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Governance, polycentricity and the global nitrogen and phosphorus cycles

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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-organized action.

Keywords: nitrogen, phosphorus, biogeochemical cycles, nutrient flows, anthropogenic change, environmental law, polycentricity, Earth system, governance

Research highlights:

- Legal instrument citation networks show architecture of global N and P governance
- Cross-scale and cross-sector links are an empirical test of polycentric theory
- Actors interact with institutional network in response to Earth system governance gap
- Polycentric governance offers an adaptive response mode for Earth system challenges

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, 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 systems (Aligica & 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; 2009b). 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 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 institutional architecture and actors interact. Borrás and Radaelli (2011) highlight the importance of both ideational and organizational dimensions of governance architectures for dealing with complex problems. It has been suggested that interactions appear through key individuals and organizations, 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; Galaz et al., 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 systems to be explored from both a structural and a process oriented point of view.

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, Peirrou 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.
	Global Program for Nutrient Management established as multistakeholder platform	N and P	Sutton et al. 2013
2010 to present	European Nitrogen Assessment published (Second Assessment currently underway)	N	Sutton, M. A., et al. 2011
	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

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).

Figures 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 Figure 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).

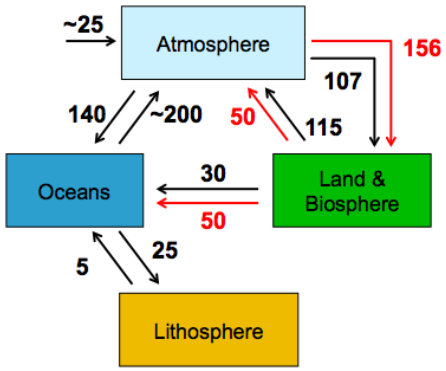

Figure 1. The global nitrogen cycle: a schematic outline showing the main flows between the different 'components' of the Earth system. Numbers show current best estimates of the N flow between components. Red arrows show main human-caused flows. Units are Tg N yr^{-1} = million tonne N yr^{-1}. Flows are based on data from Ward (2012).

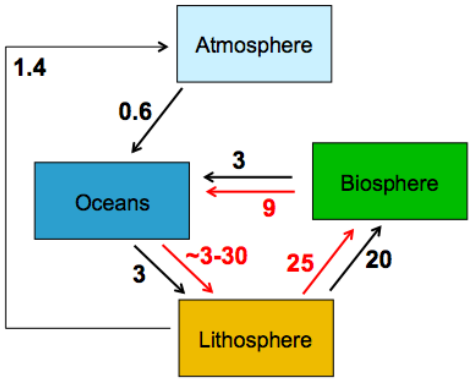

Figure 2. Global phosphorus flows through the Earth system. Units are Tg P yr^{-1} = million tonne P yr_{-1}. Flows are based on data from Sutton et al. (2013) and Filippelli (2002).

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; Galloway et al., 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 main causes of N and P flows are day-to-day actions taken by actors at multiple levels of social organisation. Governance therefore needs to consider global and sub-global levels at the same time.

3 Governance architecture and polycentricity: Network Analysis of N and P legal instruments

Progress in global N and P governance has been limited to date, and there are substantial barriers to change (Sutton et al. 2013). Considering the multilevel systemic nature of the nutrient problem, and the limited international attention on the topic, we expected the governance structures to be weak and unconnected. In our effort to address current limitations of polycentric theory, we build upon an understanding that even when 'global solutions' are negotiated at the global level, they need to be backed up by a variety of efforts at national, regional, and local levels to function effectively (Ostrom, 2010). This means addressing whether and how governance efforts at these different levels are functioning and emerging. This polycentric perspective challenges the view that institutional fragmentation results in anarchy at the international level. It involves a focus on governance arrangements that are categorized as emerging and self-organizing responses.

Institutional fragmentation is a well-discussed problem by scholars interested in international law and governance (e.g., Carlarne, 2008; van Asselt et al., 2008; Biermann et al., 2009a; Zelli and van Asselt, 2013). While institutional analysis has focused substantially on effectiveness, relationship and interactions (e.g. Biermann, 2008; Young, 2011, Oberthür and Stokke, 2011), Zelli and van Asselt (2013) highlight that at the macro-level, architecture is typically analysed as isolated cases of dyadic institutional interaction. Most studies of polycentric governance have focused on case studies, usually on specific common pool resources in relation to water, coastal, forest, and pastures management, e.g. coral reef fisheries (e.g. Ayers et al., 2017), artisanal fisheries (e.g. London et al., 2017), and village commons (e.g. Favero et al., 2016). Kim (2013) discusses the need to take empirical research

[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).

on fragmentation and polycentricity at the international level further, as these questions have been hampered by inadequate methods and a lack of large datasets.

3.1. Network analysis approach and methods

We have used the approach taken by Kim (2013) that combines the notion of degrees of polycentric governance (Galaz et al., 2012b) with Social Network Analysis (SNA; Wassermann & Faust, 1994). In SNA, relationships among social entities are analysed to uncover the underlying system architecture of aspects of the political, economic, or social environment. By creating a network, this environment can be expressed as patterns of regularities, or structures, in relationships among interacting units. A network approach enables the structure of the system to be estimated regardless of the size, which makes it possible to analyse the institutional complexity of a global system such as the governance regimes in place for N and P management. SNA enables the visualization of these institutional elements, ensuring that both the actual size of the system and to some extent its complexity can be explored. SNA has therefore become a valuable tool in the analysis of complex systems (e.g. Amaral and Ottino, 2004; Newman, 2011).

Most studies that use SNA have studied actors (e.g. Bodin and Crona, 2009; Prell et al., 2009). We have viewed different regional and international legal instruments as social entities. This approach enables us to include a wide set of legal instruments. The rationale behind treating legal documents as social entities is that although they are in one sense static texts, they are at the same time often dynamic, evolving through amendments, reinterpretation and actor collaboration. They are often closely linked within the framework of decision- making of their respective Conferences of Parties, secretariats and other treaty bodies, states, and international organizations (see Churchill and Ulfstein, 2000; Ulfstein, 2012, Kim and Mackey, 2013; Kim, 2016). In addition, MEAs (and other legal instruments) often cite a number of other agreements that their parties consider relevant (Kim, 2013). Inter-treaty citations could create an extension of the legal effect of cited texts to the texts that cite them (Kiss and Shelton, 2007). Furthermore, Kim (2013) discusses how initially favoured sets of legal instruments fall out of favour, to be replaced by different ones. Typically, this involves processes where legal instruments (such as conventions) are complemented by protocols focused on related but specific issues. These processes can be observed among norms as well; some are repeated in a way that leads to them becoming unifying principles, while others slowly become less popular, or are not used at all. Given the importance of these processes, in our analysis we view each legal instrument as 'legally autonomous'.

We created a network using citations as proxies for relationships (links) between legal instruments (nodes). Each legal instrument was manually scanned and searched for citations to other legal instruments. The network was analysed using the SNA software UCINET and visualized (figures 4, 6-9) with its NetDraw tool (Borgatti et al., 2002). A basic analysis of network topological properties was performed:

- ***Degree centrality*** measures which nodes are most connected. We calculated the number of links through inward citations and outward citations between the legal instruments. Prior studies of law have used degree centrality (and citations as links) as a way to measure the continuing relevance or importance of a given case or judge (see Landes and Posner, 1976; Kosma, 1998; Hansford and Spriggs, 2006).
- ***Betweenness centrality*** measures interactions between two nodes in terms of the path lengths between the two. We used betweenness centrality to help identify influential legal instruments and cross-scalar interactions between legal instruments at the EU and international levels (see Wasserman and Faust, 1994).

There are limitations to what citation networks can show. A citation network has directed links, with a one-way flow of information or influence from node A to node B. A citation does not say anything about (or presume the existence of) the potential flow of information or influence from node B to node A. We note that in the treaty context, citations often mean information flows in both directions (e.g., Wolfrum and Matz, 2000) so in our analysis, we have assumed citations as bidirectional links.

3.1 Source information

The dataset of source information about N and P governance used for the SNA contains 99 legal instruments (*Supplementary Materials).* Analysis of the whole governance architecture requires an understanding of all the different aspects of the N and P flows that are being altered and the actor activities that are causing this perturbation. We have therefore considered how the N and P cycles operate across the various 'components' of the Earth system, and sought to select legal instruments on the basis of their effects (direct and indirect) on drivers of Earth system change (the arrows in Figures 1-2).

Legal instruments were identified through systematic searches for keywords relating to those Earth system drivers (Table 2) in the International Environmental Agreements Database (Mitchell, 2014), the ECOLEX database (FAO/UNEP/IUCN, 2014), and the EUR-Lex database (European Union, 2014). Keywords relate to the flows, chemical forms (i.e., phosphate, nitrate, ammonia, NO_x, etc.), and physical states of the N and P cycles. Interview data obtained from nine subjects (see *Supplementary Materials)* expanded and validated the dataset, using an iterative selection strategy to ensure that the database was as complete and representative as possible.

Keeping a broad notion of the 'governance architecture' of N and P was essential to enable exploration of the contribution of polycentric networks to overcoming formal institutional gaps. This involved incorporating legal instruments into the analysis that target not just the specific use of N and P but also related activities seen from an Earth system perspective. For example, legal instruments targeting water use are highly relevant to N and P governance, via the environmental degradation caused by eutrophication. We therefore included (a) large legal instruments affecting regional agreements, (b) trade agreements affecting levels of regulation and production, and (c) legal instruments dealing with business or industry.

Table 2. Search terms for the selection of legal instruments included in SNA database. Search terms were used to identify legal substance in the text of each legal document.

Key Term	**Search terms**	**Rationale**
Nitrogen	Agriculture Nutrient Nitrogen Pollution Emission Combustion Eutrophication Fertilizer Nitrogen oxides (NO_x) Ammonia (NH_3) Nitrous oxide (N_2O) Nitrate (NO^-)	Terms represent major sources, consequences and chemical forms of reactive nitrogen (Nr)
Phosphorus	Agriculture Nutrient Fertilizer Phosphorus Phosphate Eutrophication Sewage	Terms represent major sources, forms, processes and consequences of P use

	Waste water Sewage treatment plant Sludge Detergent	

3.2 The citation network of global N and P governance

Figure 3 is a network map showing the international legal instruments regulating activities that influence the anthropogenic effects of N and P flows, both directly and indirectly. In the figure, node colour indicates issue area or objective, and node shape denotes type of legal instrument.

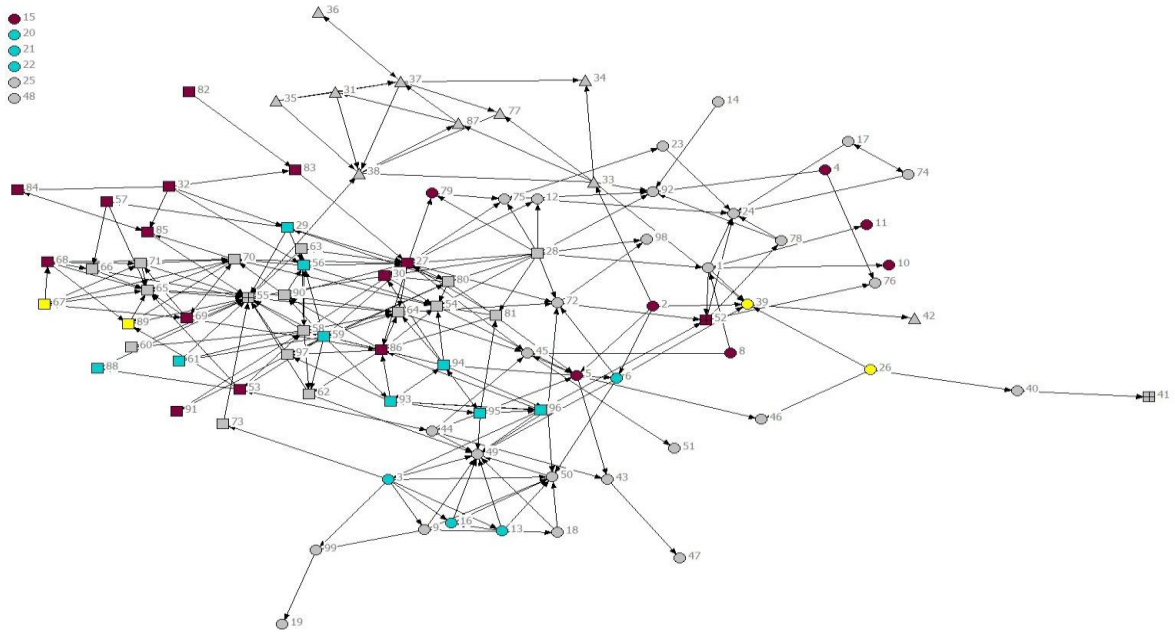

Figure 3. Visualisation of the N and P institutional network. Turquoise = N, yellow = P, wine red = N&P, and grey = other relevant factor. Circle = MEA, square = legal instrument at EU-level, triangle = trade agreement, and box = other relevant regional or international legal instrument. Nodes in the upper left corner are unconnected nodes (legal instruments without citation links). Numbers denote the legal instrument (listed in Supplementary Information)

The analysis shows that there is a network structure at the international level; however, it is a loose interconnected network. Only a few legal instruments with direct influence on N and P use have been identified. Individual element flows (turquoise and yellow nodes, 16 % and 4 % respectively) are less recognised in legal instruments than more general nutrient issues involving both N *and* P (wine red nodes). Grey nodes account for 57% of the total: most legal instruments influencing N and P flows are actually 'connecting regimes' targeted at other relevant factors (trade, sectors etc.) It is clear that these legal instruments are instrumental in holding together what would otherwise have been a very fragmented network. In figure 3, the circles denote MEAs. Several focus specifically on N and P issues. However, very few of these circles represent an MEA with global coverage. Most are at the regional level.

Instruments with a large geographic scope include the UNECE 1979 *Geneva Convention on Long-Range Transboundary Air Pollution* (grey node 49) which applies to atmospheric N emission, and its *1999 Protocol to Abate Acidification, Eutrophication and Ground-level Ozone*, often referred to as the Gothenburg Protocol (node 3) which sets out national emission caps for NO_x and NH_3 (Ebbesson, 2014). The *United Nations Convention on the Law of the Sea* (UNCLOS) (grey node 92) is global, and there are several regional seas conventions on marine pollution (see also Ebbesson, 2014).

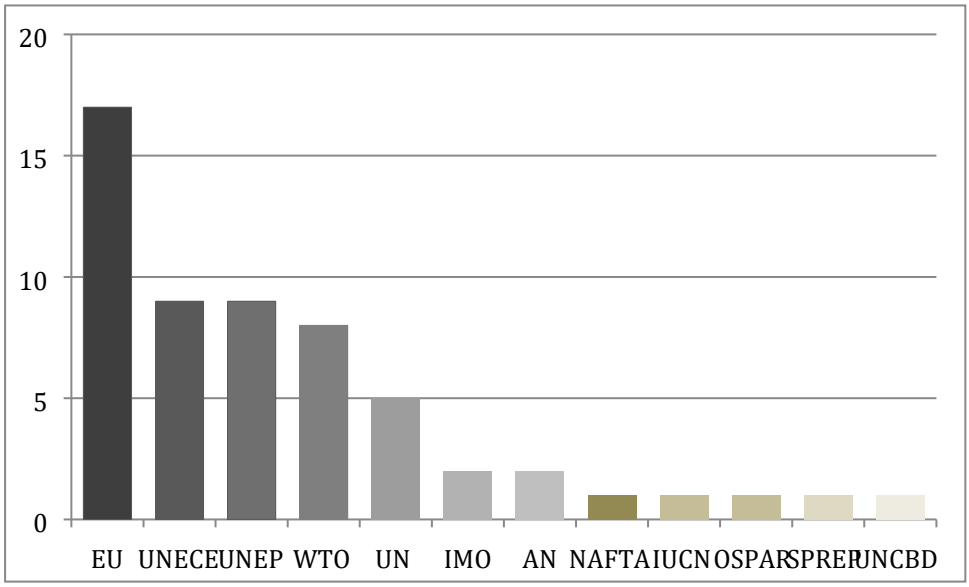

Figure 4. Distribution of secretariat groups involved in the instruments identified as 'connecting regimes' (grey nodes in figure 4). Highest numbers of legal instruments are affiliated with the EU and the UNECE, left of distribution. See Table 2 for the set of criteria and see the list of abbreivations and acronyms for full names of secretariats.

Given the importance of 'connecting regimes' (grey nodes in Figure 3) in the otherwise fragmented network structure of N and P governance, we have identified the organisations that cover these activities. Figure 4 shows the distribution of the secretariat groups involved in indirect/non-use instruments. It clearly signals the diversity of policy regimes that have an impact on N and P flows. It demonstrates that there are more actors involved in the global governance of N and P, at different levels of organisations, than one may have first expected. And it also points to the gap in governance in terms of legal instruments *directly* regulating the identified issues.

Figures 3 and 4 also illustrate the value of the chosen approach in mapping out the overall governance architecture. SNA shows that the WTO agreement system, the EU(-level) system, and the system of MEAs are networked in a *regime complex* (see Orsini et al., 2013) that ultimately governs the diverse human activities driving and impacting N and P flows. In citation network analysis, *degree centrality* and *betweenness centrality* are key topological measures, discussed in the following sections. They provide insights about the most central and important legal instruments, and about the network's cross-scalar connectivity, respectively.

3.2.1 Inward and outward citation connectivity

Figures 5 and 6 show in- and out-degree centrality of the N and P governance network, respectively. Because our focus is on the overall governance architecture, we do not explore the citation connectivity of each individual node; instead we consider the features of the most connected nodes. The distribution of links in the network is skewed, with a few 'hub' nodes having high numbers of links for both inward and outward citations. For example, node number no. 27 (*EU Water Framework Directive*, wine red square in the centre of both Figures 5 and 6) is a highly connected node, playing a central role in the network representation of N and P governance. Legal instruments that deal directly with environmental N releases (turquoise) feature more prominently in the out-degree measure, meaning that these legal instruments cite other legal instruments more than they are cited themselves. This is not surprising as significant legal efforts have been made at the international level to deal with N releases in comparison to P, and due to the interconnected issue areas around N use.

We are also interested in *where* the citation links go. One interesting case is the *United Nations Convention on the Law of the Sea* (grey circle node 92, upper left of Figure 5), which has both cross-sectoral and cross-scalar links: this legal instrument is cited by MEAs, and also EU-level and WTO agreements.

The degree centrality measure nevertheless needs to be interpreted with care. For example, *the Treaty on the Functioning of the European Union* has many inward citations (grey circle node 55, left-hand corner of Figure 5), making it a very connected node with a high level of in-degree centrality. However, this node does not play a key role in the global governance architecture for N and P although it has an impact in the overall coordination of EU law. With this in mind, it is not surprising that we find that this node has a low degree of outward citation, compared to its inward citation, as most legal instruments at the EU-level cite this Treaty but not the other way around.

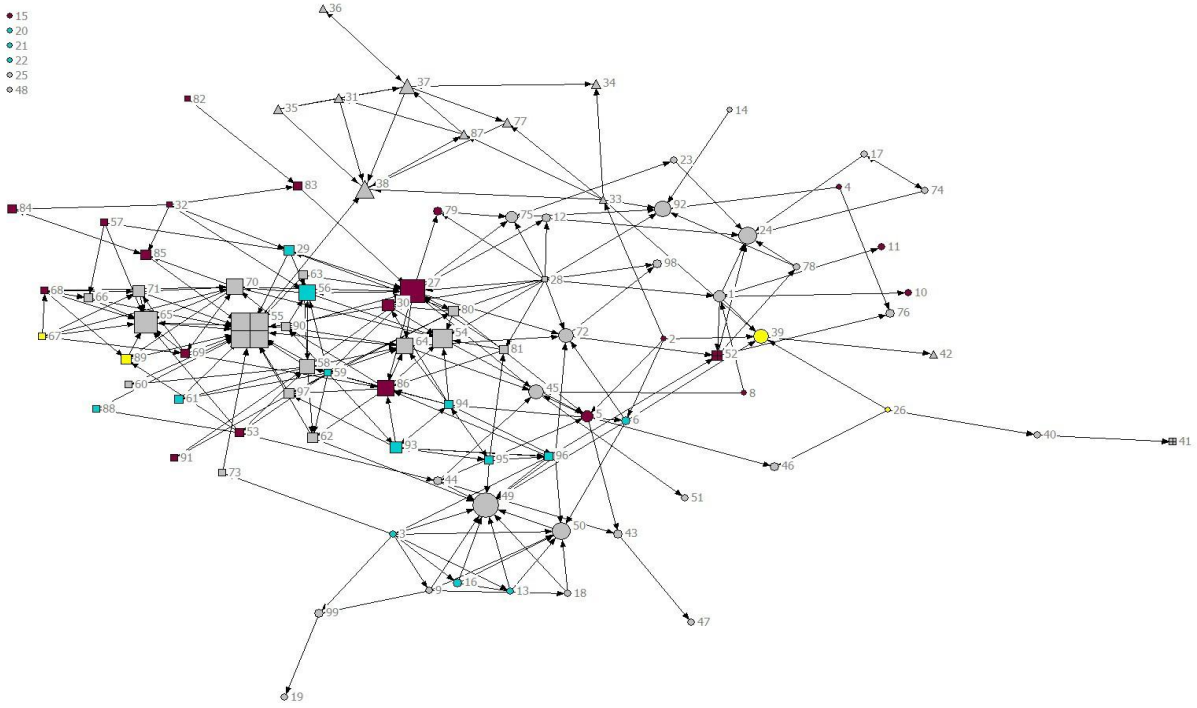

Figure 5. Visualisation of in-degree centrality of the institutional network. Larger nodes show a higher degree of inward citation. Unconnected nodes are shown in the upper left hand corner. Colour codes and shapes are the same as in Figure 4.

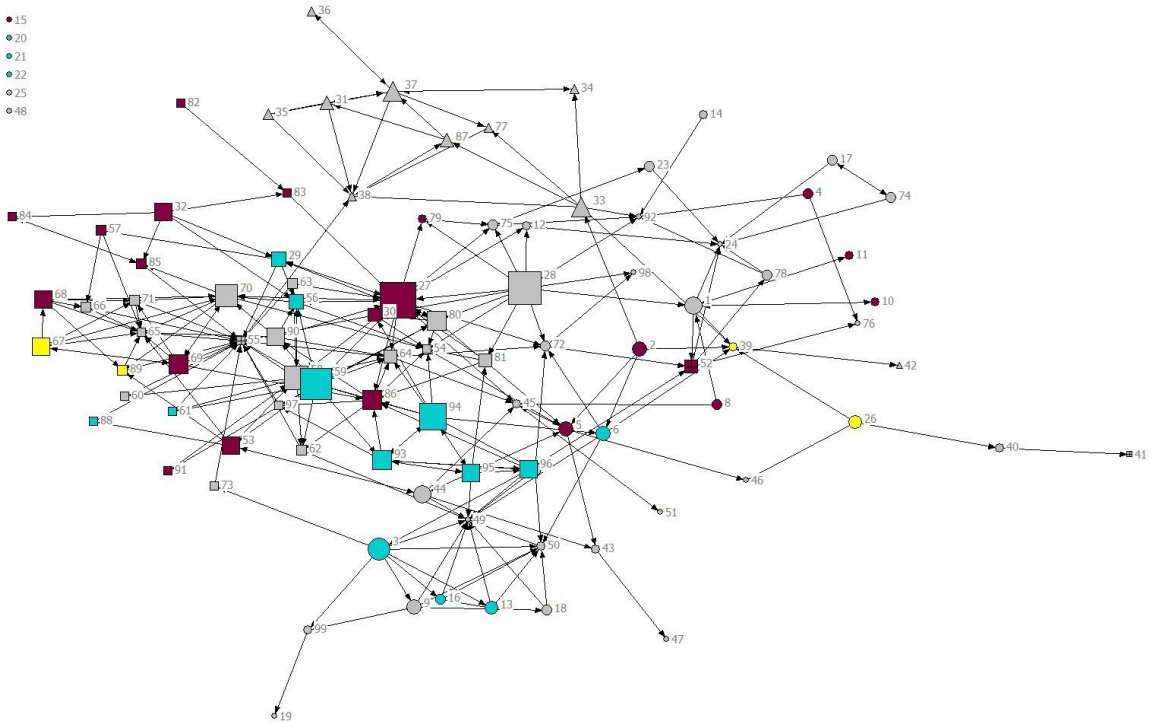

Figure 6. Visualisation of the out-degree centrality of the institutional network. Larger nodes show a higher degree of outward citation. Unconnected nodes are shown in the upper left hand corner. Colour codes and shapes are the same as in Figure 4.

3.2.2 Betweenness centrality

Figure 7 shows the betweenness centrality measures of the institutional network, an indication of the 'reach' of a legal instrument. The nodes shown as larger symbols denote instruments that lie on paths linking other nodes. The largest wine red node (no. 27) near the middle of the figure represents the EU Water Framework Directive, which deals directly with both environmental N and P releases. The largest grey node (no. 28) represents the Marine Strategy Framework Directive, an example of a node in the connecting regime that does not explicitly regulate nutrient element flows, but that list inputs of fertilisers and other nitrogen- and phosphorus-rich substances as aspects of pressures and impacts of good environmental status for marine waters. Legal instruments dealing with P (yellow nodes) become slightly more prominent when running the betweenness centrality measure. We interpret this as a result of links to legal instruments dealing with both N *and* P (wine red nodes) that are on paths between the legal instruments that deal directly and only with N and the ones dealing directly and only with P.

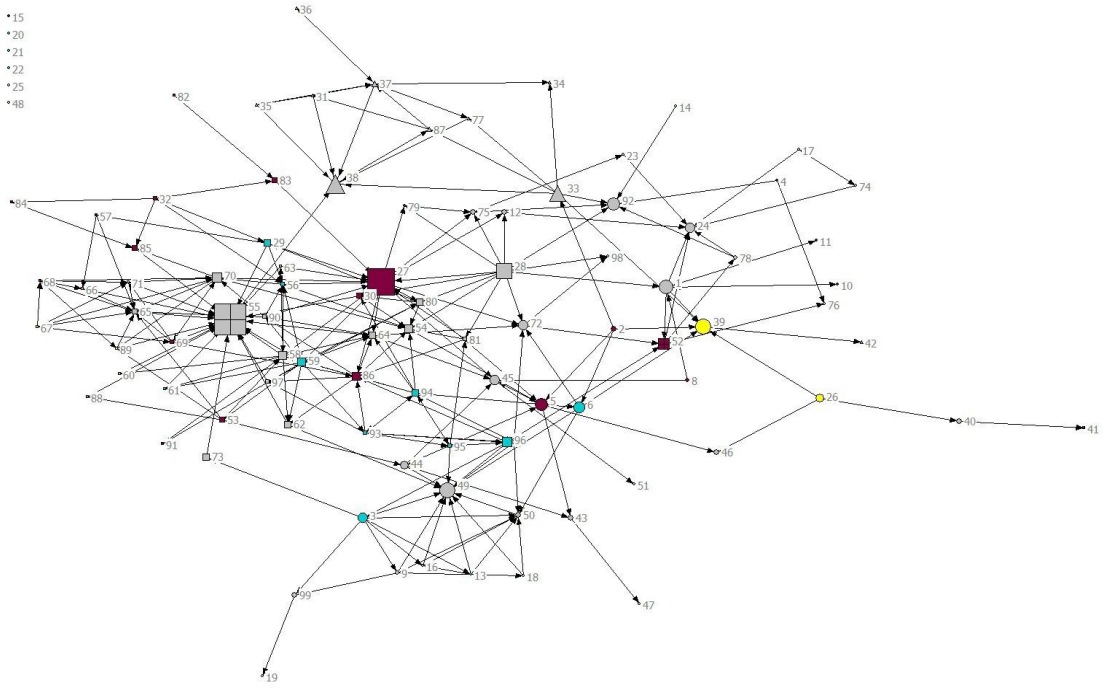

Figure 7. Visualisation of the institutional network using betweenness centrality. Larger nodes indicate higher betweenness centrality.

3.2.3 Cross-scalar and cross-sectoral connectivity

Some instruments play a role in connecting different levels of law. Analysis of these cross-level links offers the potential to explore regulatory dynamics and interactions between legal instruments situated at different governance scales. Understanding these links is important because cross-scalar structures are essential features for outlining polycentric governance.

Figure 8 displays cross-scalar citations by separating legal instruments of the European Union from the other regional and international legal instruments. It is clear that the EU-level regime is a dominant cluster within the global network of N and P governance. Several nodes act as possible 'legal gateways' between European environmental law and international regimes, notably the *EU Water Framework Directive* (node 27), *Marine Strategy Framework Directive* (node 28), and *Directive 2001/81/EC on national emission ceilings for certain atmospheric pollutants* (node 96), and the *UN Convention on the Law of the Sea* (node 92). Even more interesting is the possible role of the *1979 Geneva Convention on Long-Range Transboundary Air Pollution* (node 49), since it is a legal instrument that both cites and is cited by other legal instruments, across these scale clusters.

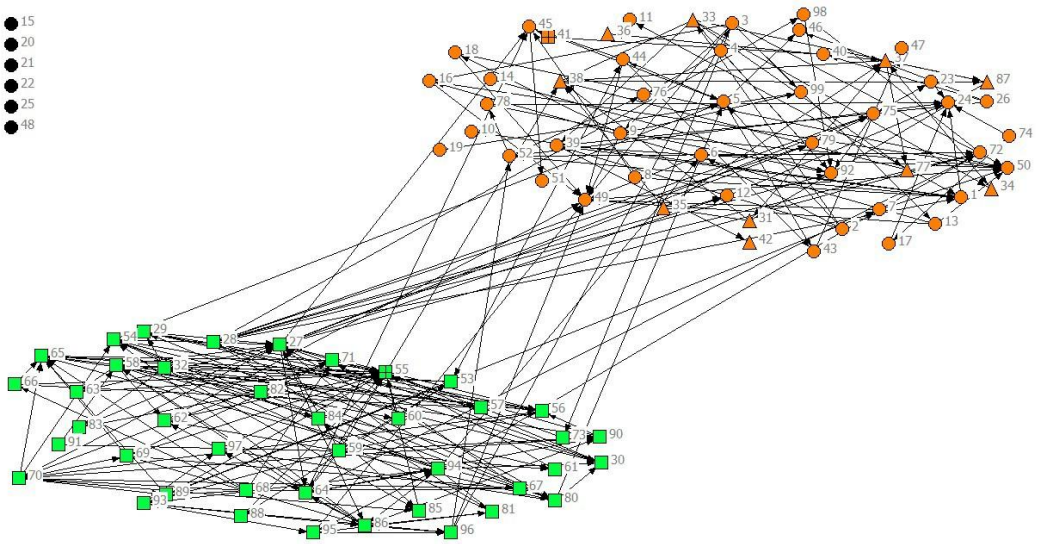

Figure 8. Cross-scale citation connectivity network. The cluster of nodes to the left represents legal intstruments of the European Union and the cluster of nodes to the right represents other regional and international agreements including European UNECE level instruments. Some nodes act as 'legal gateways' connecting the different legal levels.

Several 'legal gateways' connect across different Earth system components, with cross-sectoral effects on N and P governance structures, (see Table 3), notably the *Nitrates Directive* (node 29), *UNCBD* (node 98), and *UNFCCC* (node no. 99). The Nitrates Directive cites WFD (node 27), *The Directive on the quality of water intended for human consumption* (node 56) and the *EU regulation on relating to fertilizers* (node 57). The Nitrates Directive is furthermore cited by the *Commission Regulation laying down detailed rules for the implementation of Council Regulation on organic production and labelling of organic products with regard to organic production, labelling and control* (node 32) and the *EU(- level) Directive concerning the management of bathing water quality* (node 80). UNCBD cites the *Convention for the Protection of the Marine Environment of the North-East Atlantic* and the *Marine Strategy Framework Directive*. UNFCCC cites the *Vienna Convention for the Protection of the Ozone Layer* (node no. 19) and is cited by the LRTAP protocols to *Abate Acidification, Eutrophication and Ground-Level Ozone* (node 3) and *on further Reduction of Sulphur Emissions* (node 9).

The functioning of those 'legal gateways' could represent diffusion processes in the emergence of law between European legislation and international law. Twining (2005) defines diffusion of law as *'the processes by which legal orders and traditions are influenced by other legal orders and traditions'*. We suggest that visualisation through networks can be useful for detecting diffusion processes, as a first step in polycentric legal and policy research.

Table 3. Gateway agreements for cross-scalar and cross-sectoral connectivity in the global N and P governance

Legal instrument that cites	**Legal instrument being cited**
Water Framework Directive (node 27)	*Convention on the Protection of the Marine Environment of the Baltic Sea Area*, (node 12)
	Convention for the Protection of the Marine Environment of the North-East Atlantic, (node 72)
	Protocol for the Protection of the Mediterranean Sea Against Pollution from Land-Based Sources to the Convention for the Protection of the Mediterranean

	Sea Against Pollution (node 79)
	United Nations Convention on the protection and use of transboundary water courses and international lakes (node 46)
Marine Strategy Framework Directive (node 28)	Water Framework Directive (node 27)
Nitrates Directive (node 29)	Water Framework Directive (node 27)
	Directive on the quality of water intended for human consumption (node 56)
	EU regulation on relating to fertilizers (node 57)
Commission Regulation laying down detailed rules for the implementation of Council Regulation on organic production and labelling of organic products with regard to organic production, labelling and control (node 32)	Nitrates Directive (node 29)
Directive concerning the management of bathing water quality (node 80)	Nitrates Directive (node 29)
UNCBD (node 98)	*Convention for the Protection of the Marine Environment of the North-East Atlantic* (node 72)
	Marine Strategy Framework Directive (node 28)
UNFCCC (node 99)	*Vienna Convention for the Protection of the Ozone Layer* (node 19)
LRTAP protocol to *Abate Acidification, Eutrophication and Ground-Level Ozone* (node 3)	UNFCCC (node 99)
LRTAP protocol *on further Reduction of Sulphur Emissions* (node 9)	UNFCCC (node 99)

3.3 Citation network links and institutional network links

The legal gateways outline a particularly interesting feature of the institutional network, due to the possibility of legal diffusion processes resulting in adaptive structures. These identified features should be analysed in conjunction with the idea that the institutional network is a complex adaptive system (see Kim and Mackey, 2014). Most legal gateways are examples of legal documents in international environmental law. The reflexivity of these softer legal commitments makes them desirable instruments for adaptive Earth system governance, as Kim (2016) proposes, and as we discussed above. Adaptive management of this complex adaptive system of legal instruments involves responsive adjustments to other complex adaptive natural and social systems in an increasingly and rapidly changing world (Ruhl, 2012) in order to enhance the governance 'fit' (Young, 2002; Galaz et al., 2008).

The theoretical analysis of patterns of emerging polycentric governance needs however to be complemented with analysis of practical examples of how these gateway agreements play out, in terms of linking the different legal instruments across scales and issue areas. We found 'legal gateway' agreements linking the cluster of nodes that represent European union legal instruments with the cluster representing other regional and international agreements, bridging the legal levels of European and international environmental law. In the absence of formal regimes for nutrient element governance at the global level, the 'legal gateways' may play important roles. However, 'citation links' themselves are not evidence of legal diffusion processes, since it is not evident from citation data alone what norms or ideas are diffused.

Engel et al. (2009) suggested that the EU Water Framework Directive (and the UNECE Convention on Transboundary Waters and International Lakes) provide a framework concept where one of the main benefits is the design that enables adaptive elements in water legislation. They go on to suggest that certain elements – such as the efforts to establish synergies between international, regional, and local levels of water management and protection – can lead to certain [improved] conclusions regarding approaches to be adopted and strategic priorities realised. Such adaptiveness and cross-scale features are some of the proposed benefits of polycentric governance systems that Ostrom (2010) and Toonen (2010) and others proposed.

The WFD is relevant for water governance, but because nutrient management has an effect on water and the marine environment, the case of nutrient governance will also be affected by links to the WFD, which are key for cross-scalar connectivity and also for cross-sectoral effects. The suggestion by Engel et al. (2009) is in line with testimonies by interviewee I8:

> *'One of the most advanced regional frameworks would be the EU Water Framework Directive, which is not really about nutrients. But it is looking at the bottom view impact of nutrients, which is also widely quoted.' (I8)*

The WFD (node 27) acts as an interesting node in the network. The WFD refers to the *Convention on the Protection of the Marine Environment of the Baltic Sea Area*, (node 12), the *Convention for the Protection of the Marine Environment of the North-East Atlantic*, (node 72), and the *Protocol for the Protection of the Mediterranean Sea Against Pollution from Land-Based Sources to the Convention for the Protection of the Mediterranean Sea Against Pollution* (node 79). The WFD refers to these legal instruments as important, but the most significant citation link is to the *United Nations Convention on the protection and use of transboundary water courses and international lakes*:

> "This Directive is to contribute to the implementation of Community obligations under international conventions on water protection and management, notably the United Nations Convention on the protection and use of transboundary water courses and international lakes, approved by Council Decision 95/308/EC(1) and any succeeding agreements on its application."

This citation shows that the link between nodes 27 and 45 is an important link in legal theory, not only as an abstract representation in the institutional network.

An example of a combined top-down and horizontally linked citation is the fact that the Marine Strategy Framework Directive cites the WFD, while at the same time harnessing a main principle from the United Nations Convention on Law of the Sea, which represents a citation link with actual importance. This is done through the following text:

> "The obligations of the Community and its Member States under those agreements should therefore be taken fully into account in this Directive. In addition to the provisions applicable to the marine waters of the Parties, the Unclos includes general obligations to ensure that activities under the jurisdiction or control of a Party do not cause damage beyond its marine waters, and to avoid that damage or hazards are transferred from one area to another or that one type of pollution is transformed into another."

4 Interactions of actors and the institutional network: the Global Partnership on Nutrient Management

We used the global partnership initiative GPNM as a case study to investigate the role of

actors in facilitating the institutional network structure of regional and global legal instruments. The GPNM brings governments, scientists, policy makers, and non-governmental, private sector and international organisations together in a community platform. It was established in 2009 to address the linked challenges of promoting effective nutrient management, minimising negative impacts on the environment and human health, and maximising the contribution to global sustainable development and poverty reduction. It operates through strategic advocacy and cooperation at the global level, prompting discussion on the complexity of the nutrient challenge and the opportunities for cost effective policy and investment interventions by countries (About the GPNM, n.d.).

Identifying processes such as information sharing, coordination of efforts, knowledge production activities, and investments in monitoring systems is currently a vital limitation of polycentric governance theory. Semi-structured interviews were therefore conducted with nine subjects who have been or are actively involved in the GPNM. The interviews were conducted between January and February 2015 and the interview questions were designed to capture milestones for the partnership, its missions, its goals over time, its functioning in comparison to current governance regimes, and challenges and opportunities associated with the partnership. Four interviewees were based in Europe, two interviewees wanted to remain anonymous and three interviewees were based in other parts of the world. Among the official interviewees three interviewees were academics, three were public organisation or policy representatives and one interviewee were a practitioner.

4.1 GPNM as an emergent self-organised governance structure

When analysing how polycentric governance emerges among relevant institutions and actors, it is relevant to explore what the current overall governance structure is ***not*** doing. This means uncovering whether there is a 'governance gap', and considering possible responses to this gap.

Actors involved in the GPNM indicated that the partnership emerged as a response to a governance gap that cannot easily be described in terms of geographic scale. The partnership was established due to a recognized need for special attention to the flows between Earth system 'components': land-based sources of N and P reaching the seas and oceans, especially through run-off and leaching to estuaries. Although academic research, including global change science, has been a key driver of its formation, it is not a platform intended purely for information sharing. It is also a multi-stakeholder partnership that has the potential to facilitate a stronger form of polycentricity involving tangible joint projects and experiments, which also include people 'on the ground' participating in improving nutrient management.

The GPNM partnership is a self-organised governance structure, with multiple links into the formal institutional network structures that form the governance of N and P cycles at the global level. The partnership has been formed as a 'polycentric response' to a gap in governance, since it involves deliberate attempts for mutual adjustments and self-organised action across geographic scales, between environmental contexts, and among sectors of policy and action.

Interviewee I6 highlighted that it was crucial to have the private sector on board in the GPNM (see section 4.2), as it strengthened the whole effort. However, even though this involvement seems crucial, it directly influences power dynamics. This is especially true for regime complexes, where it is said that only powerful actors can have an influence (see Orsini et al, 2013). In an emerged [polycentric] system, actors that are already weak tend to be weaker, which can affect legitimacy. This aspect is another research gap in polycentric theory (a recent contribution is Morrison et al., 2017).

In addition, it is practically impossible to 'design' institutions that match the planetary boundaries as distinct issues, and also deal with their interactions (Galaz et al. 2012a, Galaz et al., 2012b). For N and P, which display complex, nonlinear and interacting biogeophysical thresholds at the planetary scale, the discussion of what actors are involved, and what their power to act is, is at the heart of the 'Earth system challenge' (Biermann et al. 2009b).

4.2 GPNM actors enabling cross-scalar and cross-sectoral collaboration

The GPNM has seen clear successes in terms of how partners organised themselves, including working across sectors, to create a global multi-level collaboration structure. The expanded view of governance including the actor formation of the GPNM has been crucial for being able to fully view the global governance structure of N and P flows. It could be viewed as structuring polycentric governance (see Galaz et al., 2012b), especially after the involvement of the private sector. Another dimension of this question is that decision-making with environmental impacts are not at all limited to the level of nation states, rather there are a wide array of actors involved in global production and consumption, which is also true for the market processes in relation to N and P usage. The focus on actor formations in N and P governance are hence crucial and it is in this context the GPNM creates an added value to the regulatory dynamics of global N and P governance:

> *'The partnership is a multi-sectoral partnership. It is, I guess, it intended to reflect what is the configuration of the national level. So we have different stakeholders representing different interests. We have interests in policy design, interest in research, interests from producer organisations, interests from fertilizer supply organisations, companies. So by having a governance structure with the GPNM that allows for interaction between different stakeholder groups allows for a transfer of knowledge at the local level.' (I4, programme officer)*

> *'So the International Fertilizer Association, for example, has come on-board as part of a public-private partnership (...). Which in my opinion has strengthened the whole effort. I think the real benefit of the partnership at this moment is that this problem [N and P issue] can't be solved without the cooperation with the private sector.' (I6)*

This is in line with the description by interviewee I9 (from an environment ministry) of how GPNM as an actor formation could have a role in connecting the European level with the international level. This cross-scalar dimension of the partnership can be interpreted as having a facilitating role for the identified gateway agreements node 29 in Table 3:

> *'I think there is no global governance structure for addressing nutrients (...) other than GPNM (...). I think for the European Union, the Nitrates Directive - well not completely, covers quite a lot of what we try to do with the GPNM. (...) Around the world it's quite unique I think, such detailed directive that is not voluntary. The EU directive demands that all member states come up with a plan to improve their environmental quality to limit their emissions to environment.'(I9)*

In addition, the interviewees highlighted that while the involvement of diverse stakeholders brings a multi-sectoral focus, the overall objectives of the partnership have shifted depending on which actors that have been engaged. The International Fertilizer Association is still a partner of the GPNM, however the context continues to change. For example, through the time period of this research, a follow-up Global Environment Facility funded project to GPNM was materialising called Towards the Establishment of an International Nitrogen

Management System (INMS) (International Nitrogen Management System, n.d.), which outlines a change in the actor formation focus and strategy.

4.3 Functioning of the GPNM in relation to current governance regimes

Interviewees confirmed that the GPNM has organised itself into a collaborative governance structure to the loose network structure of formal institutions, with certain synergistic features. The explicit aim of the partnership has been to enable multiple actors to come together and work towards a better governance of N and P flows. The cross-scalar dimension of this effort at coordination can especially be viewed through the GPNM's work on structuring platforms of information sharing and knowledge production activities. The main examples are the local demonstration areas that have been implemented in Manila Bay and Laguna de Bay in the Philippines and Chilika lake in Odisha state of India (see GNC Pilot Projects, n.d.) and through the publication '*Our Nutrient World -The challenge to produce more food and energy with less pollution'* (Reports and Publications, n.d.). The GPNM have in these workings applied an integrated view on nutrient management, configured at the national level and linked up to intergovernmental processes through involvement of a wide range of actors. However, views of the exact function of the GPNM differ:

Interviewee I9 described the current fragmented governance, where some global conventions deal with certain aspects of nutrient management:

> *'If you look at nitrous oxides – that's a greenhouse gas, so that's part of the UNFCCC agenda so to say. And I think also the CBD, the Convention on Biological Diversity, addresses one of the effects of nutrient use, namely the effect on biodiversity. So there're fragments so far, as there are global conventions dealing with certain aspects of nutrient management but there's no integrated approach and I think that's the main value of GPNM (…) I think that's very much an open question how GPNM will develop. It can develop into the direction of a more legally binding approach – like convention or treaty on nutrient use efficiency (…). I don't think that's very likely.' (I9)*

For interviewee I9, the GPNM could play a role in further integrating these fragments, by networking across members from different sectors and interests, and across scales. In contrast, interviewee I2 (from a government-funded research organisation) sees the role of the GPNM as setting foundations for a more formal institutional basis for N and P governance:

> *'They [actors involved in GPNM] could start the process on an inter-governmental agreement on nutrients. And that's a long way, but I think that's the role of GPNM, not only being regionally active and with demonstration areas and science development, but working towards an integrated, inter-governmental process – science based.' (I2)*

However, the GPNM will probably not facilitate the emergence of polycentric governance involving strong formal ties between key actors, nor actions on nutrient management involving joint global projects. As discussed by Galaz et al (2012b), polycentric governance formations are vulnerable to tensions between actors, unreliable flows of funding and problematic institutional interactions. All these seem to have been vulnerable features in how GPNM is structured. Interviewee testimonials were inconsistent on this matter, but overall as a collaborative governance structure, the GPNM seems not to have facilitated formation of polycentric governance involving strong formal ties. In the INMS, which was being established at the time of the interviews, the emphasis on flexibility of partner involvement in the partnership and the complexity of joint stewardship of the partnership also were seen as

representing constraints to the future emergence of formal structure. However, this trend could of course be changed; the potential, due to the acknowledged success of the partnership, is still there for a stronger polycentric governance structure in the future.

5 Conclusions: Interpreting the governance architecture for N and P

This study provides an example of exploration of polycentric theory through the application of network theory in legal studies. It demonstrates how N and P governance structures can be better understood by mapping out the network of legal instruments and their citation links in different ways. Using known Earth system flows, even as highly abstracted global budgets between major components, has helped to define the scope of the overall governance architecture. This enabled the inclusion and mapping of legal instruments with both direct effects on key flows in the N and P cycles (notably, water and air pollution) and indirect effects (e.g., via energy, trade, biodiversity, and environmental health). This perspective is important for N and P governance, where there are multiple anthropogenic disturbances affecting different types of social-ecological systems across scales. In particular, this scoping starts to point to key ways in which nutrient element flows affect the interactions of climate change and biodiversity (and the interactions of their planetary boundaries), for which the CBD and UNFCCC are long-established global-level instruments.

This analysis has shown that the global governance of N and P consists of a loose network structure of formal institutions at the international level. 'Connecting regimes' (the majority of nodes in Figures 3, 5-7) play a significant role in connecting the network. Without these, there would be a larger gap in governance, with fewer options for interrelations and possible flows between network fragments. These options may translate into vital aspects of adaptive governance. In addition, our approach enabled 'legal gateways' to be found, where cross-citations connect the network across scales, Earth system components, and policy/action sectors: these analytical links can be tested further for legal diffusion processes. Mapping the overall governance architecture has therefore yielded a network that denotes a rich regime complex for N and P.

This institutional network structure is complemented by the workings of a set of actors who, through GPNM, engage in cross-sectoral and cross-scalar collaboration. Knowledge exchange and local and regional coordination contribute to the effectiveness of the loose institutional network. This emerging 'polycentric response' to the Earth system gap in N and P governance has played a visible and important role in the current governance of global nutrient cycles. In particular, it enables the evolving scientific understanding of biogeochemical flows and their perturbations to continue to be inserted into the institutional network through various channels. This actor engagement is seen to have appeared through self-organisation, emerging in the context of increased need for international knowledge production and capacity extension, and greater policy coherence in the face of the limited capacity and scope of international frameworks such as the UNFCCC and UNCBD, which were created for other global change problems.

Actor-institutional analysis has enabled an understanding of how institutions are being developed. Actors involved in the global governance of N and P indicate a tension between emergence and design. It can be argued that a governance system that has emerged into a more networked, polycentric governance has better capacity to deal more flexibly with the context that it has emerged from. Global N and P cycles and boundaries on their human perturbation are poorly governed, despite good regional governance in some parts of the world. This may well be a case where self-organized formation of platforms and partnerships

that bridge different actors in science, policy and practice maintain the organisational flexibility of a worldwide network structure of formal institutions for the global good.

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Supplementary Materials for

Governance, polycentricity and the global nitrogen and phosphorus cycle

List of legal instruments and links

Agreement number	Title	Adoption	Geographical Scope	Secretariat	Hyperlink
1	Convention on the Protection of the Black Sea against Pollution	1992	regional	UNEP	http://www.blacksea-commission.org/_convention.asp
2	Protocol on Pollutant Release and Transfer Registers to the Convention on Access to Information, Public-Participation in Decision-Making and Access to Justice in Environmental Matters	2003	regional	UNECE	https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-13-a&chapter=27&lang=en
3	Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution to Abate Acidification, Eutrophication and Ground-Level Ozone	1999	regional	UNECE	https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-1-h&chapter=27&lang=en
4	Protocol concerning Pollution from Land-Based sources and activities to the Convention for the Protection and Development of	1999	regional	UNEP	http://www.cep.unep.org/cartagena-convention/lbs-protocol/lbs-protocol/lbs-protocol-english/view

	the Marine Environment of the Wider Caribbean Region				
5	Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters	1998	regional	UNECE	http://www.unece.org/env/pp/treatytext.html
6	Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on Persistent Organic Pollutants	1998	regional	UNECE	http://www.unece.org/env/lrtap/pops_h1.html
7	Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on Heavy Metals	1998	regional	UNECE	http://www.unece.org/env/lrtap/hm_h1.html
8	Convention on Cooperation for the Protection and Sustainable Use of the Danube River	1994	regional	icpdr	https://www.icpdr.org/main/icpdr/danube-river-protection-convention
9	Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on further Reduction of Sulphur Emissions	1994	regional	UNECE	http://www.unece.org/env/lrtap/fsulf_h1.html
10	Protocol on the Protection of the Black Sea Marine Environment against Pollution by	1992	regional	UNEP	http://www2.unitar.org/cwm/publications/cbl/synergy/pdf/cat3/UNEP_regional_seas/convention_buc

	Dumping				harest_prots/protocol_dumping.pdf
11	Protocol on the Protection of the Black Sea Marine Environment against Pollution from Land-Based Sources	1992	regional	UNEP	http://www.blacksea-commission.org/_convention-protocols.asp
12	Convention on the Protection of the Marine Environment of the Baltic Sea Area	1992	regional	UNEP	http://helcom.fi
13	Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution concerning the Control of Emissions of Volatile Organic Compounds or their Transboundary Fluxes	1991	regional	U§NECE	http://www.unece.org/env/lrtap/vola_h1.html
14	Protocol for the Protection of the Marine Environment against Pollution from Land-Based Sources	1990	regional	UNEP	http://www2.unitar.org/cwm/publications/cbl/synergy/pdf/cat3/UNEP_regional_seas/convention_kuwait/Protocols/protocol_prot_marine_env_against.pdf
15	Regulation No.83: Uniform provisions concerning the approval of vehicles with regard to the emission of pollutants according to engine fuel	1989	global	UN	https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XI-B-16-83&chapter=11&lang=en

	requirements				
16	Protocol to the Convention on Long-Range Transboundary Air Pollution concerning the Control of Emissions of Nitrogen Oxides or their Transboundary Fluxes	1988	regional	UNECE	https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-1-c&chapter=27&lang=en
17	Protocol for the Prevention of Pollution of the South Pacific Region by Dumping	1986	regional	UNEP	https://www.sprep.org/legal/the-convention
18	Protocol to the 1979 Convention on Long-range Transboundary Air Pollution on the Reduction of Sulphur Emissions or their Transboundary Fluxes by at Least 30 per Cent	1985	regional	UNECE	http://www.unece.org/env/lrtap/sulf_h1.html
19	Vienna Convention for the Protection of the Ozone Layer	1985	global	UNEP	https://treaties.un.org/doc/Treaties/1988/09/19880922_03-14 AM/Ch_XXVII_02p.pdf
20	Regulation No.49: Uniform provisions concerning the measures to be taken against the emission of gaseous and particulate pollutants from compression-ignition engines for use in vehicles, and the emission of gaseous	1982	regional	UNECE	http://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29regs/R049r5e.pdf

	pollutants from positive-ignition engines fuelled with natural gas or liquefied petroleum gas for use in vehicles				
21	Regulation No.47: Uniform Provisions concerning the Approval of Mopeds equipped with a Positive-Ignition Engine with regard to the Emission of Gaseous Pollutants by the Engine	1981	regional	UN	https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XI-B-16-47&chapter=11&lang=en
22	Regulation No.40: Uniform Provisions concerning the Approval of Motor Cycles Equipped with a Positive-Ignition Engine with regard to the Emission of Gaseous Pollutants by the Engine	1979	regional	UN	https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XI-B-16-40&chapter=11&lang=en
23	Protocol for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft	1976	regional	UNEP	http://www.unepmap.org/index.php?module=content2&catid=001001001
24	Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter	1972	global	IMO	http://www.imo.org/About/Conventions/ListOfConventions/Pages/Convention-on-the-Prevention-of-Marine-Pollution-by-Dumping-of-Wastes-and-Other-Matter.aspx

25	Regulation No. 15: Uniform Provisions concerning the Approval of Vehicles Equipped with a Positive-Ignition Engine or with a Compression-Ignition engine with regard to the Emission of Gaseous Pollutants by the Engine - Method of Measuring the Fuel Consumption of Vehicles	1970	regional	UN	https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XI-B-16-15&chapter=11&lang=en
26	Bamako Convention on the Ban of the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa	1991	regional	AN	http://www.unep.org/delc/BamakoConvention/BamakoBackgroundDocuments/tabid/106424/Default.aspx
27	Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (In short: EU Water Framework Directive)	2000	regional	EU	http://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:32000L0060
28	DIRECTIVE 2008/56/EC OF THE EUROPEAN PARLIAMENT AND OF THE	2008	regional	EU	http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:32008L005

	COUNCIL of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive) (In short: Marine Strategy Framework Directive)				6
29	Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (IN short: Nitrates Directive (1991))	1991	regional	EU	http://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:31991L0676
30	Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment	1991	regional	EU	http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:31991L0271
31	URUGUAY ROUND AGREEMENT Agreement on Agriculture	1995	global	WTO	https://www.wto.org/english/docs_e/legal_e/14-ag_01_e.htm
32	Commission Regulation (EC) No 889/2008 of September 2008 laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007 on organic prodution and	2008	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2008.250.01.0001.01.ENG

	labelling of organic products with regard to organic production, labelling and control				
33	North American Free Trade Agreement (NAFTA)	1994	regional	NAFTA	https://www.nafta-sec-alena.org/Home/Legal-Texts/North-American-Free-Trade-Agreement
34	World Trade Organization Agreement on Government Procurement (WTO-AGP)	2012	global	WTO	https://www.wto.org/english/tratop_e/gproc_e/gp_gpa_e.htm
35	Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement)	2001	global	WTO	https://www.wto.org/english/tratop_e/sps_e/spsagr_e.htm
36	Agreement on Trade-Related Aspects of Intellectual Property Rights	1994	global	WTO	https://www.wto.org/english/tratop_e/trips_e/t_agm0_e.htm
37	Marrakesh Agreement establishing the World Trade Organisation	1994	global	WTO	https://www.wto.org/english/docs_e/legal_e/legal_e.htm
38	General Agreement on Tariffs and Trade	1947	global	WTO	https://www.wto.org/english/docs_e/gattdocs_e.htm
39	1989 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal	1989	global	UNEP	http://www.basel.int/TheConvention/Overview/TextoftheConvention/tabid/1275/Default.aspx

40	African Convention on the Conservation of Nature and Natural Resources	1968	regional	OAU/AEC	http://www.au.int/en/content/african-convention-conservation-nature-and-natural-resources-revised-version
41	Treaty Establishing the African Economic Community	1991	regional	OAU/AEC	http://www.wipo.int/wipolex/en/profile.jsp?code=AEC
42	Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade	1998	global	UNEP/FAO	http://www.pic.int/TheConvention/Overview/TextoftheConvention/tabid/1048/language/en-US/Default.aspx
43	Convention on Environmental Impact Assessment in a Transboundary Context (in short Espoo Convention)	1991	regional	UNECE	http://www.unece.org/env/eia/eia.html
44	Convention on the Transboundary Effects of Industrial Accidents	1992	regional	UNECE	http://www.unece.org/env/teia/about.html
45	Convention on the Protection and use of Transboundary Water courses and International Lakes	1992	regional	UNECE	http://www.unece.org/env/water/text/text.html
46	The World Charter for Nature 37/7	1982	global	UN	http://www.un-documents.net/a37r7.htm

47	Ramsar Convention	1971	global	IUCN	http://archive.ramsar.org/cda/ramsar/display/main/main.jsp?zn=ramsar&cp=1-31-38_4000_0__
48	Convention on the Law of the Non-Navigational Uses of International Watercourses (Watercourses Convention)	1997	regional	UN	https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXVII-12&chapter=27&lang=en
49	1979 Convention on Long-Range Transboundary Air Pollution	1979	regional	UNECE	http://www.unece.org/env/lrtap/lrtap_h1.html
50	Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on Long-Term Financing of the Cooperative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe	1984	regional	UNECE	http://www.unece.org/env/lrtap/emep_h1.html
51	Charter on Groundwater Management	1989	regional	UNECE	http://www.internationalwaterlaw.org/documents/regionaldocs/groundwater_charter.html
52	International Convention for the Prevention of Pollution from Ships (MARPOL)	1973	global	IMO	http://www.imo.org/KnowledgeCentre/ReferencesAndArchives/HistoryofMARPOL/Pages/default.as

					px
53	COUNCIL DIRECTIVE 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances	1996	regional	EU	http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:31996L0082
54	DIRECTIVE 2003/4/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 28 January 2003 on public access to environmental information and repealing Council Directive 90/313/EEC	2003	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32003L0004
55	Treaty on the Functioning of the European Union	1958 (2007)	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:12012E/TXT&from=EN
56	COUNCIL DIRECTIVE 98/83/EC of 3 November 1998 on the quality of water intended for human consumption	1998	regional	EU	http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:31998L0083
57	Regulation 2003/2003 of the European Parliment and of the Council of 13 October 2003 relating to fertilizers	2003	regional	EU	http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32003R2003

58	COUNCIL DIRECTIVE 91/692/EEC of 23 December 1991 standardizing and rationalizing reports on the implementation of certain Directives relating to the environment	1991	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31991L0692
59	COUNCIL DIRECTIVE 90/656/EEC of 4 December 1990 on the transitional measures applicable in Germany with regard to certain Community provisions relating to the protection of the environment	1990	regional	EU	http://eur-lex.europa.eu/legal-content/LV/TXT/;ELX_SESSIONID=vHCJJ4gfPfc1mZzr1pPlPnsX4TRCKSyWG2QtlVM0LTLWhHPyVcKB!-2075031620?uri=CELEX:31990L0656
60	Council Directive of 15 July 1980 on air quality limit values and guide values for sulphur dioxide and suspended particulates (80/779/EEC)	1980	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31980L0779
61	Council Directive of 7 March 1985 on air quality standards for nitrogen dioxide (85/203/EEC)	1985	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31985L0203
62	COUNCIL DIRECTIVE of 28 June 1984 on the combating of air pollution from industrial plants (84/360/EEC)	1984	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31984L0360

63	COUNCIL DIRECTIVE of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture (86/278/EEC)	1986	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31986L0278
64	COUNCIL DIRECTIVE of 4 May 1976 on pollution caused by certain dangerous substances discharged into the aquatic environment of the Community (76/464/EEC)	1976	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31976L0464
65	Council Directive of 27 1967 on the approximation of laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances (67/548/EEC)	1967	regional	EU	http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:31967L0548
66	Commission Directive 91/155/EEC of 5 March 1991 defining and laying down the detailed arrangements for the system of specific information relating to dangerous preparations in implementation of Article 10 of Directive 88/379/EEC	1991	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31991L0155

67	Regulation (EC) No 648/2004 of the European Parliament and of the Council of 31 March 2004 on detergents	2004	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32004R0648
68	DIRECTIVE 1999/45/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 31 May 1999 concerning the approximation of the laws, regulations and administrative provisions of the Member States relating to the classification, packaging and labelling of dangerous preparations	1999	regional	EU	http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:31999L0045
69	Council Directive 76/769/EEC of 27 July 1976 on the approximation of the laws, regulations and administrative provisions of the Member States relating to restrictions on the marketing and use of certain dangerous substances and preparations	1976	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31976L0769
70	Directive 98/8/EC of the European Parliament and of the Council of 16 February 1998 concerning the placing of	1998	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:31998L0008

	biocidal products on the market				
71	Council Directive of 27 July 1976 on the approximation of laws of the Member States relating to cosmetic products (76/768)	1976	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=URISERV:l21191
72	Convention for the Protection of the Marine Environment of the North-East Atlantic	1992	regional	OSPAR	https://www.ospar.org/convention/text
73	Council Directive 70/156/EEC of 6 February 1970 on the approximation of the laws of the Member States relating to the type-approval of motor vehicles and their trailers	1970	regional	EU	http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:31970L0156
74	Convention for the Protection of the Natural Resources and Environment of the South Pacific Region	1986	regional	SPREP	https://www.sprep.org/legal/the-convention
75	Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean	1976	regional	UNEP	http://www.unepmap.org/index.php?module=content2&catid=001001004
76	Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	1983	regional	UNEP-CAR/RCU	http://www.cep.unep.org/cartagena-convention/text-of-the-cartagena-convention

77	Agreement on Implementation of Article VI of the general agreement on Tariffs and Trade 1994	1994	global	WTO	https://www.wto.org/english/res_e/booksp_e/analytic_index_e/anti_dumping_e.htm
78	1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter	1996	global	IMO	http://www.imo.org/en/OurWork/Environment/PollutionPrevention/Pages/1996-Protocol-to-the-Convention-on-the-Prevention-of-Marine-Pollution-by-Dumping-of-Wastes-and-Other-Matter,-1972.aspx
79	Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources and Activities	1996	regional	UNEP	http://www.unep.ch/regionalseas/main/med/mlbsprot.html
80	Directive 2006/7/EC of the European Parliament and of the Council of 15 February 2006 concerning the management of bathing water quality and repealing Directive 76/160/EEC	2006	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32006L0007
81	Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial	2007	regional	EU	http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32007L0002

	Information in the European Community				
82	Commission Regulation (EC) No 1235/2008 of 8 December 2008 laying down detailed rules for implementation of Council Regulation (EC) No 834/2007 as regards the arrangements for imports of organic products from third countries	2008	regional	EU	http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32008R1235
83	Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91	2007	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32007R0834
84	Council Directive 96/25/EC of April 1996 on the circulation of feed materials, amending Directives 70/524/EEC, 74/63/EEC, 82/471/EEC and 93/74/EEC and repealing Directive 77/101/EEC	1996	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:31996L0025
85	Council Directive of 30 June 1982 concerning certain products used in animal nutrition (82/471/EEC)	1982	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:31982L0471
86	Council	1996	regional	EU	http://eur-

	Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control				lex.europa.eu/legal-content/EN/TXT/?uri=celex:31996L0061
87	Protocol of Provisional Application of the General Agreement	1948	global	WTO	https://www.wto.org/english/res_e/booksp_e/gatt_ai_e/prov_appl_gen_agree_e.pdf
88	Council Directive of 15 July 1980 on the approximation of the laws of the Member States relating to straight ammonium nitrate fertilizers of high nitrogen content (80/876/EEC)	1980	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:31980L0876
89	Council Directive of 26 June 1978 on the approximation of the laws of the Member States relating to the classification, packaging and labelling of dangerous preparations (pesticides) (78/631/EEC)	1978	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31978L0631
90	Directive 2008/105/EC of the European Parliement and of the Council of 16 December 2008 on environmental quality standards in the field of water policy, amending and	2008	regional	EU	http://faolex.fao.org/cgi-bin/faolex.exe?rec_id=068466&database=faolex&search_type=link&table=result&lang=eng&format_name=@ERALL

	subsequently repealing Council Directives 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council				
91	Directive 2006/44/EC of the European Parliment and of the Council of 6 September 2006 on the quality of fresh waters needing protection or improvement in order to protect fish life	2006	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32006L0044
92	United Nations Convention on the Law of the Sea	1958	global	UN	http://www.un.org/Depts/los/convention_agreements/convention_overview_convention.htm
93	Directive 2001/80/EC of the European Parliament and of the Council of 23 October 2001 on the limitation of emissions of certain pollutants into the air from large combustion plants	2001	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32001L0080&from=EN
94	Directive 2000/76/EC of the European Parliament and of the Council of 4 December	2000	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32000

	2000 on the incineration of waste				L0076&from=EN
95	Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe	2008	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0050&from=EN
96	Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain atmospheric pollutants	2001	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32001L0081&from=EN
97	Council Directive of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment (85/337)	1985	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31985L0337&from=EN
98	Convention on Biological Diversity	1992	global	CBD	https://www.cbd.int/doc/legal/cbd-en.pdf
99	United Nations Framework Convention on Climate Change	1992	global	UNFCCC	https://unfccc.int/resource/docs/convkp/conveng.pdf

REVISED – October 2017

List of interviewees for Case Study (GPNM)

I1	University professor	Institute strategic policy University, The Netherlands
I2	CEO/Professor	Independent research institute University, The Netherlands
I3	Anonymous A	
I4	Programme Officer	UNEP
I5	Environmental Affairs Officer	UNECE
I6	Anonymous B	
I7	Project manager /Coordinator	Research Organization, UK/Task Force on Reactive Nitrogen
I8	Environmental Affairs Officer	Convention on Biological Diversity
I9	Representative	Ministry of Infrastructure and Environment, The Netherlands

REVISED – October 2017

ABBREVIATIONS AND ACRONYMS

EU	European Union
FAO	Food and Agriculture Organisation
GEF	Global Environment Facility
GPA	Global Programme of Action for the Protection of the Marine Environment from Land-based Activities
GPNM	Global Partnership on Nutrient Management
IMO	International Maritime Organization
INI	International Nitrogen Initiative
IUCN	International Union for Conservation of Nature
MEA	Multilateral environmental agreement
N	Nitrogen
NAFTA	North American Free Trade Agreement
P	Phosphorus
OAU/AEC	Organization of African Unity/African Economic Community
OSPAR	Oslo/Paris convention (for the Protection of the Marine Environment of the North-East Atlantic)
SNA	Social Network Analysis
SPREP	Secretariat of the Pacific Regional Environment Programme
UN	United Nations
UNCBD	United Nations Convention on Biological Diversity
UNCLOS	United Nations Convention on the Law of the Sea
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WTO	World Trade Organisation

Supplementary Materials for

Governance, polycentricity and the global nitrogen and phosphorus cycle

List of legal instruments and links

Agreement number	Title	Adoption	Geographical Scope	Secretariat	Hyperlink
1	Convention on the Protection of the Black Sea against Pollution	1992	regional	UNEP	http://www.blacksea-commission.org/_convention.asp
2	Protocol on Pollutant Release and Transfer Registers to the Convention on Access to Information, Public-Participation in Decision-Making and Access to Justice in Environmental Matters	2003	regional	UNECE	https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-13-a&chapter=27&lang=en
3	Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution to Abate Acidification, Eutrophication and Ground-Level Ozone	1999	regional	UNECE	https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-1-h&chapter=27&lang=en
4	Protocol concerning Pollution from Land-Based sources and activities to the Convention for the Protection and Development of	1999	regional	UNEP	http://www.cep.unep.org/cartagena-convention/lbs-protocol/lbs-protocol/lbs-protocol-english/view

	the Marine Environment of the Wider Caribbean Region				
5	Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters	1998	regional	UNECE	http://www.unece.org/env/pp/treatytext.html
6	Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on Persistent Organic Pollutants	1998	regional	UNECE	http://www.unece.org/env/lrtap/pops_h1.html
7	Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on Heavy Metals	1998	regional	UNECE	http://www.unece.org/env/lrtap/hm_h1.html
8	Convention on Cooperation for the Protection and Sustainable Use of the Danube River	1994	regional	icpdr	https://www.icpdr.org/main/icpdr/danube-river-protection-convention
9	Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on further Reduction of Sulphur Emissions	1994	regional	UNECE	http://www.unece.org/env/lrtap/fsulf_h1.html
10	Protocol on the Protection of the Black Sea Marine Environment against Pollution by	1992	regional	UNEP	http://www2.unitar.org/cwm/publications/cbl/synergy/pdf/cat3/UNEP_regional_seas/convention_buc

	Dumping				harest_prots/protocol_dumping.pdf
11	Protocol on the Protection of the Black Sea Marine Environment against Pollution from Land-Based Sources	1992	regional	UNEP	http://www.blacksea-commission.org/_convention-protocols.asp
12	Convention on the Protection of the Marine Environment of the Baltic Sea Area	1992	regional	UNEP	http://helcom.fi
13	Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution concerning the Control of Emissions of Volatile Organic Compounds or their Transboundary Fluxes	1991	regional	UNECE	http://www.unece.org/env/lrtap/vola_h1.html
14	Protocol for the Protection of the Marine Environment against Pollution from Land-Based Sources	1990	regional	UNEP	http://www2.unitar.org/cwm/publications/cbl/synergy/pdf/cat3/UNEP_regional_seas/convention_kuwait/Protocols/protocol_prot_marine_env_against.pdf
15	Regulation No.83: Uniform provisions concerning the approval of vehicles with regard to the emission of pollutants according to engine fuel	1989	global	UN	https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XI-B-16-83&chapter=11&lang=en

	requirements				
16	Protocol to the Convention on Long-Range Transboundary Air Pollution concerning the Control of Emissions of Nitrogen Oxides or their Transboundary Fluxes	1988	regional	UNECE	https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-1-c&chapter=27&lang=en
17	Protocol for the Prevention of Pollution of the South Pacific Region by Dumping	1986	regional	UNEP	https://www.sprep.org/legal/the-convention
18	Protocol to the 1979 Convention on Long-range Transboundary Air Pollution on the Reduction of Sulphur Emissions or their Transboundary Fluxes by at Least 30 per Cent	1985	regional	UNECE	http://www.unece.org/env/lrtap/sulf_h1.html
19	Vienna Convention for the Protection of the Ozone Layer	1985	global	UNEP	https://treaties.un.org/doc/Treaties/1988/09/19880922_03-14 AM/Ch_XXVII_02p.pdf
20	Regulation No.49: Uniform provisions concerning the measures to be taken against the emission of gaseous and particulate pollutants from compression-ignition engines for use in vehicles, and the emission of gaseous	1982	regional	UNECE	http://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29regs/R049r5e.pdf

	pollutants from positive-ignition engines fuelled with natural gas or liquefied petroleum gas for use in vehicles				
21	Regulation No.47: Uniform Provisions concerning the Approval of Mopeds equipped with a Positive-Ignition Engine with regard to the Emission of Gaseous Pollutants by the Engine	1981	regional	UN	https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XI-B-16-47&chapter=11&lang=en
22	Regulation No.40: Uniform Provisions concerning the Approval of Motor Cycles Equipped with a Positive-Ignition Engine with regard to the Emission of Gaseous Pollutants by the Engine	1979	regional	UN	https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XI-B-16-40&chapter=11&lang=en
23	Protocol for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft	1976	regional	UNEP	http://www.unepmap.org/index.php?module=content2&catid=001001001
24	Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter	1972	global	IMO	http://www.imo.org/About/Conventions/ListOfConventions/Pages/Convention-on-the-Prevention-of-Marine-Pollution-by-Dumping-of-Wastes-and-Other-Matter.aspx

25	Regulation No. 15: Uniform Provisions concerning the Approval of Vehicles Equipped with a Positive-Ignition Engine or with a Compression-Ignition engine with regard to the Emission of Gaseous Pollutants by the Engine - Method of Measuring the Fuel Consumption of Vehicles	1970	regional	UN	https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XI-B-16-15&chapter=11&lang=en
26	Bamako Convention on the Ban of the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa	1991	regional	AN	http://www.unep.org/delc/BamakoConvention/BamakoBackgroundDocuments/tabid/106424/Default.aspx
27	Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (In short: EU Water Framework Directive)	2000	regional	EU	http://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:32000L0060
28	DIRECTIVE 2008/56/EC OF THE EUROPEAN PARLIAMENT AND OF THE	2008	regional	EU	http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:32008L005

	COUNCIL of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive) (In short: Marine Strategy Framework Directive)				6
29	Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (IN short: Nitrates Directive (1991))	1991	regional	EU	http://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:31991L0676
30	Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment	1991	regional	EU	http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:31991L0271
31	URUGUAY ROUND AGREEMENT Agreement on Agriculture	1995	global	WTO	https://www.wto.org/english/docs_e/legal_e/14-ag_01_e.htm
32	Commission Regulation (EC) No 889/2008 of September 2008 laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007 on organic prodution and	2008	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2008.250.01.0001.01.ENG

	labelling of organic products with regard to organic production, labelling and control				
33	North American Free Trade Agreement (NAFTA)	1994	regional	NAFTA	https://www.nafta-sec-alena.org/Home/Legal-Texts/North-American-Free-Trade-Agreement
34	World Trade Organization Agreement on Government Procurement (WTO-AGP)	2012	global	WTO	https://www.wto.org/english/tratop_e/gproc_e/gp_gpa_e.htm
35	Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement)	2001	global	WTO	https://www.wto.org/english/tratop_e/sps_e/spsagr_e.htm
36	Agreement on Trade-Related Aspects of Intellectual Property Rights	1994	global	WTO	https://www.wto.org/english/tratop_e/trips_e/t_agm0_e.htm
37	Marrakesh Agreement establishing the World Trade Organisation	1994	global	WTO	https://www.wto.org/english/docs_e/legal_e/legal_e.htm
38	General Agreement on Tariffs and Trade	1947	global	WTO	https://www.wto.org/english/docs_e/gattdocs_e.htm
39	1989 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal	1989	global	UNEP	http://www.basel.int/TheConvention/Overview/TextoftheConvention/tabid/1275/Default.aspx

40	African Convention on the Conservation of Nature and Natural Resources	1968	regional	OAU/AEC	http://www.au.int/en/content/african-convention-conservation-nature-and-natural-resources-revised-version
41	Treaty Establishing the African Economic Community	1991	regional	OAU/AEC	http://www.wipo.int/wipolex/en/profile.jsp?code=AEC
42	Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade	1998	global	UNEP/FAO	http://www.pic.int/TheConvention/Overview/TextoftheConvention/tabid/1048/language/en-US/Default.aspx
43	Convention on Environmental Impact Assessment in a Transboundary Context (in short Espoo Convention)	1991	regional	UNECE	http://www.unece.org/env/eia/eia.html
44	Convention on the Transboundary Effects of Industrial Accidents	1992	regional	UNECE	http://www.unece.org/env/teia/about.html
45	Convention on the Protection and use of Transboundary Water courses and International Lakes	1992	regional	UNECE	http://www.unece.org/env/water/text/text.html
46	The World Charter for Nature 37/7	1982	global	UN	http://www.un-documents.net/a37r7.htm

47	Ramsar Convention	1971	global	IUCN	http://archive.ramsar.org/cda/ramsar/display/main/main.jsp?zn=ramsar&cp=1-31-38_4000_0__
48	Convention on the Law of the Non-Navigational Uses of International Watercourses (Watercourses Convention)	1997	regional	UN	https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXVII-12&chapter=27&lang=en
49	1979 Convention on Long-Range Transboundary Air Pollution	1979	regional	UNECE	http://www.unece.org/env/lrtap/lrtap_h1.html
50	Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on Long-Term Financing of the Cooperative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe	1984	regional	UNECE	http://www.unece.org/env/lrtap/emep_h1.html
51	Charter on Groundwater Management	1989	regional	UNECE	http://www.internationalwaterlaw.org/documents/regionaldocs/groundwater_charter.html
52	International Convention for the Prevention of Pollution from Ships (MARPOL)	1973	global	IMO	http://www.imo.org/KnowledgeCentre/ReferencesAndArchives/HistoryofMARPOL/Pages/default.aspx

53	COUNCIL DIRECTIVE 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances	1996	regional	EU	http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:31996L0082
54	DIRECTIVE 2003/4/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 28 January 2003 on public access to environmental information and repealing Council Directive 90/313/EEC	2003	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32003L0004
55	Treaty on the Functioning of the European Union	1958 (2007)	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:12012E/TXT&from=EN
56	COUNCIL DIRECTIVE 98/83/EC of 3 November 1998 on the quality of water intended for human consumption	1998	regional	EU	http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:31998L0083
57	Regulation 2003/2003 of the European Parliment and of the Council of 13 October 2003 relating to fertilizers	2003	regional	EU	http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32003R2003
58	COUNCIL DIRECTIVE	1991	regional	EU	http://eur-lex.europa.eu/l

	91/692/EEC of 23 December 1991 standardizing and rationalizing reports on the implementation of certain Directives relating to the environment				egal-content/EN/TXT/?uri=CELEX:31991L0692
59	COUNCIL DIRECTIVE 90/656/EEC of 4 December 1990 on the transitional measures applicable in Germany with regard to certain Community provisions relating to the protection of the environment	1990	regional	EU	http://eur-lex.europa.eu/legal-content/LV/TXT/;ELX_SESSIONID=vHCJJ4gfPfc1mZzr1pPlPnsX4TRCKSyWG2QtlVM0LTLWhHPyVcKB!-2075031620?uri=CELEX:31990L0656
60	Council Directive of 15 July 1980 on air quality limit values and guide values for sulphur dioxide and suspended particulates (80/779/EEC)	1980	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31980L0779
61	Council Directive of 7 March 1985 on air quality standards for nitrogen dioxide (85/203/EEC)	1985	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31985L0203
62	COUNCIL DIRECTIVE of 28 June 1984 on the combating of air pollution from industrial plants (84/360/EEC)	1984	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31984L0360
63	COUNCIL DIRECTIVE of 12 June 1986 on	1986	regional	EU	http://eur-lex.europa.eu/legal-

	the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture (86/278/EEC)				content/EN/TXT/?uri=CELEX:31986L0278
64	COUNCIL DIRECTIVE of 4 May 1976 on pollution caused by certain dangerous substances discharged into the aquatic environment of the Community (76/464/EEC)	1976	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31976L0464
65	Council Directive of 27 1967 on the approximation of laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances (67/548/EEC)	1967	regional	EU	http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:31967L0548
66	Commission Directive 91/155/EEC of 5 March 1991 defining and laying down the detailed arrangements for the system of specific information relating to dangerous preparations in implementation of Article 10 of Directive 88/379/EEC	1991	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31991L0155
67	Regulation (EC) No 648/2004 of the European Parliament and	2004	regional	EU	http://eur-lex.europa.eu/legal-content/EN/T

	of the Council of 31 March 2004 on detergents				XT/?uri=CELEX:32004R0648
68	DIRECTIVE 1999/45/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 31 May 1999 concerning the approximation of the laws, regulations and administrative provisions of the Member States relating to the classification, packaging and labelling of dangerous preparations	1999	regional	EU	http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:31999L0045
69	Council Directive 76/769/EEC of 27 July 1976 on the approximation of the laws, regulations and administrative provisions of the Member States relating to restrictions on the marketing and use of certain dangerous substances and preparations	1976	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31976L0769
70	Directive 98/8/EC of the European Parliament and of the Council of 16 February 1998 concerning the placing of biocidal products on the market	1998	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:31998L0008
71	Council	1976	regional	EU	http://eur-

	Directive of 27 July 1976 on the approximation of laws of the Member States relating to cosmetic products (76/768)				lex.europa.eu/legal-content/EN/TXT/?uri=URISERV:l21191
72	Convention for the Protection of the Marine Environment of the North-East Atlantic	1992	regional	OSPAR	https://www.ospar.org/convention/text
73	Council Directive 70/156/EEC of 6 February 1970 on the approximation of the laws of the Member States relating to the type-approval of motor vehicles and their trailers	1970	regional	EU	http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:31970L0156
74	Convention for the Protection of the Natural Resources and Environment of the South Pacific Region	1986	regional	SPREP	https://www.sprep.org/legal/the-convention
75	Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean	1976	regional	UNEP	http://www.unepmap.org/index.php?module=content2&catid=001001004
76	Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	1983	regional	UNEP-CAR/RCU	http://www.cep.unep.org/cartagena-convention/text-of-the-cartagena-convention
77	Agreement on Implementation of Article VI of the general agreement on	1994	global	WTO	https://www.wto.org/english/res_e/booksp_e/analytic_index_e/anti_dum

	Tariffs and Trade 1994				ping_e.htm
78	1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter	1996	global	IMO	http://www.imo.org/en/OurWork/Environment/PollutionPrevention/Pages/1996-Protocol-to-the-Convention-on-the-Prevention-of-Marine-Pollution-by-Dumping-of-Wastes-and-Other-Matter,-1972.aspx
79	Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources and Activities	1996	regional	UNEP	http://www.unep.ch/regionalseas/main/med/mlbsprot.html
80	Directive 2006/7/EC of the European Parliament and of the Council of 15 February 2006 concerning the management of bathing water quality and repealing Directive 76/160/EEC	2006	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32006L0007
81	Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community	2007	regional	EU	http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32007L0002
82	Commission Regulation (EC)	2008	regional	EU	http://eur-lex.europa.eu/l

	No 1235/2008 of 8 December 2008 laying down detailed rules for implementation of Council Regulation (EC) No 834/2007 as regards the arrangements for imports of organic products from third countries				egal-content/EN/ALL/?uri=CELEX:32008R1235
83	Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91	2007	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32007R0834
84	Council Directive 96/25/EC of April 1996 on the circulation of feed materials, amending Directives 70/524/EEC, 74/63/EEC, 82/471/EEC and 93/74/EEC and repealing Directive 77/101/EEC	1996	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:31996L0025
85	Council Directive of 30 June 1982 concerning certain products used in animal nutrition (82/471/EEC)	1982	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:31982L0471
86	Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution	1996	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:31996L0061

	prevention and control				
87	Protocol of Provisional Application of the General Agreement	1948	global	WTO	https://www.wto.org/english/res_e/booksp_e/gatt_ai_e/prov_appl_gen_agree_e.pdf
88	Council Directive of 15 July 1980 on the approximation of the laws of the Member States relating to straight ammonium nitrate fertilizers of high nitrogen content (80/876/EEC)	1980	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:31980L0876
89	Council Directive of 26 June 1978 on the approximation of the laws of the Member States relating to the classification, packaging and labelling of dangerous preparations (pesticides) (78/631/EEC)	1978	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31978L0631
90	Directive 2008/105/EC of the European Parliement and of the Council of 16 December 2008 on environmental quality standards in the field of water policy, amending and subsequently repealing Council Directives 82/176/EEC, 83/513/EEC,	2008	regional	EU	http://faolex.fao.org/cgi-bin/faolex.exe?rec_id=068466&database=faolex&search_type=link&table=result&lang=eng&format_name=@ERALL

	84/156/EEC, 84/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council				
91	Directive 2006/44/EC of the European Parliment and of the Council of 6 September 2006 on the quality of fresh waters needing protection or improvement in order to protect fish life	2006	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32006L0044
92	United Nations Convention on the Law of the Sea	1958	global	UN	http://www.un.org/Depts/los/convention_agreements/convention_overview_convention.htm
93	Directive 2001/80/EC of the European Parliament and of the Council of 23 October 2001 on the limitation of emissions of certain pollutants into the air from large combustion plants	2001	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32001L0080&from=EN
94	Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the incineration of waste	2000	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32000L0076&from=EN
95	Directive 2008/50/EC of	2008	regional	EU	http://eur-lex.europa.eu/l

	the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe				egal-content/EN/TXT/PDF/?uri=CELEX:32008L0050&from=EN
96	Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain atmospheric pollutants	2001	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32001L0081&from=EN
97	Council Directive of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment (85/337)	1985	regional	EU	http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31985L0337&from=EN
98	Convention on Biological Diversity	1992	global	CBD	https://www.cbd.int/doc/legal/cbd-en.pdf
99	United Nations Framework Convention on Climate Change	1992	global	UNFCCC	https://unfccc.int/resource/docs/convkp/conveng.pdf

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IMO	International Maritime Organization
INI	International Nitrogen Initiative
IUCN	International Union for Conservation of Nature
MEA	Multilateral environmental agreement
N	Nitrogen
NAFTA	North American Free Trade Agreement
P	Phosphorus
OAU/AEC	Organization of African Unity/African Economic Community
OSPAR	Oslo/Paris convention (for the Protection of the Marine Environment of the North-East Atlantic)
SNA	Social Network Analysis
SPREP	Secretariat of the Pacific Regional Environment Programme
UN	United Nations
UNCBD	United Nations Convention on Biological Diversity
UNCLOS	United Nations Convention on the Law of the Sea
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WTO	World Trade Organisation