Environmental Science and Policy 79 (2018) 54–65

Contents lists available at ScienceDirect

Environmental Science and Policy

journal homepage: www.elsevier.com/locate/envsci

Governance, polycentricity and the global nitrogen and phosphorus cycles

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ARTICLE INFO

Keywords:
Nitrogen
Phosphorus
Biogeochemical cycles
Nutrient flows
Anthropogenic change
Environmental law
Polycentricity
Earth system
Governance

ABSTRACT

Global change and governance scholars frequently highlight polycentricity as a feature of resilient governance, but both theoretical and empirical knowledge about features and outcomes of the concept are lacking at the global scale. Here we investigate the structural properties of governance of global nitrogen (N) and phosphorus (P) cycles, two processes in the 'planetary boundaries' framework. We have used a mixed-methods approach to institutional analysis, integrating polycentric theory with social network theory in environmental policy and legal studies. We include an actor collaboration case study, the Global Partnership on Nutrient Management (GPNM), to explore governance challenges associated with global N and P cycles. We set the scope for selection of relevant legal instruments using an overview of global N and P flows between Earth system 'components' (land, water, atmosphere, oceans, biosphere) and the major anthropogenic N and P perturbations. Our network analysis of citations of global N and P governance exposes the structural patterns of a loose network among the principal institutions and actors, in which legal instruments of the European Union serve as key cross-scale and cross-sectoral 'gateways'. We show that the current international regimes in place for regulating N- and P-related issues represent a gap in governance at the global level. In addition, we are able to show that the emergence of GPNM provides synergies in this context of insufficient governance. The GPNM can be viewed as a structure of polycentric governance as it involves deliberate attempts for mutual adjustments and self-organised action.

1. Introduction: polycentric governance as a strategy for global change problems

The international community has been struggling to identify an effective governance model for systemic perturbations of global biophysical systems. The global cycles of nitrogen (N) and phosphorus (P), two nutrient elements essential for sustaining life, are becoming issues of concern in light of scientific understanding of anthropogenic changes (Table 1), but only a few studies have focused on the governance challenge of nutrient elements (e.g., Galloway et al., 2008; Sutton et al., 2011; de Vries et al., 2013; Ebbesson, 2014; Scholz et al., 2014; Schroeder, 2014; Iwaniec et al., 2016). These studies call for stronger governance of these nutrient element flows at the international level. However, 'top-down' natural resource management institutions are often not well suited for local social and ecological realities, while 'bottom up' institutions may be blind to the complex social-ecological interactions that characterize large-scale environmental systems (Ostrom, 2007). Polycentric governance, which involves *'many centres of decision making that are formally independent of each other'* (Ostrom et al., 1961, p. 831), is often mentioned as a possible alternative (e.g. Andonova et al., 2009; Ostrom, 2010; Galaz et al., 2012a,b). Among the proposed benefits of such governance arrangements (Ostrom, 2010; Toonen 2010) are their ability to entrain local knowledge; support learning, adaptation and innovation through trial-and-error experimentation processes; and address problems of trust and cooperation among actors as larger units get involved.

However, there is a dearth of empirical evidence about features and outcomes of polycentric governance (Aligica and Tarko, 2011). In particular, the way that governance systems shift from one phase of polycentricity to another is poorly understood (Galaz et al., 2012b). Biermann (2007) highlighted the need to study the 'architecture' of global governance systems, that is, the overarching system of institutions at the macro-level (Biermann et al., 2009a,b). Kim (2013) sought to better understand the emergent network structure and the polycentric order of the multilateral environmental agreement (MEA) system, using a network-based approach (see Newman, 2010). This reduced a system of MEAs to an abstract structure, uncovering the underlying system architecture that captured connection patterns between its components. Kim and Mackey (2014) elaborate further around the understanding of international environmental law as a complex adaptive system. International environmental law tends to be more reflexive to change than hard law, making it a desirable

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http://dx.doi.org/10.1016/j.envsci.2017.10.005
Received 21 July 2017; Received in revised form 6 October 2017; Accepted 7 October 2017
1462-9011/

Table 1
Indicative timeline of scientific information underpinning the nutrient elements governance challenge.

Year	Initiative	Focus area	Key references
1970s	Biogeochemical flows prioritised by the international Scientific Committee on Problems of the Environment (SCOPE)	N and P	Delwiche (1970), Pierrou (1976), Söderlund and Svensson (1976)
	Global budgets of N and P flows compiled		
1980s	European Monitoring and Evaluation Programme established for long-range transport of air pollutants	N	Tørseth et al. (2012)
1990s	Global network of biogeochemical flux time series studies established	N and P	Karl et al. (2003)
2000s	International Nitrogen Initiative established (jointly sponsored by SCOPE and the International Geosphere-Biosphere Programme)	N	Galloway et al. (2008), Sutton et al. (2013)
	Global Program for Nutrient Management established as multistakeholder platform	N and P	
2010 to present	European Nitrogen Assessment published (Second Assessment currently underway)	N	
	Proposals for setting boundaries for planetary/systemic perturbation	N	de Vries et al. (2013), Steffen et al. (2015), Kahiluoto et al. (2014)
	Emerging attention to global policy regimes for nutrient elements	N and P	Ebbesson (2014)
	Science community develops outlines for globally sustainable phosphorus management:	P	Scholz et al. (2014)
	International Nutrient Management System founded	N and P	Sutton/INMS (2015)

instrument for adaptive governance of the Earth system (Kim, 2016).

Despite the development of such useful theoretical approaches to study polycentric governance at the international level, we have little empirical knowledge about how institutions and actors interact. Borrás and Radaelli (2011), highlight the importance of both ideational and organisational dimensions of governance architectures for dealing with complex problems. It has been suggested that interactions appear through key individuals and organisations, in attempts to overcome institutional fragmentation and actor complexity (see proposition 2 in Galaz et al., 2012b). Yet it remains unclear whether and how partnerships between different actors and interconnected networks enhance the 'fit' between environmental governance and social–ecological dynamics at planetary scales (Young, 2002; Galaz et al., 2008, 2012a). These gaps pose constraints to the application of polycentric governance theory.

In this study, we investigate the governance structures associated with the global cycles of N and P, to explore degrees of polycentric governance (Galaz et al., 2012b), in terms of connectivity and cross-scale interaction. As an emerging issue at the global level, N and P governance is an interesting case to study: it is a clear example of where the application of theories about polycentric governance should be fruitful, giving insights into the emergence, function and effectiveness of governance systems.

A focus on polycentric governance entails not only formal institutions but also different regimes and clusters of norms, principles and social entities. Therefore, we have investigated institutional structures and actor collaborations, '*that are valid or active*' following Biermann et al. (2009a, p. 15, 2009b) in the world politics of anthropogenic disturbance of the N and P cycles. In particular, we have studied a fairly recent international initiative, the Global Partnership for Nutrient Management (GPNM) and its workings during the time period of September 2014–June 2015. The GPNM was formed as a constellation of actors in response to the challenge of *'how to reduce the amount of excess nutrients in the global environment consistent with global development'* (About GPNM, n.d.). We structured our analysis in two steps: (a) an analysis of institutional structures, using social network analysis techniques in combination with expert interviews; and (b) an in-depth study of actor collaborations in the GPNM, based on a review of documents and semi-structured interviews. This approach allows formal institutional processes in polycentric governance to be explored from both a structural and a process oriented point of view.

2. Nitrogen and phosphorus flows – a global concern, an Earth system governance gap

The nutrient elements N and P are essential, life-supporting elements, but their biogeochemical cycles have been greatly perturbed by human activities (Fowler et al., 2013; Scholz et al., 2014). When these elements are mobilized in the environment in excessive concentrations, the nutrient enrichment leads to soil and water pollution and problematic ecosystem changes in land and aquatic environments. N emissions are also important causes of air pollution, and some N compounds are climate-active substances (nitrous oxide is a powerful greenhouse gas, and organic and inorganic N are major components of atmospheric aerosol).

Figs. 1 and 2 represent the global N and P cycles respectively, showing the main flows between the major Earth system components: the oceans, atmosphere, the living biosphere, and the geological lithosphere.

The main human alteration of N fluxes (shown in red arrows in Fig. 1) is the intentional conversion of non-reactive atmospheric N to environmentally reactive forms for use as fertiliser and as an industrial feedstock, mainly via the Haber–Bosch process. Non-intentional sources of reactive N are cultivation-induced biological N fixation, and the combustion of fossil fuels (e.g. Galloway et al., 2013). The main human perturbation of the P cycle is the mining of finite phosphate rock deposits, for industrial conversion to fertilisers, detergents and industrial feedstocks (Steffen et al., 2004; Scholz et al., 2014).

Global N and P cycles are among the critical Earth-system processes for which Rockström et al. (2009) defined 'planetary boundaries',[1] which, if crossed, would increase the likelihood of intolerable global environmental risks. Reactive N exists in several different chemical forms, with multiple 'cascade' effects on land, freshwater and marine ecosystems (Galloway et al., 2003, 2013; Sutton et al., 2011). The nutrients issue has an additional critical feature, as P is a finite mineral resource. Current trade and use poses potential risks for future supply, given that there is no alternative to P as an essential plant nutrient (Sutton et al., 2013).

While the direct, often local, ecological and environmental health effects of increased N and P flows are reasonably well understood (e.g. Sutton et al., 2014; Hicks et al., 2014; Scholz et al., 2014), there is less knowledge about large-scale systemic responses (Rockström et al., 2009; Fowler et al., 2013). This knowledge gap translates to a major societal challenge, since current governance and management often do not take complex interacting planetary risks into account, and lack a mandate to act upon them (Walker et al., 2009). Another challenge arises from the spatial variability of N and P impacts and their thresholds. N and P biogeochemical cycles are globally systemic processes – and their anthropogenic effects are evident at multiple scales from local (soil degradation) up to the global (climate change). The

[1] More recently, Steffen et al. (2015) have revised the quantitative N and P boundaries in the planetary boundaries framework in light of critiques and recent research (notably de Vries et al., 2013; Carpenter and Bennett 2011).