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# The conceptual basis of water-energy-food nexus governance: systematic literature review using network and discourse analysis

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## ABSTRACT

In the last decade, the debate on the governance of water, energy, and food (WEF) has intensified, spurring the emergence of the term “nexus governance.” In general, the reduction of trade-offs and construction of synergies between WEF have been placed on the scientific, political, and economic agenda. However, although increasingly used, it is difficult to find a clear meaning and definition of what the term represents. Based on a systematic literature review (SLR), using text-mining and machine learning algorithms, this article investigates what are the conceptual basis of the nexus governance debate, and attempts to clarify the main themes, networks, and gaps within this literature. The analysis is based on quantitative and qualitative methods, combining social network analysis (SNA) and discourse analysis (DA). The results highlighted that twenty-four governance-related concepts support this literature, breaking down into eight groups: water and basin governance; environmental and systems governance; risk and resource security governance; economic governance; global governance; urban governance; integrative and cooperative governance; and “epistemic” and transdisciplinary governance.

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## KEYWORDS

Water-energy-food nexus; nexus governance; social network analysis; discourse analysis; systematic literature review

## 1. Introduction

In the last decade, many authors have tried to address the governance of water, energy, and food (WEF) holistically. The concept of WEF nexus has allocated this debate. In general, authors agree that the nexus is defined by the integration capacity of different sectors from generation to distribution in the search for more viable solutions for the planet. This is amid scenarios of inequalities, scarcity, misdistribution, and misuse of natural resources, and uncertainties associated with global changes (Hoff 2011; Dupar and Oates 2012; Reynolds and Cranston 2014; Allouche et al. 2015; Giatti et al. 2016; Lal 2016).

Important events in the last decade fostered the use of the concept, such as the Bonn 2011 Conference, Sixth Edition of Global Risks in 2011, World Water Forum 2012 in Marseilles, Rio+20 in 2012, and Stockholm Water Week in 2014 (Allouche et al. 2015). These conferences addressed integrated solutions in search of global environmental

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sustainability. The relationships between WEF can be defined as follows. Water is needed to generate energy; energy is needed for the supply of water; energy is needed to produce food; food can be used to produce energy; water is needed to grow food; and food transports (virtual) water, usually using energy (Stringer et al. 2014). Thus, any problem in the management of one resource can directly affect the others (Hussey and Pittock 2012).

Since both governance and WEF nexus have different meanings in the literature, it is a challenging task to understand them together. Nexus governance seems to appear as an umbrella concept for integrated decision-making and solutions for environmental issues. However, although this association is becoming increasingly common, it is not possible to say that it is an already well-defined concept.

A previous non-systematic review on nexus governance was carried out by the Stockholm Environment Institute (Weitz et al. 2017a), which pointed out the main gaps and proposals for the future regarding the governance debate on the WEF nexus. According to the authors, the literature on nexus governance is based on three perspectives: risk, economic rationality, and political economy. First, this is an important contribution, as it is the first effort to categorize seemingly unrelated studies published in recent years. Another working paper (in the Nexus Network Think Piece Series) by Stein et al. (2014) approaches the discussion on nexus governance by developing a foundation for a strategic action perspective. They recognize that nexus challenges are intrinsically linked to the perceptions, interests, and practices of actors, and construct an approach for the relational understanding of nexus governance. They also emphasize the need to address nexus challenges through existing governance arrangements.

Moving forward, in this work we are interested in capturing which are the governance concepts that constitute the literature about WEF nexus governance through a systematic literature review (SLR). It is, therefore, an attempt to understand whether nexus governance can be defined conceptually but also the way this is addressed in the literature. The innovative aspect of this research is to understand the conceptual foundations of nexus governance and identify the differences found within quantitative and qualitative methods. This includes text-mining tools and machine learning algorithms, Social Network Analysis (SNA), and discourse analysis (DA). Three research questions guided this study:

- What governance concepts constitute nexus literature?
- What are their main themes and networks within the selected articles?
- Which are the research gaps in the nexus-governance discussion?

The paper is structured as follows: In [Section 2](#) we describe the theoretical background of this research; [Section 3](#) describes materials and methods used in this study; [Section 4](#) presents the results of the study; in [Section 5](#) we discuss the results; [Section 6](#) refers to the research gaps; and finally in [Section 7](#) we present the final remarks.

## 2. Theoretical background

The overlapping of decision-making possibilities is one of the main constraints for nexus governance, which faces the challenge of promoting interaction among pre-existing governance structures (Benson et al. 2015). One idea repeatedly addressed is the need

to “break down the silos” (Cairns and Krzywoszynska 2016). That is, there is progressive encouragement to expand research and policy decisions beyond specialized knowledge and traditional governance structures based on sectors. The possibility that WEF interactions go beyond the siloes can be supported by two concepts: *trade-offs* and *synergies*. Trade-offs analysis may reveal priorities in the governance process and inform locally defined norms of fairness in interventions. Institutional synergies can determine progress in ensuring balance and mitigation of possible rebound effects in environmental planning and management (Kurian et al. 2016). Besides, robust synergy can be defined by knowledge exchange among and across different sectors, enhancement of capacities by key players and the appropriation by agencies and departments of financing and technology (Gregory 1997). Ultimately, the two concepts present similarities; “trade-offs” refers to a compromise that involves negotiation, while “synergies” means that inter-connection necessitates collective action (Kurian et al. 2016).

Based on this, institutional arrangements and governance structures in the nexus approach can be guided by 1) intersectionality, 2) interactionality and 3) hybridity (Kurian and Kardanian, 2015). These three components are much more uncertain possibilities than achieved characteristics. It would be necessary to change the intersection between material flows, financing and institutions; the vertical and horizontal interaction between economy, politics and society; and the analysis based on hybridity and trans-disciplinarity (Kurian et al. 2016). To some extent, this approach interacts with many governance concepts, focusing on integrative governance across diverse sectors and actors.

Governance has increasingly become a fashionable term, gaining traction from the “Our Global Neighborhood” report in 1995 (Commission on Global Governance 1995). It has also been the subject of multiple disciplines and kinds of literature, all of which give the term governance different meanings (Kersbergen and Waarden 2004). At least six different uses were selected, namely as the minimal state, corporate governance, new public management, “good governance,” socio-cybernetic system, and self-organizing networks (Rhodes 1996; Pierre and Peters 2000). Despite their use in diverse disciplines, including development studies, economics, political science and international relations, law, planning, geography, business administration, public administration, sociology, and history. However, the concept could precisely connect different disciplines and thus stimulate comparisons between quite different phenomena (Kersbergen and Waarden 2004). Essentially, governance was portrayed as socio-political and understood to have complex processes and interactions, constituting patterns of law (Bevir 2011; Benites-Lazaro et al. 2018a). “It replaces a focus on the formal institutions of states and governments with recognition of the diverse activities that often blur the boundary of state and society” (Bevir 2011, p. 2).

Thus, following the work of Stoker (1998), governance can be understood as a set of institutions and actors beyond the boundaries of government. The term identifies different responsibilities for tackling social and economic issues, as well as power dependencies involved between institutions. In addition, governance can represent an autonomous self-governing network of actors, recognizing capacities beyond the control of the government but also seeing the latter as able to use new tools as a guide (Stoker 1998).

### 3. Materials and methods

#### 3.1. Methods

In this study, we first performed social network analysis (SNA), a tool that facilitates communication between a group of actors (individuals or organizations) called nodes. Nodes are coupled by some common ground, such as interests, financial exchanges, friendships, dislikes, knowledge, prestige, etc. SNA operates on many levels, from family relationships and disease-spreading to the level of corporate strategies, social movements or even nations. This method is a way to re-incorporate context and bridge the gap between the micro and the macro, the cells constituting the animal, the individuals constituting groups, or the actors constituting a political system. This also allows researchers to retain the traditional units of recording, while simultaneously broadening the perspective by including information about the relationships across these units. This additional structural information allows researchers to address existing research questions using new tools, approaching them from a different theoretical perspective (Benites-Lazaro et al. 2018b). Second, discourse analysis (DA), which consists of a set of techniques for the structured research of texts. It is “the study of language-in-use and is employed to engender a range of meanings varying from the analysis of linguistic regularities to the normative quality of discussions” (Benites-Lazaro et al. 2018b, p. 320). Similar to Benites-Lazaro et al. (2018b) in this study, we used a mixed-method for the DA, in order to take advantage of both qualitative and quantitative techniques. It assumes that, both, the number of word repetitions performed by software and the exploratory lexical patterns, play important roles in textual analysis. The analyses were deemed necessary to cope with the in-depth examination of twenty-eight articles. The aim was to find community and a relationship among themes, surrounding nexus governance and discovery patterns, and extract elementary contexts. Through this, a qualitative analysis could be conducted to identify the context of predominant discourses on nexus governance.

#### 3.2. Materials

The data collected are articles from the database of Scopus, Web of Science and Science Direct over the period 2007–2018 with the keyword “water-energy-food nexus” and “water-energy-food nexus AND governance.” The results of the collection were 1455 articles ( $N_1 = 1455$ ). The SLR was performed in two steps. First, we cleaned the duplicate articles. After this, we applied to this big data the open-source software *Gephi* for visual exploration of networks and compute centrality measures. This is a network analytic tool that is used to represent the nodes (themes) and edges (relationships) in a network to analyse the network data (Benites-Lazaro et al. 2018c). Second, the searches were deepened using *T-Lab* software, performing text-mining and machine learning to select only articles in English that focus on “water-energy-food nexus AND governance” in titles, abstracts and keywords in the same period (2007–2018). We did not consider papers that dealt with only one or two elements of the nexus, such as only “water” or “water-energy”: the three elements would need to appear together. Moreover, books, book chapters, working papers, conference papers, and reports were excluded. The  $N_f$  is twenty-eight papers.

### 3.3. Data analysis

Quantitative and qualitative analysis were performed using the *T-Lab* software. This program uses a set of statistical, linguistic, and graphic tools to analyse texts (Lancia 2012). In general, the steps of this software are the processing of documents creating a database, its transformation creating a target data, text mining discovering patterns and, finally, the interpretation that creates knowledge. One advantage is that it facilitates mixing qualitative and quantitative methods, performing a quantitative treatment of textual data, and enabling a qualitative analysis of the results to understand the discourse (Benites-Lazaro et al. 2018a). The adjacency matrix of the network (a matrix where each element  $[i, j]$  is equal to the weight of the arc from Node  $i$  to Node  $j$ ) was performed, using *T-Lab* software. This included: i) an ego network analysis (ENA), using *T-Lab* software; ii) discourse analysis (DA), also using *T-Lab* software; and iii) social network analysis (SNA), using the open-source software *SocNetV* (*Social Network Visualizer*) for visual exploration of the networks.

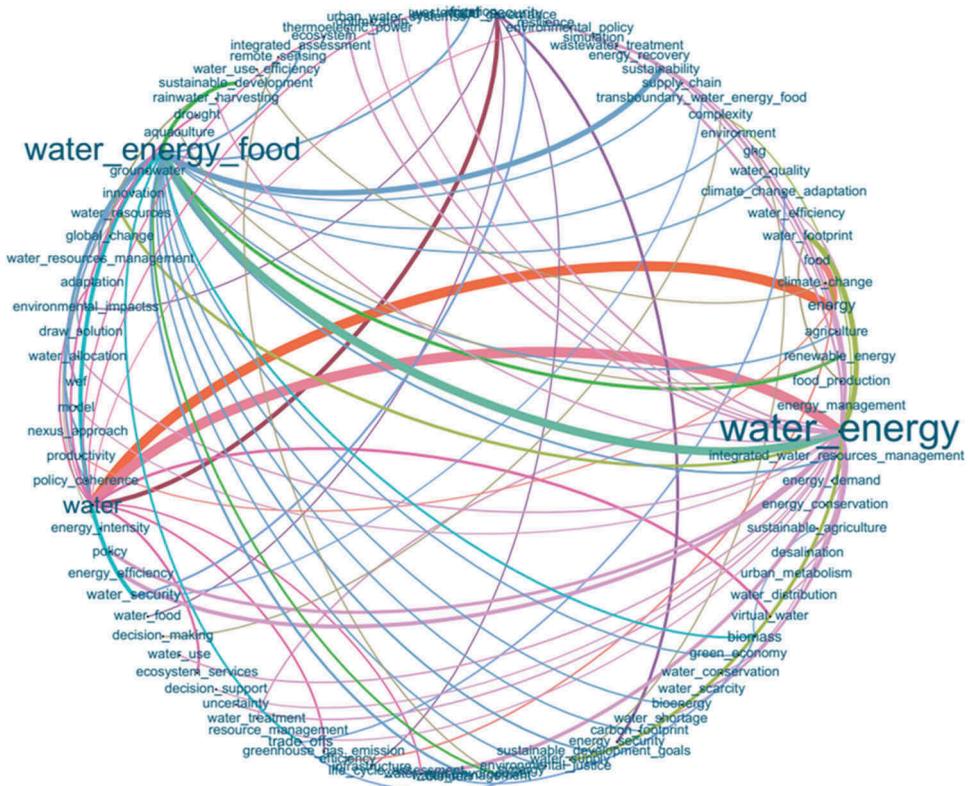
ENA enables a description of the relationship and role of the “ego” in its social network. The network is composed of one user centring the graph (the ego), all users linked to this ego (called “alters”), and all relations between the alters (Benites-Lazaro and Andrade 2019). One objective of using this method was to identify the most important themes linked to governance, in the context of the WEF nexus. Hence, a network measure enabled comparing of the centralities of the ego “governance,” in our sample. The result is a mini-network, or immediate neighbourhood surrounding an ego that can, perhaps, reveal something important about the theme or social world from the ego’s perspective (Benites-Lazaro and Andrade 2019). The different metrics of the *SocNetV* are: a) Degree Centrality (DC), which quantifies how many ties a node has compared to other nodes in the network, indicating a measure of actor activity; b) Closeness Centrality (CC), which focuses on how close each node is to all other nodes in the network, that is, nodes with high CC are those who can reach many other nodes in a few steps; and c) Betweenness Centrality (BC) shows that each actor can be interpreted as a measure of potential control as it quantifies just how much that actor acts as an intermediary to others. An actor which lies between many others is assumed to have a higher likelihood of being able to control information flow in the network (Kalamaras 2019).

## 4. Results

### 4.1. Social network analysis (SNA)

Figure 1 shows the SNA applied in the 1455 articles ( $N_1$ ) to identify the term “governance” within the research in the theme WEF nexus. “Governance” appear with 7 value of frequency. This value is not representative if compared with the topic “water-energy” that has 54 of frequency or topic such as “food security” with 18, and “climate change” with 16 of frequency. The frequency represents the count of the number of times the keyword appears by using the TF-IDF measure. This measure allows us to evaluate the weight of a term (lexical unit) within a document (context unit). Table 1 shows the values for Figure 1.

Figure 2 shows the ego network analysis (ENA) for the word “governance” applied to the  $N_f$ , highlighting topics with a high probability of predecessor connection such as “water” (0.08 or 8%) follow by the topic “nexus” with probability 5% of links, and topic

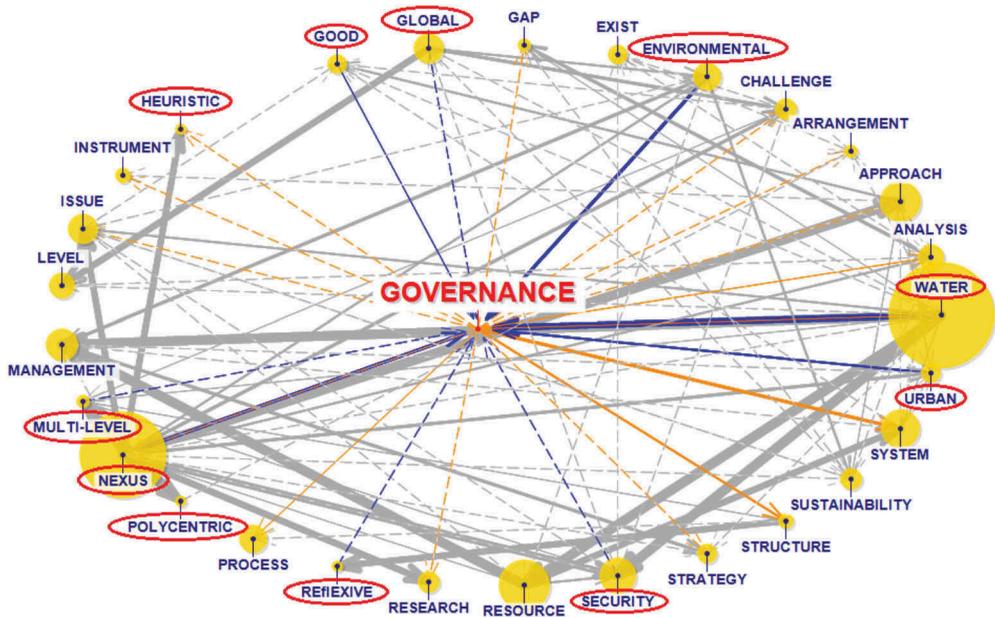


**Figure 1.** The network of subjects on water-energy-food nexus-related research.  
Source: The authors.

**Table 1.** Values referring to Figure 1.

Keywords	Freq	Keywords	Freq	Keywords	Freq
water_energy	54	sustainable_development	11	climate_change_adaptation	6
water_energy_food	46	virtual_water	10	integrated_water_resources_management	6
water	36	policy	10	water_scarcity	6
energy	32	wastewater_treatment	9	bioenergy	6
sustainability	22	hydropower	9	trade_offs	6
water_footprint	19	ecosystem_services	9	wef	6
food_security	18	energy_efficiency	9	water_resources_management	6
food	17	irrigation	8	environment	5
climate_change	16	water_supply	8	biomass	5
water_resources	13	water_management	8	integrated_assessment	5
renewable_energy	12	<b>governance</b>	7	sustainable_development_goals	5
desalination	11	energy_security	7	biofuel	5
life_cycle_assessment	11	drought	7	uncertainty	5
water_security	11	resilience	6	water_use	5

“environmental” and “urban” with (4%) and (3%) of probability respectively. Topics as successors of governance or those words that appear after the word governance are “system” (4%), “structure” (3%), and “process” (3%). Also, it was possible to identify some of the concepts that most relate to the word governance. They are: “water”, “nexus”,



**Figure 2.** Ego network for the word “governance”.

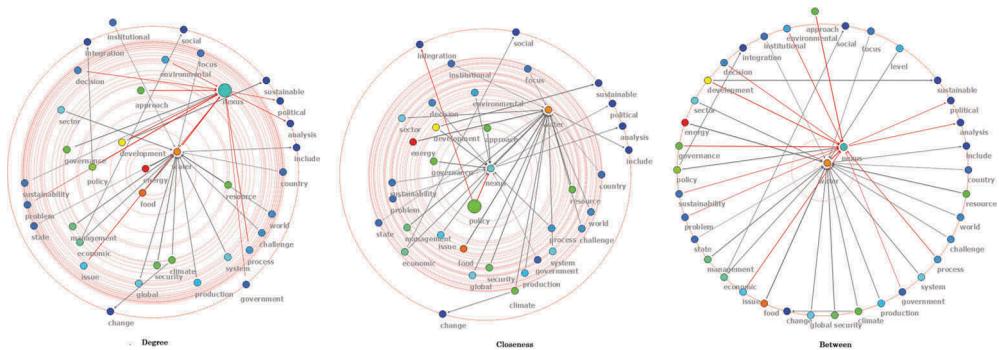
Source: The authors

**Table 2.** Values referring to Figure 2.

Prob	“Governance” predecessor	“Governance” successor	Prob
0.08	water	system	0.04
0.05	neuxs	structure	0.03
0.04	environmental	process	0.03
0.03	urban	water	0.02
0.02	good	analysis	0.02
0.02	security	approach	0.02
0.02	multi-level	gap	0.02
0.02	global	nexus	0.02
0.02	reflexive	research	0.02
0.01	level	arrangement	0.02
0.01	exist	strategy	0.01
0.01	management	challenge	0.01
0.01	policycentric	mechanism	0.01
0.01	resource	management	0.01
0.01	sustainability	policy	0.01
0.01	different	complex	0.01
0.01	integrate	understanding	0.01
0.01	policy	wef-nexus	0.01
0.01	system	global	0.01
0.01	adaptation	policy	0.01

“environmental”, “good”, “global”, “urban”, “polycentric”, “multi-level”, “reflexive”, and “security”. This analysis focuses only on the closest connections. Table 2 shows the values for Figure 2.

While Figure 2 focuses on the network from a single word, Figure 3 shows more diverse groups of words. Figure 3 shows the network analysis employing centrality and connections between themes in the N<sub>r</sub>. The three metrics (DC, CC and BC) indicate thirty-eight



**Figure 3.** Degree Centrality, Closeness Centrality and Betweenness Centrality applied to  $N_f$ . Source: The authors.

“actors” with some degree of centrality. The words “water” and “nexus” are prominent, i.e., those with the highest degree of connection. The word with the highest DC value is “energy,” indicating a large number of arches from it; the word with the highest CC value is “nexus;” and the word with the highest BC value is “water,” evidencing that it is the main intermediary among the other actors. From DC and CC it is possible to notice, besides those more frequent words like “nexus,” “water,” “energy,” “food,” “approach” and “governance,” the most prominent words are “policy integration” and “sustainable development.” In addition, the centrality of the words “climate change” and “economic” in DC, and “environmental,” “security” and “management” in CC are highlighted in the table below. Table 3 shows the values for Figure 3.

#### 4.2. Systematization and discourse analysis (DA) of the literature

The systematization was performed following the qualitative research from the elementary contexts provided by the *T-Lab* software, which allows identifying the context of predominant discourses on nexus governance and the categorization of different concepts that constitute the literature on nexus governance from the different scientific research. Table 4 summarizes the concepts used by the authors, the main focus of the articles, and correlation with nexus governance. This also helps to clarify the relationships resulting not only from DA but also from SNA.

### 5. Discussion

The mixed-methods used in this paper provided diverse possibilities to reflect on the associations found. SLR is an important tool when there is uncertainty about the evidence on a topic, with the main objective of clarifying some issue in a detailed and organized way (Petticrew and Roberts 2006). The SNA can provide analyses and visualizations of multiple relational measures, such as centrality, to support research hypotheses. In the case of WEF nexus, the SNA has the potential to make visible complex interactions, for example, between financing, technology and leadership in conditions of scale and limits previously defined, showing if the character of the decisions about water, energy and

**Table 3.** Values referring to Figure 3.

Node	Label	DC	CC	BC
1	country	1.136130	5.144472	0.000000
2	resource	5.053780	10.038323	0.000000
3	world	1.423530	5.892662	0.000000
4	challenge	1.529410	6.136923	0.000000
5	process	1.574790	10.585003	0.000000
6	system	2.361340	7.636276	0.000000
7	government	1.000000	8.007078	0.000000
8	production	1.937820	6.953677	0.000000
9	climate	4.057150	6.623620	0.000000
10	security	3.813450	9.211764	0.000000
11	global	2.436970	7.744224	0.000000
12	change	0.000000	0.000000	0.000000
13	food	8.910920	11.399594	0.000000
14	issue	2.119330	12.364489	0.000000
15	economic	3.225210	5.970632	0.000000
16	management	3.541180	8.980117	0.000000
17	state	1.090760	5.013329	0.000000
18	problem	1.151260	8.776500	0.000000
19	sustainability	1.226890	9.134206	0.000000
20	policy	6.174790	13.129889	0.000000
21	governance	4.115970	16.180571	0.000000
22	energy	10.000000	11.624536	0.000000
23	sector	2.527730	7.868926	0.000000
24	development	7.475630	13.542240	0.000000
25	decision	1.393280	9.865136	0.000000
26	integration	0.000000	0.000000	0.000000
27	institutional	1.151260	5.187346	0.000000
28	environmental	1.695800	11.025700	0.000000
29	approach	5.189920	17.357212	0.000000
30	social	0.000000	0.000000	0.000000
31	focus	1.287390	5.554934	0.000000
32	level	1.831930	5.013021	0.000000
33	water	8.610090	13.862694	68.000000
34	nexus	2.680670	24.063813	58.000000
35	sustainable	0.000000	0.000000	0.000000
36	political	0.000000	0.000000	0.000000
37	analysis	0.000000	0.000000	0.000000
38	include	0.000000	0.000000	0.000000

Note: DC range:  $0 \leq DC \leq \infty$  (node energy); BC range:  $0 \leq BC \leq 1260$  (node water); CC range:  $0 \leq CC \leq 0.0277778$  (node nexus).

food are coordinated or siloed (Kurian et al. 2018). In this paper, the SNA was used not for physical actors, but for protagonist words within the text corpus of the twenty-eight selected articles. DA is an important complement to understanding interactions, seeking to identify the relationship between linguistic regularities such as meanings, purpose and negotiations through discourse (Suciu 2019).

The first network analysis (Figure 1) showed that “governance” is not central in all articles collected primarily. This result illustrates that the concept of governance within WEF nexus research is underdeveloped. Figure 1 shows the predominance in researches of two sectors “water-energy” or “energy-water” and “water-food.” Due to the water-centred nature and trend in many studies, some researchers have criticized that the current analyses of the link are insufficiently intersectoral, or even a new challenge to be consolidated towards integration (Benson et al. 2015). The focus on water alone undermines the original intention of developing an explicit intersectoral perspective and response options to replace the traditional sectors (Smajgl et al. 2016). In addition,



**Table 4.** Concepts, focus and correlation with nexus governance.

CONCEPT	AUTHORS	FOCUS	CORRELATION WITH NEXUS GOVERNANCE
WATER GOVERNANCE (WG)	Gupta et al. 2013	Literature review on the state-of-the-art of water governance science	It does not go deeper into the concept; it only recognizes that single-sector water governance is not sufficient to regulate land, agriculture, and other issues. It needs to be a cross-sector process.
TRANSBOUNDARY BASIN GOVERNANCE (TBG)	Al-Said and Hefny, 2018	Analysis of regional cooperation in the Eastern Nile Basin	The WEF Nexus approach can be useful for highlighting key neglected issues on interlinked resources, at the basin and regional levels.
INTEGRATED WATER RESOURCE MANAGEMENT (IWRM)	Hagemann and Kirschke 2017 Benson et al. 2015	How to strengthen nexus governance analysis from IWRM experiences Relation between IWRM and nexus	The importance of existing and useful governance strategies as conditions for governance transitions. Governance analysis should refer to different types of problems, contexts, and inter- and transdisciplinary research. Both IWRM and nexus provide guidance on optical governance. Nexus aim at policy coherence and multi-level interaction, but the concept provides few normative principles on how governance should occur.
SOCIO-ECOLOGICAL SYSTEM (SES)	Giampietro 2018 Al-Said & Elagib, 2017 Villamayor-Tomas et al. 2015	Perception and representation of the nexus at the interface between society and the natural environment Literature review on WEF nexus Value-chain and institutional analysis of four irrigation-related cases studies	The concept of SES lends itself, particularly well, to the purpose of the abandonment of the current technocratic and top-down approach. Nexus governance is the missing link in the nexus debate. It holds the promise of needed innovations and reconstructing policy and institutions to tackle issues of resource use and security.
ECOSYSTEM SERVICES (ES)	Pahl-Wostl et al., 2017	Analytical framework, using a network and ecosystem services to identify coordination failures and persistent sustainability problems, as well as leverage points for transformative change	The conceptual bridge between value chains and institutional analysis would seem well-suited to the challenge of understanding nexus research, given the importance of resource flows and governance dynamics in these coupled systems. The concept of Ecosystem Services (ES) may help to (a) operationalize the WEF nexus in terms of trade-offs and synergies, (b) develop a common language to negotiate risks, framed according to different logics in different security concepts (c) support the integration of fragmented institutional settings, and (d) encourage negotiation and cooperation among ES users. Thus, if combined with appropriate multi-level governance settings, the ES concept may become instrumental in supporting transformative change, overcoming sustainability deficits in the WEF nexus.

(Continued)

**Table 4.** (Continued).

CONCEPT	AUTHORS	FOCUS	CORRELATION WITH NEXUS GOVERNANCE
INTEGRATIVE ENVIRONMENTAL GOVERNANCE (IEG)	Weitz et al., 2017b Visseren-Hamakers 2015	Literature review on the IEG literature	The IEG literature offers analytical insights that could help close gaps in the nexus literature, in relation to the conditions for cross-sector coordination and collaboration, dynamics beyond cross-sector interactions, and political and cognitive factors, such as determinants of change. Since 2010, the IEG literature has turned to the WEF nexus debate. These studies have focused on governance systems, at all levels, prioritizing policies and sectors. Introducing the concept of EJ into the nexus, especially where narratives, trade-offs, and outcomes are contested, could make better use of how the nexus is framed, understood, and acted upon. Proposition for the new High-level Political Forum and Global Sustainable Development Report to adopt a nexus perspective. It also emphasizes the importance of designing partnerships that are focused on cross-national nexuses in sustainable development.
ENVIRONMENTAL JUSTICE (EJ)	Middleton et al. 2015	Mapping of the rise of the WEF nexus as a research, policy, and project agenda, in mainland Southeast Asia.	
GLOBAL GOVERNANCE (GG)	Boas et al. 2016	It contributes to the institutionalization of a “nexus approach,” in the global institutional setting of the Sustainable Development Goals.	
GLOBAL FINANCIAL NETWORKS (GFN)	Schimdt & Matthews, 2018	The role of global financial networks in articulating the nexus and connecting it to sustainability programmes	The shift from ‘state to system’ of the nexus structures draws on the repertoire of financial techniques that delineate facts of the world descriptions of complex, adaptive systems – and makes accounts of the integrated dynamics linking economies, environments, and societies. Rethink the role of an actor with a new quantitative Economic Platform working in a new knowledge-based management system, by employing trade-offs, synergies, acts of influence, intermediation and governance which are suitable to the new state of world governance and its main players. Risk management can contribute to more effective governance. It also emphasizes the failure of national and regional, or global governance, as geopolitical risk to water, energy, and food. The article proposes three points for sustainable development: externalities and shared risks across multiple scales; innovative government mechanisms for shared risks; and negotiating the balance between silos, politics, and power in addressing shared risks.
WORLD GOVERNANCE (WG)	Zisopoulo et al., 2018	It establishes the existence of the WEF Nexus approach, in a more concrete way, and includes proposals for holistic and increased internal structure and for a set of rules, recasting the current role into that of an actor with a Computable General Equilibrium platform. Understanding how the global risks impact the nexus between water, energy, and food through a systemic analysis	
GOVERNANCE OF GLOBAL RISKS (GGR)	Amorim et al. 2018		
INNOVATIVE GOVERNANCE OF SHARED RISKS (IGSR)	Gallagher et al. 2016	The policy and research agenda on the WEF nexus needs to consider dimensions of shared risks	

(Continued)



Table 4. (Continued).

CONCEPT	AUTHORS	FOCUS	CORRELATION WITH NEXUS GOVERNANCE
GOVERNANCE OF NEXUS SECURITY (GNS)	Beck and Walker 2013	Insights from cross-system mapping to assess the role of city governance in achieving nexus security (or not) and the role of technological innovations in serving the same purpose	High quality governance entails granting access to the debate, for instance, how to manage the man-environment relationship – by each of the three actively engaged parties: individualists (I), hierarchists (H), or egalitarians (E). Each of the three will have a voice in the debate. It is important to take the nexus out of the global resources management debate and resituate it in broader political debates about government transformations in urban measures. Additionally, recognize the nexus as more of a driver policy change than a threat.
URBAN GOVERNANCE (UG)	Artioli et al. 2017	'Urbanize' the nexus agenda and consider the implications of policy integration for urban governance	The application of Ostrom's CG principles to city carbon and water budgets. Encouraging systems approaches at the nexus sectors may improve the management of successful "budget-based" approaches across sectors. It also suggests improvements in governance process to carbon and water budgets, such as the development of appropriate incentive, enforcement, and flexible mechanisms, among others.
COOPERATIVE GOVERNANCE (CG)	Sperling & Raswami, 2017	Review of city case studies to inform a framework, for developing urban infrastructure design standards and policy instruments, in order to achieve energy efficiency and greenhouse gas mitigation through city carbon budgets and water use efficiency	Contextualized solutions to challenges of WEF nexus security should be considered. Beyond that, develop an understanding of the roles, and linkages, between policies and institutions at various political and administrative levels. It requires the involvement of all stakeholders, and their collective impacts, on the short- and long-run outcomes.
GOOD GOVERNANCE (GG)	Lele et al. 2013	It uses examples from recent global developments (and from China and India) to place empirical analysis of governance issues at the top of global agenda	PI is essential for implementing the WEF nexus approach. In this way, inter-ministerial collaboration is required among the Ministry of Water Resources, Ministry of Power, Energy and Mineral Resources, Ministry of Food, Ministry of Environment and Forest, and other relevant ministries and government bodies. Also, collaborative problem-solving processes are required through participation of the different level stakeholders.
POLICY INTEGRATION (PI)	Gain et al. 2015	Review of the emerging literature on the water-energy-food (WEF) nexus and, then, analyzes the nexus in the context of Bangladesh	The implementation of the nexus requires an "inter-governance" unit that operates to bridge the gaps between different ministries, while understanding and implementing the cross-cutting and integrative nature of the nexus.
INTER-GOVERNANCE (IG)	Mohtar 2016	It examines the governance of the nexus, understanding capacity building and models or tools available to support decision makers.	

(Continued)

**Table 4. (Continued).**

CONCEPT	AUTHORS	FOCUS	CORRELATION WITH NEXUS GOVERNANCE
ORGANIZATIONAL GOVERNANCE (OG)	Harwood 2018	It presents an approach that addresses the complexity that characterizes the WEF nexus in the context of the Mekong River Basin.	The approach of the Viable System Model presents a powerful means to address the complexity of the WEF nexus and, as such, should be used in an appropriate "mess" to demonstrate the reality of its potential. Organizational governance issues are effectively modelled using the VSM, revealing the multi-level perspective and drawing attention to the relevant governance mechanisms.
GOVERNANCE OF SOCIO-TECHNO-ECONOMIC-POLITICAL (STEP) NEXUS SOLUTION	Daher et al. 2018	It presents a framework for resource and stakeholder interactions and trade-offs, addressing governance and financing schemes for carrying forward the implementation of those scenarios	The STEP framework offers guidance through the different elements that need to be accounted for while assessing and promoting a nexus solution. Proposing feasible, implementable, sustainable solutions requires truly inclusive transdisciplinary conceptualization, quantification, and assessment of current and projected resource hotspots.
KNOWLEDGE CO-PRODUCTION (KCP)	Howarth and Monasterolo 2016	Decision-making in response to shocks to the WEF nexus and barriers to the application of a transdisciplinary approach	Transdisciplinary approaches to knowledge production, such as participatory workshops, helps overcome gaps in the research-policy interface. Also, it is important to understand characteristics of the nexus to build resilience to shocks, thus, tackling risk.
REFLEXIVE GOVERNANCE (RG)	Halbe et al. 2015	Methodological framework to analyse sustainability innovations in the water-energy-food nexus and strategies for governing transition processes in Cyprus	The reflexive governance approach can induce a sustainability transition, and learning processes have to take place, simultaneously, at different levels. Participatory model-building, using the causal loops diagram (CLD), turned out to be a suitable method to systematically analyse stakeholder perceptions on issues in the WEF nexus.
GOVERNANCE HEURISTIC (GH)	Müller et al. 2015	This review article argues for systematic nexus thinking, based on the intrinsically linked systems of soil, water, and biodiversity.	The nexus thinking and landscape lens, in combination with virtual resource cycles, offers an opportunity to address trade-offs and utilize existing synergies to develop pathways towards integrated resource governance. It may serve as a GH to implement the post-2015 Development Agenda in a variety of national contexts. Hence, nexus thinking may serve as a GH for nation states to understand and, subsequently, operationalize the implementation of the post-2015 Development Agenda.
TRANSDISCIPLINARY APPROACHES (TA)	Kurian 2017	It focuses on implications of the nexus approach for public policy formulation, implementation, and monitoring, and emphasizing the importance of transdisciplinary approaches.	An institutional framework that accounts for the role of the government in shaping individual behaviour, with regard to management and use of environmental resources, needs to be delineated. It highlights the need to look at ecosystem and public services. Transdisciplinary approaches have the potential to better shape the translation of scientific results to respond to global challenges.

Source: The authors based on literature review.

isolated sector investments risk prioritizing the goals of one specific sector over others. Integrated analytical approaches that understand the complexity of WEF nexus can identify intersectoral trade-offs and internalize driving forces that might otherwise be overlooked in dual-sector approaches (Miralles-Wilhelm 2016).

From both Figure 2 and the DA, it was also possible to identify the “water centrism” as the literature on the nexus suggests (Allan et al. 2013; Schimdt and Matthews, 2018). Even though the concept of water governance is not the main concept in most articles, the vast majority recognize this centrality. Those using more focused concepts are Gupta et al. (2013) (water governance), Al-Said & Hefny, (2018) (Transboundary Basin Governance – TBG) and Hagemann and Kirschke (2017) and Benson et al. (2015) (Integrated Water Resources Management – IWRM). According to Gupta et al. (2013), the global water crisis cannot be solved through technocratic and depoliticized management or engineering processes; it needs a radical political challenge, from a global to the local level (glocal). Since TBG has historically been focused on state and water-related issues, the nexus approach extends the scope to important sectors such as agriculture and energy (Al-Saidi and Hefny 2018).

This crucial connection between governance and water is precisely related to a legacy of the Integrated Water Resources Management (IWRM) approach. This concept encompasses many principles with a holistic and systemic view, and while it seems closely related to the nexus concept, it differs in certain aspects (Benson et al. 2015). Two points bridge this relation. First, IWRM was an attempt to create governance reform and integrate water with other policy objectives (Pahl-Wostl et al. 2011; Pahl-Wostl 2017). Second, IWRM researchers and practitioners have generated important lessons that can help analyse and implement nexus governance (Hagemann and Kirschke 2017). Regarding the differences, the one that interests us most is related to governance approaches. Benson et al. (2012), (2015) show that nexus conceptualizations provide few normative principles on how governance should occur, while IWRM is often based on “good governance” principles, fostering transparency, and collaborative decision-making.

The World Bank introduced “good governance” in the 1990 s as part of a controversial neoliberal agenda concerning the public sector, but it also brought important incentives to the ideas of representative and responsible government and absence of corruption (Bevir 2013). However, this term may represent other different ideas, such as an objective solution of policy problems through decision-making, political dimensions of the extension to which decision-making processes are open and democratic, political assessment of the success of decisions, among others (Bevir 2011).

Although more frequent in IWRM, the discussion on good governance has also recurred in selected papers. In the work of Lele et al. (2013), good governance assumes the merits concerning the enhancement of a personal and collective security sense within a community and its representativeness. Gupta et al. (2013) reinforce that even the fact that good governance has the potential to achieve multi-level coherence, there is tensions and trade-offs between effectiveness, participation and legitimacy. Pahl-Wostl et al., (2017) show the importance of engagement in supporting the design and the implementation of polycentric arrangements and the possibility of enabling good governance principles such as multi-level and coordinated systems of governance.

Also from Figure 2, the word “system” appeared as strictly related to “governance.” It is not new to think that the nexus is an interconnected system between WEF. However, it can be deduced that if there is a unit in this literature, it can be tangible from the idea of a

“system.” It is also not novel to think about the world in a systemic and integrated way, even considering socio-political dimensions. For example, the Harappan civilization, which existed from 3300 to 1300 BC in the Indus Valley, proposed an “Ecological Consciousness.” Other examples include “The discourse of the culture of nature” by the Assyrian king Assurbanipal in Mesopotamia (2700 BC) and “The Rig Veda” holistic approach by peoples from north-west India from 1500 to 1000 BC (Lal 2016). In the last century, we find exponents such as the controversial General Systems Theory by Ludwig von Bertalanffy, who sought to approach holistically from a biological perspective alternatives to the methodological reductionism imposed by the Industrial Revolution (Hammond 2003). In contemporary times, an example is a great effort made through Earth System Governance and the Sustainable Development Goals to face climate change in an integrated way. Perhaps the great contribution of the WEF nexus is to bring to the debate different sectors of society, which are often on opposite sides of the debate, in an attempt to incorporate systems thinking into the policy-making process (Bazilian et al. 2011).

What is important here is that the idea of “systems thinking” defines some fundamental concepts in the nexus analyses. For instance, “water-energy-food system,” “resource system,” “ecosystem service,” “socio-ecological system,” “management system,” “urban infrastructure system” and “viable system models.” According to Pahl-Wostl (2017), nexus governance encompasses a broad understanding of governance in terms of political, social, economic, and administrative systems that determine the use of WEF and related service delivery. Harwood (2018) argued that a systems approach faces many challenges such as asking what should be recognized within the system in terms of its boundaries. It is, therefore, necessary to rethink conceptual boundaries to better fit this integration as a natural system to improve the decision-making process (Weitz et al. 2017b). The WEF nexus approach requires new models of analysis based on complex systems thinking (Giampietro 2018) as well as facilitates the shift of techniques from state to system (Schmidt and Matthews 2018). This shift takes place, for example, in the repertoire of financial techniques that consider the integrated dynamics linking economies, environments, and societies.

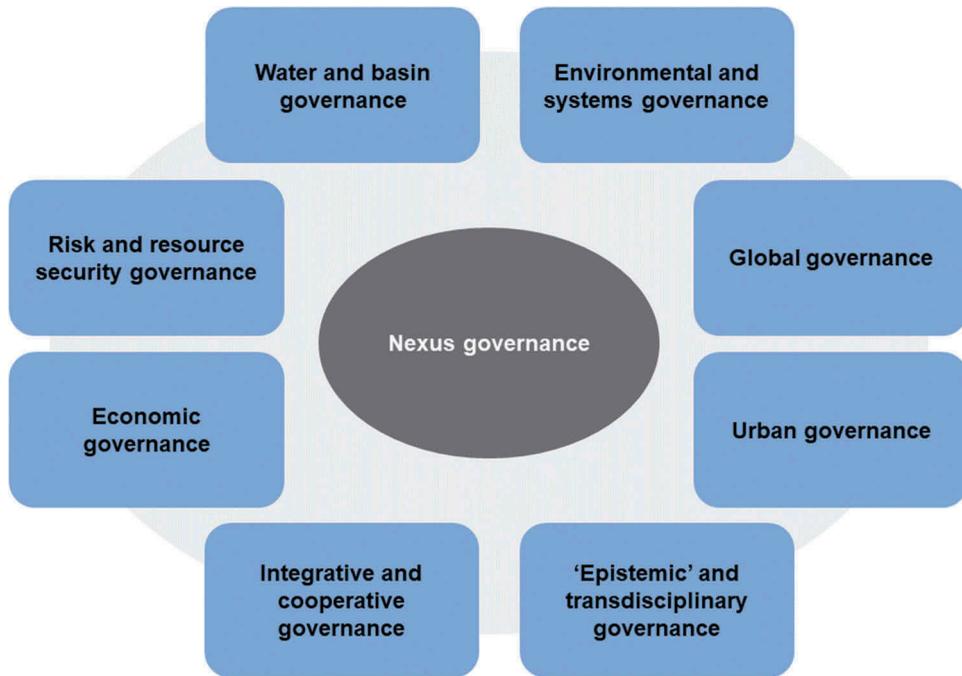
Figure 3 shows that in addition to the prominence of “water” and “nexus,” it is possible to identify the centrality of the terms “policy integration” and “sustainable development.” Environmental policy integration has been a widely debated concept since the publication of the Brundtland report, in 1987 (Boas et al. 2016; Weitz et al. 2017b). According to Gain et al. (2015), policy integration is essential for implementing the WEF nexus approach. This has been addressed in this literature mainly from the need to expand the levels of governance towards sustainable development. The term “multi-level” becomes important in this context, as shown in Figure 2. Harwood et al. (2018) clarify that governance should be viewed as multi-tiered, nested, and at multiple levels. In other words, cross-scale governance arrangements should be tied to nexus systems integration (Sperling and Raswami, 2017). In contrast, as Artioli et al. (2017) said, policy integration should not be considered to be inherently beneficial; it needs to consider the power relations that shape policy change. That is, it is crucial to understand the negotiation process of possible policy integrations, considering whether, and how, cross-sectoral policies can contribute to universal, equitable, and sustainable access to resources. Sustainable development is one of the debates present in the WEF nexus approach because the concept is closely related with the ecological modernization debate (Wiegleb and Bruns 2018). Nevertheless, the Sustainable Development Goals (SDGs) are

important bases for the nexus debate (Boas et al. 2016; Pahl-Wostl 2017; Amorim et al. 2018; Schmidt and Matthews 2018; Daher et al. 2018).

The nexus literature often relates climate change as an element of the nexus as important as water, energy and food (Benson et al. 2015). Global climate change trends and competitive land-use patterns have dispelled the systemic ability to compensate for increased demand in an integrated manner that is both reliable and orderly (Zisopoulou et al. 2018). It can be said that the dimension of security and risk is closely associated with climate change (Amorim et al. 2018). Gallagher et al. (2016) remarked that risks could be better addressed if policy-makers increased the use of flexible governance mechanisms at multiple scales through the decentralization of authority. In this case, polycentric governance, which gained impetus in the 1960 s, and integrative environmental governance can be appropriate concepts to provide it (Visseren-Hamakers 2015). Weitz et al. (2017b) argued that nexus governance is to some extent a question of environmental governance.

Figure 3 also illustrates the importance of socio-economic perspectives. As Zisopoulou et al. (2018) indicate, socio-economic factors are associated with the structure of the particular economy and actors profile which leads to policy determination. Weitz et al. (2017b) argued that in nexus governance, a technical and administrative matter prevails, which often focuses on optimizing system performance. This is why the WEF nexus is commonly understood from a financial perspective. In general, financialization describes patterns of accumulation that accrue profit. However, Schmidt and Matthews (2018) believe that it is not a defence of capitalism, but a harbinger of how this shift from “state to system” draws based on financial techniques that delineate facts of the world. The possibilities of implementing the nexus are directly associated with saving resources, in other words, financial savings (Mohtar 2016). This is a relevant feature of the WEF nexus because it brings to the debate important economic actors in the global scenario such as the World Bank and World Economic Forum. Notwithstanding, most authors understand that economic development should be associated with social development, especially of marginalized groups with restricted access to resources (Middleton et al. 2015). “Solutions for such complex, interconnected, and uncertain problems cannot be only technical; they cannot account only for physical resource constraints, or offer only socio-economic, technological, political, or financial interventions.” (Daher et al. 2018, p. 08).

Based on the different methods, it is concluded that eight themes are central to this literature: i) water centrism; ii) systems; iii) policy integration; iv) sustainable development v) environmental governance; vi) social-economics and management; vii) resource security; and viii) climate change. Finally, as shown in Table 4, twenty-four concepts correlated with nexus governance were identified in the papers analysed. They use different approaches to look at the same issue, which is the governance of water, energy and food together. In another synthesis effort, it can be said that the concepts related to governance are grouped into: *water and basin governance*; *environmental and systems governance*; *risk and resource security governance*; *economic governance*; *global governance*; *urban governance*; *integrative and cooperative governance*; and “*epistemic*” and *transdisciplinary governance*. Figure 4 illustrates these groups.



**Figure 4.** Thematic groups of concepts related to nexus governance.

Source: The authors.

## 6. Research gaps in this literature

Three gaps were noted in this review. The first of these is the lack of theoretical approaches that define the concept of nexus governance more densely. According to [Figure 1](#), few of the 1455 papers initially found develop the governance theme within the nexus literature. Most of those who develop merely recommended the necessity of nexus governance, and did not clarify how this should be implemented. In other words, governance has often appeared as a "recommendation". Only twenty-eight articles focused more closely on the topic. The most common strategy was to associate more established concepts of governance theory with the nexus debate. Nevertheless, twenty-four concepts were found as central. On the one hand, this represents how nexus studies have diversified over recent years. This is convenient, as nexus-related methods may acknowledge ambiguities, complexities, uncertainties, and ignorance to alleviate pressure on appraisal ([Stirling 2015](#)). On the other, it is an opportunity for future theoretical studies on nexus governance to strengthen the concept.

The second gap is related to participatory approaches and methods. [Al-Said and Elagib \(2017\)](#) point out the unclear dimension in the nexus literature regarding the participatory measures needed to achieve policy integration. [Gain et al. \(2015\)](#) propose that ministries should formulate policies in dialogue with stakeholders, experts, professionals, non-governmental organizations (NGOs), and the private sector through participatory approaches. [Howarth and Monasterolo \(2016\)](#) applied a participatory and bottom-up interdisciplinary approach, collecting and analysing data from workshops in the UK with stakeholders in the field of business and finance, knowledge production, and policy-

making, identifying barriers to the nexus. Halbe et al. (2015) indicate participatory model building using Causal Loop Diagrams (CLDs) as a suitable method for analysing stakeholder perceptions on issues in the WEF nexus and related sustainability innovations. In this way, participatory approaches are promoted as a means to address integrated management problems and support the development of a systemic understanding among sectors and actors to search for innovative ways to cooperate and collaborate. The above examples show that these methods are being applied by some authors, however, in general, the science produced towards the WEF nexus is still little open to different knowledge, such as traditional knowledge.

The third gap follows this argument; it is the lack of critical approaches to the nexus debate itself. Similarly to Williams et al. (2019, p. 663), who questioned “[...] what is the political performativity of nexus thinking?,” pointing out that there is little visibility for *nexus politics* and therefore a need for a more progressive concept of integration. In this review, it can be noted that some authors mention the power relations that exist in governance processes, but few of them discuss beyond the institutions and political actors, showing the very power of science being produced in this direction. Hagemann and Kirschke (2017) believe that to address nexus issues in governance, it is necessary to improve inter and transdisciplinary collaboration. Otherwise, one can note barriers due to the lack of involvement of the relevant social science disciplines such as political science, economics, and law in governance analyses. In addition, according to the authors, researchers do not use the results from different disciplines in their work. Transdisciplinary approaches are necessary to implement nexus governance since it encompasses decision-making through horizontal relations, that is, bottom-up approaches, rather than vertical top-down ones (Stirling 2015; Kurian and Ardakanian 2015; Howarth and Monasterolo 2016; Artioli, 2017).

## 7. Final remarks

The innovative character of this research is to approach the governance of the nexus from different and complementary methodologies – SLR, SNA, and DA. In agreement with Stirling (2015), there are no ideal methods for nexus-related challenges, but a requirement for methodological pluralism. This choice helped in addressing the initial questions, as it brought to the nexus governance debate a more in-depth look at articles related to this topic.

Based on the first question (what governance concepts constitute nexus literature?), we have found twenty-four different concepts related to governance, elucidating a diversity of approaches. They were placed in Table 4 from approximations taken from the qualitative methodology. These concepts were mobilized to add to the governance of the nexus and to provide a base for reconsideration, in the future. The main themes of this literature can be categorized into eight groups: i) water centrism; ii) systems; iii) policy integration; iv) sustainable development v) environmental governance; vi) social-economics and management; vii) resource security; and viii) climate change. Similarly, as shown in Figure 4, the related concepts were also grouped into eight: water and basin governance; environmental and systems governance; risk and resource security governance; economic governance; global governance; urban governance; integrative and cooperative governance; and “epistemic” and transdisciplinary governance. And we also found three gaps in this literature: 1) a lack of theoretical approaches that define the

concept of nexus governance more densely, 2) the necessity to enhance focus on participatory approaches, and 3) a lack of critical analysis of the WEF nexus perspective.

This paper ends with three final suggestions. First, it must be assumed that the concept of nexus governance cannot be universally applicable. This means that each context of analysis will have its own governance arrangements for water, energy and food. Second, it is necessary to recognize the diverse conceptual basis on which the concept has been approached. Exactly for this reason, it is a very open concept, based on different points of view and friendly to transdisciplinary approaches. Third, in our opinion, the WEF nexus approach is important in mitigating inequities, and thus, nexus governance must have strong inclusive characteristics to advocate the participation of several stakeholders including the most disadvantaged in the nexus. Here, participatory approaches can enhance the trans-disciplinary perspective for the nexus, and research or evaluation should incorporate those often left outside formal processes of policy research (Stirling 2015). Sometimes, more participation means more complexity; however, this complexity seems necessary in facing contemporary environmental problems. Some questions may be asked for future studies: Under what circumstances can we have more inclusive governance processes? What are the possibilities for marginalized actors in decision-making processes to decide which integrations matter? How can these actors become not only consumers but also agents of change?

Understanding the diversity of approaches and methods analysed here can be an important lesson not only for the nexus debate but also for governance processes. Notwithstanding, given that the literature on nexus governance is focused on the issue of water, it is important to consider the need for more horizontal analysis on resources. This horizontality may also be important in understanding that no scale is more important than the other. The trans-scalar nature of the nexus is an essential characteristic in understanding that no scale becomes sufficient, putting different angles in perspective, and viable interactions will always be the object of political decisions. Particularly in relation to the concept of nexus governance, it should be noted that the debate has reshaped other concepts related to governance within the debate on water, energy and food. But there is still a long way to go to make this concept more robust. There is a need for articles that theoretically contribute to the concept of nexus governance in a more critical way. These may be alternatives to ensure that the concept does not remain restricted to scientific debate, but influences decision-making processes around the planet.

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