jakarta. *Geoforum* 39 (6), 1843–1858.
- Lawhon, M., Ernstson, H., Silver, J., 2013. Provincializing urban political ecology: towards a situated UPE through African urbanism. *Antipode* 46 (2), 497–516.
- Lawhon, M., Nilsson, D., Silver, J., Ernstson, H., Lwasa, S., 2018. Thinking through heterogeneous infrastructure configurations. *Urban Studies* 55 (4), 720–732.
- Lawhon, M., Truelove, Y., 2020. Disambiguating the southern urban critique: Propositions, pathways and possibilities for a more global urban studies. *Urban Studies* 57 (1), 3–20.
- Lebek, K., Twomey, M., Krueger, T., 2021. Municipal failure, unequal access and conflicts over water—a hydro-social perspective on water insecurity of rural households in KwaZulu-Natal, South Africa. *Water Altern.* 14, 271–292.
- Leck, H., Conway, D., Bradshaw, M., Rees, J., 2015. Tracing the Water-Energy-Food Nexus: Description, Theory and Practice. *Geography Compass* 9 (8), 445–460.
- Leese, M., Meisch, S., 2015. Securitising Sustainability? Questioning the 'Water, Energy and Food-Security Nexus'. *Water Altern.* 8, 695–709.
- Lövbrand, E., Beck, S., Chilvers, J., Forsyth, T., Hedrén, J., Hulme, M., Lidskog, R., Vasileiadou, E., 2015. Who speaks for the future of Earth? How critical social science can extend the conversation on the Anthropocene. *Global Environ. Change* 32, 211–218.
- Luke, T.W., 2005. Neither sustainable nor development: reconsidering sustainability in development. *Sust. Dev.* 13 (4), 228–238.
- Martey, E., 2019. Tenancy and energy choice for lighting and cooking: Evidence from Ghana. *Energy Econ.* 80, 570–581.
- McCourt, D.M., 2016. Practice theory and relationalism as the new constructivism. *Int. Stud. Quart.* 60 (3), 475–485.
- Mehta, L., 2005. The politics and poetics of water: the naturalisation of scarcity in Western India. *Orient Blackswan*.
- Meisch, S., 2019. I Want to Tell You a Story: How Narrative Water Ethics Contributes to Re-theorizing Water Politics. *Water* 11 (4), 631. <https://doi.org/10.3390/w11040631>.
- Meissner, R., 2015. The governance of urban wastewater treatment infrastructure in the Greater Sekhukhune District Municipality and the application of analytic eclecticism. *Int. J. Water Governance* 79–110.
- Moioli, E., Salvati, F., Chiesa, M., Siecha, R.T., Manenti, F., Laio, F., Rulli, M.C., 2018. Analysis of the current world biofuel production under a water–food–energy nexus perspective. *Adv. Water Resour.* 121, 22–31.
- Molle, F., 2008. Nirvana Concepts, Narratives and Policy Models: Insights from the Water Sector. *Water Altern.* 1, 131–156.
- Moss, T., 2014. Socio-technical Change and the Politics of Urban Infrastructure: Managing Energy in Berlin between Dictatorship and Democracy. *Urban Studies* 51 (7), 1432–1448.
- Nicolini, D., 2012. *Practice Theory, Work, and Organization: An Introduction*. Oxford University Press, p. 29.
- Ntombela, C., Masangane, W., Funke, N., Nortje, K., 2013. Sekhukhune District Municipality workshop proceedings: Wastewater treatment: Towards improved water quality to promote social and economic development. CSIR Rep.
- Owusu, F., Kuraniche, F.A., Odonkor, S., Frimpong, K., Muri, M., 2019. Biomass Stove for Pelletized Sawdust Fuel in Ghana. *Combust. Sci. Technol.* 192 (9), 1719–1730.
- Pelling, M., Dill, K., 2010. Disaster politics: tipping points for change in the adaptation of sociopolitical regimes. *Prog. Hum. Geogr.* 34 (1), 21–37.
- Reckwitz, A., 2002. Toward a theory of social practices: a development in culturalist theorizing. *Eur. J. Soc. Theory* 5 (2), 243–263.
- Robbins, P., 2004. *Political Ecology: A Critical Introduction*. Blackwell Publishers.
- Romero-Lankao, P., Bruns, A., Wiegler, V., 2018. From risk to WEF security in the city: the influence of interdependent infrastructural systems. *Environ. Sci. Policy* 90, 213–222.
- Schatzki, T., 2010. Materiality and social life. *Nat. Culture* 5, 123–149.
- Schmidt, J.J., Matthews, N., 2018. From state to system: Financialization and the water-energy-food-climate nexus. *Geoforum* 91, 151–159.
- Schoneveld, G.C., German, L.A., Nutakor, E., 2011. Land-based Investments for Rural Development? A Grounded Analysis of the Local Impacts of Biofuel Feedstock Plantations in Ghana. *E&S* 16.
- Shove, E., 2017. Matters of Practice. In: Hui, A., Schatzki, T.R., Shove, E. (Eds.), *The nexus of practices. Connections, constellations and practitioners*. Routledge, London, New York, pp. 155–168.
- Silver, J., 2013. Reconfiguring electricity infrastructures in Accra and Cape Town: Understanding the political ecologies of networked urbanism. Durham theses, Durham University. Available at Durham E-Theses Online: <http://etheses.dur.ac.uk/7719/>, 260 pp.
- Silver, J., 2015. Disrupted infrastructures: an urban political ecology of interrupted electricity in Accra. *Int. J. Urban Regional* 39 (5), 984–1003.
- Simone, A., 2004. People as infrastructure: intersecting fragments in Johannesburg. *Public Culture* 16, 407–429.
- Spiegelberg, M., Baltazar, D.E., Sarigumba, M.P.E., Orenco, P.M., Hoshino, S., Hashimoto, S., Taniguchi, M., Endo, A., 2017. Unfolding livelihood aspects of the Water–Energy–Food Nexus in the Dampalit Watershed, Philippines. *J. Hydrol.: Reg. Stud.* 11, 53–68.
- Statistics South Africa, 2018. Provincial profile: Limpopo Community Survey 2016. Report number 03-01-15, Pretoria.
- Stimie, C., Richters, E., Thompson, H., Perret, S., Matete, M., Abdallah, K., Kau, J., Mulibana, E., 2001. Hydro-institutional mapping in the steelpoort river basin. *IWMI Working Paper* 17, Colombo, Sri Lanka.
- Stoler, J., Fink, G., Weeks, J.R., Otoo, R.A., Ampofo, J.A., Hill, A.G., 2012. When urban taps run dry: Sachet water consumption and health effects in low income neighborhoods of Accra, Ghana. *Health & Place* 18 (2), 250–262.
- Sultana, F., 2021. Political ecology 1: From margins to center. *Prog. Hum. Geogr.* 45 (1), 156–165.
- Truelove, Y., 2019. Rethinking water insecurity, inequality and infrastructure through an embodied urban political ecology. *WIREs Water* 6 (3). <https://doi.org/10.1002/wat2.2019.6.issue-310.1002/wat2.1342>.
- van Kerkhoff, L., Lebel, L., 2006. Linking Knowledge and Action for Sustainable Development. *Annu. Rev. Environ. Resour.* 31 (1), 445–477.
- Water Resources Commission, 2018. *Water Use Register 2018*.
- Wesselink, A., Kooy, M., Warner, J., 2017. Socio-hydrology and hydrosocial analysis: toward dialogues across disciplines. *WIREs Water* 4 (2), e1196. <https://doi.org/10.1002/wat2.1196>.

Wiegleb, V., Bruns, A., 2018. What Is Driving the Water-Energy-Food Nexus? Discourses, Knowledge, and Politics of an Emerging Resource Governance Concept. *Front. Environ. Sci.* 6, 870.

Williams, J., Bouzarovski, S., Swyngedouw, E., 2019. The urban resource nexus: On the politics of relationality, water–energy infrastructure and the fallacy of integration. *Environ. Planning C: Politics Space* 37 (4), 652–669.

World Economic Forum, 2011. *Water security: The water-food-energy-climate nexus*. The World Economic Forum Water Initiative. Island Press, Washington, DC, 248 pp.