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Water quality trading schemes as a form of state intervention: Two case studies of state-market hybridization from Canada and New Zealand

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ABSTRACT

The agricultural sector is considered as an important contributor to diffuse nutrient pollution within watersheds. While hierarchical models of environmental governance are costly to implement when targeting diffuse pollution, market-based water quality trading (WQT) is viewed as a win–win solution. Based on economic incentives, WQT promoters suggest that it offers greater flexibility to implicated actors for attaining environmental goals within watersheds, provides private funds to finance agro-environmental practices and diversifies income sources for farmers. These programs, however, have produced few results, and where they are successful, WQT schemes appear strongly dependent on institutional support from public agencies. This paper explores the gap between what is theorized on WQT institutional operation and what occurs in practice. In particular, this work adopts a lens of *hybridization* to understand how institutional forms that emerge around WQT blend both market-based techniques, while retaining top-down hierarchical structures. Through analysis of two case studies – *South Nation Total Phosphorus Management Program* (Canada) and *Lake Taupo Nitrogen Trading Program* (New Zealand) – we argue that WQT programs serve as a novel intervention framework for public authorities to retain their influence on the way watershed management takes place. In both case studies, we find the state also uses the WQT discourse and established institutional structures to channel new funding sources, target a broader range of actors and manage a suite of environmental and socio-economic objectives. These new institutional arrangements reframe traditional modes of environmental management and affect the way private and public resources are used and distributed among implicated actors. Both case studies illustrate how hybrid forms of financing and governance strategies, in which heterogeneous private and public institutions are brought together, are a response to the transaction costs and particular socio-ecological contexts faced in the implementation of WQT.

1. Introduction

Nitrogen and phosphorus flows to marine and freshwaters have significantly increased over the last century and have led to eutrophication problems worldwide (Vilmin et al., 2018). The agricultural sector has been recognized as one of the main contributors of nutrient emissions and pollution (Hall and Raffini, 2005; Mariola, 2011). Agricultural emissions are commonly considered as non-point source or diffuse pollution, characterized by random and intermittent occurrence, and influenced by a number of different drivers, e.g. land use, soil type, management practices (Hu and Huang, 2014). Diffuse pollution is inherently difficult to control, monitor and effectively regulate (Duncan, 2017), and as a result, top-down systems of environmental governance that engage farmers to address diffuse nutrient pollution are costly to implement (Woodward and Kaiser, 2002). In this context, alternative models of governance, such as water quality trading (WQT) have been considered as a promising and cost-effective way to address nutrient pollution.

WQT schemes are market-oriented mechanisms in which participants can voluntarily exchange their water pollution rights with respect to certain biophysical criteria related to water quality improvement (Stephenson and Shabman, 2011). These schemes are often hailed as win–win solutions as they are expected to reduce the costly regulatory burden of the state while mobilizing new sources of private funding to address water quality issues. WQT also provide new sources of revenue to farmers through direct payments for nutrient credit offsets and offer greater flexibility to polluters in achieving environmental goals (Abdalla et al., 2007; Corrales et al., 2013; Ribaudo and Gottlieb, 2011). Despite the tendency towards market transactions in WQT schemes, the state remains an important actor, responsible for setting

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nutrient emissions limits and for providing the regulatory context in which these trading programs operate (Hahn et al., 2015; Lemos and Agrawal, 2006).

To date, analyses of WQT systems have focused on schemes in the United States and have concluded that there is insufficient internal motivation on the part of private actors for WQT to ensure their self-regulation and that the active participation of the state is essential for the proper functioning of programs (Abdalla et al., 2007; GAO, 2017; King, 2005; Mariola, 2011; Ribaudo and Gottlieb, 2011; Ribaudo and Nickerson, 2009; Shabman et al., 2002; Shortle, 2013). Typically, the concept of *hybridization* has been used to understand the cohabitation of plural forms of governance within ecosystem service programs (Mariola, 2011; Shapiro-Garza, 2013). It refers to the coexistence and coordination of market-based approaches and regulations sustained by the power of public authorities. It also refers to the ways in which local actors adapt, modify, and re-work program goals and approaches according to their particular context (Van Hecken et al., 2018).

In applying the concept of hybridization, we explore the gap between what is theorized on WQT institutional operation and what occurs in practice. This paper examines the role of public authorities in the development and application of two WQT programs: *South Nation Total Phosphorus Management Program (TPMP)* (Canada) and *Lake Taupo Nitrogen Trading Program (LTNTP)* (New Zealand). In particular, we extend the application of the hybridization lens to the analysis - of not only the structures - but also the source and allocation of private and public financial resources in the development of WQT programs. As a result, we characterize the forms of structural and financial hybridization in both case studies. Our work addresses the question of how the hybridization of the institutions around market-based mechanisms may similarly influence the source and allocation of financial resources, and the impact on program design, scope and outcomes.

In the following Section 2, we discuss the literature on WQT and how it can be assessed through the concept of hybridization. Section 3 presents the two case studies, focusing on their structures of funding and allocation of resources. The Section 4 is a discussion of the implication of public authorities, the hybrid structures developing around financial elements and on the issue of transaction costs. Finally, Section 5 concludes with a summary of the content and ways forward.

2. Background & theoretical context

2.1. Market-based mechanisms and the provision of ecosystem services

Payments for ecosystem services (PES) cover the broad range of mechanisms that seek to influence environmental behaviour through the use of economic incentives by bringing beneficiaries and potential ecosystem service providers into negotiation over land-use management to deliver particular ecosystem services (Muradian, 2013). These mechanisms can cover different organizational forms of coordination including markets, hierarchies, but also hybrid structures as defined in neo-institutional economics (Vaissière and Levrel, 2015). However, most market-based instruments adopt economic incentives to affect agents' behaviors without creating a true market structure (Muradian and Gómez-Baggethun, 2013). Hahn et al. (2015) distinguish between instruments processing through an alteration of price signals (*e.g.* taxes) and those which imply the complete constitution of a market structure. These two categories of market-based instruments can be configured in complex ways within existing programs. Therefore, while public payments are pervasive within WQT schemes and PES programs at large, Vatn (2010) underlines that private payments represent also a mode of transfer within hierarchical structures of governance and considers markets for environmental services (such as WQT) as a restricted category inside the broader family of PES.

Given the difficulty in defining PES, an important debate pertains to the characteristics of such arrangements, and whether they are primarily public or private in nature (Milne and Adams, 2012; Muradian and Gómez-Baggethun, 2013; Sandbrook et al., 2013). Ezzine-De-Blas et al. (2016) use the financing criterion to distinguish public from private schemes. Methodologically, financing appears as a focal point since it becomes possible to explore the origins of payments and allows for an examination of resource distribution within a scheme. Of importance, they claim that public schemes include programs where the "public sector entity acts as collector and custodian of PES funding" (p. 2). Many scholars thus refute a plain opposition between market-based instruments and regulatory structures (Gómez-Baggethun and Muradian, 2015; Hahn et al., 2015; Lemos and Agrawal, 2006; Vatn, 2010). Moreover, they defend the "*complementary nature of command and voluntary approaches*" in environmental governance, stressing that markets for environmental services require an important regulatory framework to operate effectively and point out the "*reconfiguration of state-market-community relationships*". In this perspective, PES can be seen as "*another way of using the capacities and funds of states and communities* [rather] *than about abandoning them*" (Vatn, 2010).

2.2. Water quality trading programs and transaction costs

Water quality trading is a tradable permits scheme, in which public authorities impose a pollution emission cap, i.e. an allowable global level of pollutant discharge within a watershed. Discharge allowances are then distributed amongst identified polluting actors and take the form of permits specifying the allowable quantity of pollutant to be discharged within a specific time-scale. Through the creation of WQT, a greater flexibility is provided to polluters (dischargers) in how to achieve pollution reduction, while the exchange provides an additional source of income to the credit providers. Water quality trading is used to address numerous pollution issues including elevated nutrient or sediment concentrations, high water temperatures or salinity (Corrales et al., 2013; Greenhalgh and Selman, 2012; Kerr et al., 2015). However, used as an agro-environmental policy, WQT mainly targets diffuse nitrogen and phosphorus pollution (Selman et al., 2009).

Despite empirical evidences of cost savings related to trades between point and nonpoint sources exist (Ribaudo and Gottlieb, 2011: p. 11), there is a near-inexistence of trading schemes established outside the United States, and anemic level of trades within the country (GAO, 2017; Shortle, 2013; Stephenson and Shabman, 2011). As stated by King (2005), water quality trading programs are confronted by "*a simple absence of willing buyers and sellers*" (p. 71). Numerous scholars recognize that, within WQT schemes, the demand for discharge allowances is institutionally created by legally imposing a cap for nutrient emissions on a watershed and concerned stakeholders (Abdalla et al., 2007; King, 2005; Ribaudo and Gottlieb, 2011; Ribaudo and Nickerson, 2009). Shabman et al. (2002) claim that (allowance) markets "*do not just happen*" and that they need to be accompanied by binding regulations in order to be implemented, which suggest that costs are borne by public authorities to insure compliance with regulations and to direct fund allocation (p. 154). The cost of monitoring is also a crucial component of transaction costs observed in water quality trading (Corrales et al., 2013: p. 89) and can overly burden WQT. Due to the watershed and farming practice specific nature of nutrient pollution from agriculture (Goyette et al., 2018), as well as temporal lags in nutrient movement (Van Meter and Basu, 2017), estimating allowable inputs and monitoring changes in water quality present challenging and costly elements in WQT.

The financing structure of a pollutant emission control scheme has important implications for its effectiveness and its sustainability (Pirard, 2012). Performance in the allocation and distribution of financial resources is therefore largely determined by transaction costs, such as brokering and administrative fees. The limits of market mechanisms are generally recognized within the literature on WQT. Woodward and Kaiser (2002) recuse the ideal of a perfect market and regard "*transaction costs as an inevitable consequence of market structure and [that] different structures yield different transaction-cost outcomes*" (p.

374).

2.3. Hybrid governance and financing mechanisms

As Pirard and Lapeyre (2014) emphasize, environmental policy increasingly involves "*many characteristics that simultaneously relate to regulation, free market exchanges, negotiations, distribution of monetary rewards, etc.*" (112). In this sense, policy does not fall into an unblemished category, but often actualizes as a policy mix. Environmental governance hence is neither exclusively private or public, but is rather a hybrid between both forms. Hybrid governance integrates elements from the two archetypes of coordination mechanisms - market and hierarchical - combining monetary transfers with authoritative control (Muradian, 2013). In the case of WQT, the high cost of commodifying ecosystem services in establishing and trading emissions credits related to water quality excludes the possibility of solely depending on market governance. The common-pool properties of many regulating ecosystem services, notably for water quality protection, make it equally difficult to implement command-driven regulation since no single actor is legally responsible.

In the literature, there are two perspectives on hybridization. A first one states that the formulation and implementation of environmental policies is affected *informally* by the behavior and interests of different stakeholders, including outside the policy-design phase, which influences final program design (Corbera, 2015; Froger et al., 2016; McAfee and Shapiro, 2010; Shapiro-Garza, 2013; Van Hecken et al., 2018). The second considers hybrid structures as a *formal* combination between different modes of governance (Lemos and Agrawal, 2006; Mariola, 2011; Muradian, 2013). For the purposes of this article, we concentrate on this second perspective, focusing on the state-market hybridization within the design and structure of WQT schemes.

Mariola (2011), in its study of WQT programs throughout the United States, conceives the role of public authorities in the case of WQT as *preemptive*. He states, "*what we witness is not social protections* following *a period of market expansion but environmental protections preceding and then* accompanying *a move to markets*" (p. 237–238). In this vein, public regulation is seen as a requirement for the market to appear. However, in his treatment of WQT structures, Mariola (2011) focuses on the institutional and regulatory hybridization of WQT schemes but does not assess the role of hybridization in the financing or payment structures of these programs. Understanding the origins of financing in WQT programs and their allocation across actors are equally important, though often unexplored, dimensions of hybridization. The contribution of the state versus private actors in funding the economic incentives provided in WQTs may have important implications for the programs aims, how it is run, and its eventual success.

Through the analysis of two WQT schemes – *South Nation Total Phosphorus Management Program* (Canada) and *Lake Taupo Nitrogen Trading Program* (New Zealand) in Section 3 – we argue that WQT can be approached as a new public intervention framework. The state uses WQT mechanisms to create new funding sources, to target a broader range of actors and to address a diversity of environmental and socio-economic objectives. This new institutional environment reframes traditional modes of environmental management and affects the way private and public resources are used and distributed amongst the stakeholders. Finally, both studies illustrate hybrid forms of governance in which heterogeneous modes of regulation are combined in order to adapt to the particular character of environmental issues and the complexity of socio-natural contexts.

3. Case studies

In this section we describe the two case studies WQT programs. To do this, an in-depth review of official documents, grey literature from stakeholders and experts' statements of the two case studies was carried out. A direct open-ended interview has been conducted with administrators of the TPMP scheme and communications were also conducted with program managers of the two programs. Firstly, we explore the South Nation Total Phosphorus Management Program (TPMP) which offers an example of hybridization in WQTs where non-point sources remain unregulated. Next, we turn to the Lake Taupo Nitrogen Trading Program (LTNTP), where contrary to TPMP, the WQT is employed to alleviate the costs of legal restrictions on farmers on the quantity of allowable nutrient emissions and is based on bilateral trades between permit sellers and buyers. For each case study, we provide an overview of the socio-ecological and regulatory setting in which the program evolves, a description of the structure of its funding and financial resource allocation, as well as the performance of the program since its inception.

Hence, our coverage of these two case studies is intended to understand specific dimensions of hybridization processes within WQT: i) how does the participation of public authorities in WQT programs influence the structure of the exchange mechanism? ii) Is the participation of public authorities in WQT programs accompanied by parallel financial support, and if so, how does this influence the functioning of the WQT? And iii) in what ways has the participation of public authorities contributed to outcomes of the WQT?

3.1. South Nation – Total Phosphorus Management Program (Ontario, Canada)

The South Nation Total Phosphorus Management Program (TPMP) takes place within the South Nation river's watershed, situated at the extreme South-East of the province of Ontario, Canada. In the 1990s, high concentrations of phosphorus have been observed in South Nation's watercourses, exceeding by 3–5 times Provincial Water Quality Objectives (Government of Canada, 2006). These high concentrations of nutrients have been mainly attributed to agricultural runoff (Conservation Ontario, 2003).

In 1998, the provincial Ministry of Environment stopped providing permits which previously allowed point sources to continue the emission of nutrients even where water quality doesn't respect concentration limits (South Nation Conservation, 2010). These deviation permits were justified by "*the high financial burdens that required improvements in wastewater treatment would impose on small communities to bring point source emissions into compliance with regulatory limits*" (O'Grady, 2011: p. 43). Hence, the regulators effectively imposed a "zero discharge" condition for new treatment plants or expansion of existing ones. (South Nation Conservation, 2010).

To alleviate the pressure imposed on point sources by the new regulation on phosphorus pollution, in 1999 the Ministry of Environment launched the TPMP. This plan went further by targeting agricultural non-point sources of pollution within the watershed, which are not formally regulated.

3.1.1. TPMP governance structure

The TPMP program is administered through the South Nation Conservation (SNC) Authority, one of 36 local watershed management bodies across the province mandated to deliver services and programs to protect and manage impacts on water and other natural resources (Conservation Ontario, 2003). Conservation Authorities are charitable or non-profit organizations that work partnership with all levels of government, landowners and many other organizations and with a board of directors appointed by local municipalities.

The TPMP is intended to provide a mechanism by which to transfer money from point sources to non-point sources for the implementation of agricultural best management practices to reduce phosphorus pollution and to offset new emissions (Conservation Ontario, 2003). Participation by municipalities (i.e. wastewater treatment plants) and/or industries in the TPMP is voluntary as a means to address and respect emissions quotas. As an alternative to the Program, the installation of on-site technological upgrades to reduce emissions is also possible, but

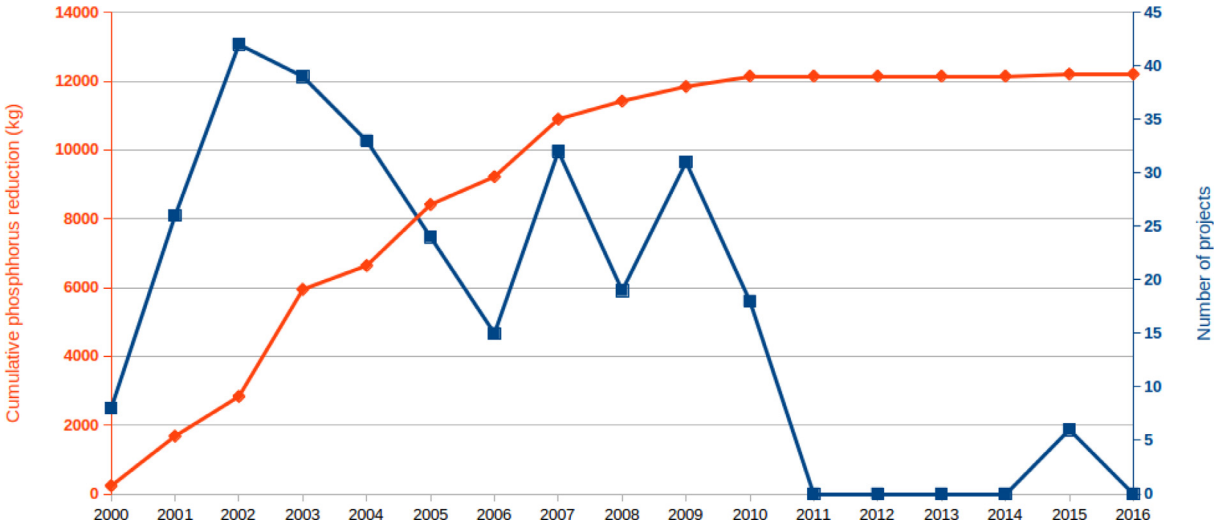

Fig. 1. Cumulative phosphorus reduction (kg) and number of projects in the TPMP (2000–2016). Source: South Nation Conservation (undated).

this option often remains prohibitively costly (*Ibid.*).

The TPMP is seen by the SNC as one element of a broader watershed plan. The SNC chairs the Clean Water Committee, a clearing house structure charged with administering payments deriving from point sources to offset their discharges. The committee is composed of representatives from the Ministry of Environment, the Ministry of Agriculture, farmers' organisations, municipalities and industries within the watershed. It defines the grants available for best management practices, establishes the conditions of approval and assess the projects submitted by landowners (Conservation Ontario, 2003). As a result the committee acts as a centralized structure linking credit providers (principally farmers implementing best management practices (BMP) on their lands) and buyers (wastewater treatment facilities). In the context of this program, credit providers are "*not bound, legally or otherwise*" to attain any concrete phosphorus reductions (*Ibid.*, p. 10). Rather, the credits they produce are considered as deregulated offset points, while the legal liability to ensure compliance with environmental policies remains the responsibility of point source dischargers. To ensure point sources achieve compliance, the TPMP enforces a 4:1 trading ratio, imposed by the Ministry of Environment. This requires that for each kilogram of phosphorus released by a point source, 4 kg needs to be offset by agro-environmental practices within the watershed (O'Grady, 2011). The accepted agro-environmental practices are limited to a list of *Best Management Practices* (BMP) assessed by algorithms based on the available scientific literature (South Nation Conservation, 2003).

3.1.2. Structure of funding and allocation of resources

As mentioned above, the SNC is charged with running the TPMP that falls within the SNC's Clean Water Program (CWP). The CWP is the main vehicle of the SNC to fund best management practices within the watershed to improve water quality. As such, the CWP "*provides the delivery mechanism for the TPMP*" and the latter can be considered as a supplementary source of funds for the CWP (South Nation Conservation, 2010, p. 10). On average, for the years where the data are accessible the TPMP's contribution to the annual budget of the CWP varied between 13% (2010) and 62% (2005) (South Nation Conservation, 2005, 2006, 2007, 2010, 2011). Other financial sources included a municipal levy, funds from provincial and federal authorities as well as donations from private companies (Conservation Ontario, 2003).

As funds to the TPMP are combined with existing public sources of financing, farmers receiving funding through the CWP are not aware whether the grants they receive originate from the financial contribution of point source payments or a subsidy program supported by regional and federal government. The SNC sees these grants not as a source of revenue for farmers, but as a means to help concretize agro-environmental measures in the watershed (O'Grady, 2011). The grants don't cover fully the costs of agro-environmental practices and act as incentives for their implementation. In the case of the TPMP, the economic instrument did not replace but rather complemented traditional approaches based on command-and-control policy. Conservation Ontario (2003: p. 9) appears to recognize a certain degree of hybridization in its functioning when it states that a "clear line cannot be drawn between economic instruments and command-and-control approaches, since many economic instruments incorporate elements of command-and-control".

3.1.3. Outcomes

Since 1994, the CWP has allocated $2.3 million (CAD) towards the adoption of best management practices, funding 742 projects, of which 293 were financed by the TPMP (http://www.nation.on.ca/clean-water-program [consulted October 12th, 2017]).

While it is difficult to assess the ecological impact of the TPMP in terms of water quality due to the long residence time of phosphorus in soils and groundwater (Kusmer et al., 2018), the program has been highly successful in terms of the engagement of point source actors, the number of actions implemented and anticipated benefits. According to estimations made through the use of SNC's emission reduction algorithms, the Program expects that projects financed by the TPMP between 2000 and 2016, would have reduced phosphorus emissions by 12 204 kg of phosphorus in the watershed, with an average of 718 kg per year (Fig. 1). However, after 2011, few additional projects were funded by the TPMP due to the fact that no expansions of existing point sources or new installations were installed during that period, highlighting the role of market demand in driving the program. However, as the TPMP program only regulates point-source emissions in the watershed, water quality may continue to deteriorate if exports from other actors continue to increase.

3.2. Lake Taupo Nitrogen Trading Program (Waikato, New Zealand)

In the beginning of 2000 s, regional authorities registered a gradual deterioration of water quality in the Lake Taupo watershed due to a growing concentration of nitrogen (Kerr et al., 2015). An important preoccupation of the regional council was the preservation of the lake's water quality to secure its attractivity for tourists (Roper et al., 2015). In response, the Waikato Regional Council – a local government body –

set an objective to recover the 2001 nitrogen levels by the year 2080 through its Regional Plan Variation 5 (Duhon et al., 2011). The Regional Plan Variation 5 is the legal framework supporting efforts to preserve Lake Taupo's water quality and it aims to share the economic costs of remedial action between local, regional and national levels.

Environmental governance within Lake Taupo's watershed is founded on three independent, but linked, elements. The first is a catchment-level cap on nitrogen discharge at 915 tonnes per year, applied globally across the watershed. The second is the LTNTP which allows non-point sources (farmers), under certain conditions, to exchange nitrogen discharge allowances amongst themselves. The third part involves the creation of the Lake Taupo Protection Trust (LTPT), an independent organization that aims to reduce nitrogen discharged within the watershed by 20% in order to recover 2001 nitrogen levels (Kerr et al., 2015).

3.2.1. LTNTP governance structure

Unlike most other WQT schemes, non-point sources are regulated within the LTNTP and are the primary actors between which credits are exchanged. Allowable discharge emissions are set on a farm-by-farm basis and farmers exceeding their allowable limits are required to purchase offsets credits from other farmers in the watershed. Farm-level baselines are assessed through a modelling software, OVERSEER, which estimates nitrogen export for each farm depending on its type, structure of production and characteristics (Connor et al., 2009). Farmers are permitted to select a baseline year between July 2001 and June 2005 against which their emissions allowances will be set. In essence, this corresponds to a "*grandfathering scheme where historical nitrogen losses determine future nitrogen allowances*" (Duhon et al., 2011: p. 6–7).

The use of OVERSEER is also compulsory for any change within the farm's structure of production or before the exchange of discharge allowances between farmers to estimate the size of the transaction in terms of nitrogen emissions (Duhon et al., 2011). Trades within the market are bilateral, in the sense that they occur directly between the two parties (i.e. farmer to farmer). To facilitate the encounter of potential buyers and sellers and reduce transaction costs, the Waikato Regional Council has put in place an online marketplace (*Ibid.*).

3.2.2. Structure of funding and allocation of resources

However, the catchment cap coupled to the Nitrogen Trading Program can only prevent a growth in nitrogen exports. To realize net environmental gains, the Regional Plan Variation 5 instituted the Lake Taupo Protection Trust. Established in 2007, this independent organization is required to achieve a 20% reduction in nitrogen discharges within the watershed by buying discharge allowances from farmers to remove them from further trading, effectively reducing the allowable emissions available in the watershed. The Trust also buys lands within the watershed to modify their use in reducing nitrogen exports (Roper et al., 2015). Moreover, the Trust financed the initial benchmarking of farm emissions to remove additional transaction costs and obstacles to participation in the Nitrogen Trading Program. They manage a public fund of $81.5 million NZ of which contributions are shared between the Taupo District Council, the Waikato Regional Council and the central government (Kerr et al., 2015).

The Lake Taupo Protection Trust is directly liable to a joint committee composed of representatives from the Ministry of Environment, the District Council, the Regional Council and the local maori tribe, the Ngati Tuwharetoa (http://www.laketaupoprotectiontrust.org.nz/page/lake_5.php [consulted January 17th, 2018]). This joint committee has also the responsibility to nominate the administrators at the head of the Lake Taupo Protection Trust (http://www.laketaupoprotectiontrust.org.nz/page/lake_6.php [consulted January 17th, 2018]).

3.2.3. Outcomes

Since the full effects of nitrate emissions on the watershed do not manifest themselves immediately it is also difficult in this case to assess the potential results of the program in terms of water quality (Waikato Regional Council, 2003). Indeed, according to the OECD (2015), the water residence time is estimated to be around 15 years, and nutrients can remain in underground aquifers for up to 100 years.

However, in 2015, the Lake Taupo Protection Trust carried out sufficient interventions to eliminate 170 300 kg of nitrate emissions in the watershed, corresponding to the fixed objective of 20% reduction (Lake Taupo Protection Trust, 2016). The present objective of the organisation is to concretize the signed contracts within the horizon of 2018/2019 (*Ibid.*). In the future, the Trust will continue to finance research within the program framework and to assure mediation between the different stakeholders (Lake Taupo Protection Trust, 2017). Because all actors in the watershed are regulated within the LTNTP, reductions in nutrient emissions from trading are likely to reflect reductions in total nutrient export in the watershed. However, lag times in nutrient movement may mask these changes in watershed nutrient loads in the near term.

Until 2014, nearly 66% of the realized transactions in the context of the program had been initiated by the Lake Taupo Protection Trust and correspond to approximately 90% of nitrate quantities traded. The remaining 34% reflects bilateral trades between farmers (see Table 1). In 2012, the price of nitrate kg was traded around 300$ NZ. However, it is important to underline that this price is greatly influenced by a single actor, the Lake Taupo Protection Trust (Kerr et al., 2015; OECD, 2015).

4. Analysis and discussion

4.1. The role of public authorities

In South Nation and Lake Taupo, public authorities play a major role at every stage of these programs and their support is essential to the implementation and functioning of the trading schemes. Public authorities are active actors in the recognition and definition of the problem, providing an official status and a legal framework to the program. They also provide financial, material, technical and symbolic resources, as well as ensure lawful enforcement of the rules.

In the two case studies presented, public authorities remain the initiators of the WQT schemes while preserving their role as the ultimate legal authority responsible for water quality management. A significant part of the capacity of the state to influence the performance of these programs is due to the fact that the programs' administrators are directly dependent of public authorities, both financially and in terms of legal liability. Moreover, state representatives are present within central organizational elements of the programs as the *Clean Water Committee* for the TPMP or the *Joint Committee* of the LTPT. These positions contribute to the state's direct control over the programs' activities and results.

A crucial element regarding the implication of public authorities resides in the creation and enforcement of conventions which provide a

Table 1
Number of trades and quantity traded (kg of nitrogen) by the Lake Taupo Protection Trust (LTPT) and by farmers (2009–2014).[1]

	By the LTPT		Between farmers		TOTAL	
Year	Number of trades	Quantity traded (kg)	Number of trades	Quantity traded (kg)	Number of trades	Quantity traded (kg)
2009	3	17 242	3	12 184	6	29 426
2010	5	56 100	2	3 500	7	59 600
2011	4	43 614	2	1 311	6	44 925
2012	9	24 311	3	362	12	24 673
2013	2	9 799	1	113	3	9 912
2014	0	0	1	164	1	164
TOTAL	**23**	**151 066**	**12**	**17 634**	**35**	**168 700**

[1] Source: Kerr et al. (2015). Data end in June 2014.

framework and facilitate participation in the programs. In both case studies, an important convention surrounds the estimation of nutrient emissions. There exists an important trade-off between the accuracy of the emission estimates and their costs of assessment. Stakeholders must agree *a priori* on an acceptable level of uncertainty in these estimations, in concordance with the program's resources. By establishing a limited and quantified set of mitigation practices (e.g. through a list of *Best Management Practices* in the case of South Nation's TPMP and through the application of the OVERSEER model in Lake Taupo), public authorities played a central role in helping to establish transparency and trust, and in avoiding costly direct measurement of emissions. Accordingly, and as a direct result of state intervention, a greater proportion of private funds could be dedicated to the purchase of emission credits by potential buyers.

Extending the conclusions of Mariola (2011), the state implication does not limit itself to *preemptive* or supporting roles in the functioning of a market exchange. As observed in our two case studies, public organisations were actively participating in the trading exchanges of the programs. This active and salient role of state intervention problematizes the market character of these WQT schemes.

4.2. Hybridization and the setting of price signals

In South Nation, the TPMP is embedded within the Clean Water Program, a pre-existent structure of grants provision to local landowners. While the TPMP provides the regulatory framework and stimulates the funding of compensatory practices from point sources, it is the Clean Water Committee of the CWP that takes on the role of assessing projects of credits' provision and delivering the corresponding grants. Hence, the TPMP and even more the CWP, with its Clean Water Committee, play the role of a clearinghouse (Greenhalgh and Selman, 2012; Woodward and Kaiser, 2002), connecting buyers and sellers of emissions' credit. No trades take place through any other structure, or even directly between regulated point source dischargers and farmers within the watershed.

Public authorities are also able to influence emission credit supply through the determination of granting terms (e.g. total amount, costs' coverage rate, etc.). Although it reduces market flexibility for its participants, the centralization of the decision-making within a clearinghouse highly simplifies the process of monetary transfers between heterogeneous actors by reducing transaction costs. For example, dischargers do not have to find credit buyers by themselves, while the legal liability represented by non-regulated participants (e.g. farmers) is assumed by the program. Hence, dischargers and credits' buyers are never contractually dependent upon one another. As dischargers do not know and cannot decide in which specific compensatory practices their payments will be invested, WQT could be considered as a system of taxation imposed on point source dischargers. The Clean Water Program also includes public financial sources coming from municipal levies or provincial and federal fundings. The TPMP is then considered as an additional source of funds to the CWP. The nutrient emissions trading occurring in South Nation is a good illustration of what Vatn (2015) categorizes as an "incomplete market with intermediary" (p. 227). Moreover, the fact that the financial help provided covers only part of the costs of the implemented agro-environmental practices implies that the implication of farmers in the program depends on motivation that are not completely internalized within the monetary retributions provided by the program (Mariola, 2012).

In the context of the LTNTP, such a clear distinction between regulated and non-regulated actors does not exist. In adopting a bilateral trading market structure (Greenhalgh and Selman, 2012, Woodward and Kaiser, 2002), the LTNTP lacks a formalized central structure as seen in the clearinghouse system in South Nation. Rather, in Lake Taupo, dischargers and credit buyers interact and negotiate their contractual relationships directly, even if the permission of public authorities is required to complete the trades. As such, a hierarchical character is less present in this trading scheme. However, in the program design, one of the objectives of the LTNTP is to alleviate the costs imposed on the dischargers by maintaining the *status quo* in terms of discharge allowances according to previous emissions. The concrete reduction of emissions within the watershed thus crucially takes place through the engagement and financial resources of the Lake Taupo Protection Trust. Even if its status as an independent organization is important in order to gain the confidence of local stakeholders, the funds used by the organisation are public, thus resulting in a hybridized public–private financial system. Hence, the LTNTP appears as a *new* mechanism through which public authorities can finance and implement desired practices within the watershed.

The use of price signals within the TPMP and LTNTP also provides important insight into the character of their respective hybridization systems. Typically, in a market, the price signal plays the role of an index aggregating decentralized economic information (Hahn et al., 2015). However, in South Nation, the price per kilogram of phosphorus regulating the transactions is not directly affected by stakeholders' demand and supply but is rather determined through deliberation and public authority. In this case, the decision-making process is centralised within the hands of regulators (i.e. Clean Water Committee) wherein price serves as a tool to frame stakeholders' behavior in correspondence to the decisions taken. Therefore, public authorities become formally institutionalized as instrumental in establishing price.

In contrast in Lake Taupo, the price is affected by the contractual engagement of private and public participants to the trading scheme. Through mechanisms of supply and demand, the price has the potential to express the effects of diverse ecological and social factors on the provision of emissions credits. However, the economic power provided by public financial resources to the Lake Taupo Protection Trust and its dominant activity within the trading scheme reiterates the LTPT as being instrumental in the establishment of price. Since the LTPT drives rather than being affected by the price adopted through the functioning of the market, important consequences on the logic of the program become clear. In particular, the role of the price signal within the market changes as it reflects the decisions of a single stakeholder rather than reflecting the economic decisions taken by other actors within the watershed. The price signal thus no longer has the function of aggregating decentralized economic information but on the contrary, it rather acts as a means of diffusing state influence through reliance on a price signal. Therefore, in Lake Taupo, through a combination of price signal and centralized influence, publicly-funded regulators are able to impose their choices on the private stakeholders of the watershed. These results follow previous work underlining the pragmatic views practitioners establish with ecosystem services concepts (Fisher and Brown, 2015).

4.3. The issue of transaction costs

Scholars point out that efforts to reduce transaction costs are the principal factors driving hybridization between regulatory tools and market dynamics in the management of ecosystem services (Muradian and Rival, 2012; Vatn, 2010). Many elements of WQT programs are designed to reduce these transaction costs and take on a hybrid form, as they depend on both public and private actors to do so. As seen in our two case studies, some programs reduce the costs of credit assessment by restricting the range of accepted agro-environmental practices a farmer can adopt (Ribaudo and Gottlieb, 2011). Trade intermediaries, from public or private origin, as the TPMP or the LTPT, can also appear within the WQT schemes to reduce transaction costs by facilitating encounters of buyers and providers of credits (*Ibid.*). These actors take over the role of "supplying, certifying, and guaranteeing credits" (Hall and Raffini 2005: p. 41), assuming to different degrees the legal liability surrounding the trades.

According to some, there exists a trade-off between market efficiency and the simplicity of the overall trading scheme (Horan and

Shortle, 2011). In order to reduce transaction costs, elements of a program such as monitoring or exchange protocols tend to be restricted. These simplifications might be seen as ways to harness the potentialities of market efficiency by allowing the trading of discharge rights by participants to sufficiently arrive at desired outcomes. These state-driven measures, which help to ensure the viability of the scheme by diversifying its sources of income and reducing transaction costs, also limit the development of fully-fledged market mechanism.

Through a review and analysis of market mechanisms within environmental governance, Vatn (2018) underlines that these instruments are mostly "*based on state power to tax and pay subsidies*" (p. 175). Pointing out transaction costs and the complexity surrounding the governance of environmental resources to explain the strong implication of public authorities, he moderates the view of market-based instruments seen as a trend to an extension of capital accumulation. As stated by Boisvert et al. (2013), they are better considered as "a new way of considering and grouping together existing environmental policy tools" and expressing "new representations and expectations [that] have been adopted" (p. 1132).

5. Conclusion

The management of water quality involves high complexity due to the specificity of socio-ecological factors present in watersheds. In this context, we observe challenges in both command-and-control and market-based modes of governance. The level of transaction costs imposes an important implication for public authorities within WQT schemes. Regulators assume a large part of the structural costs, constructing the legal and physical framework in which such programs evolve. However, as shown by the WQT structures in South Nation and Lake Taupo, the state does not limit itself to *preemptive* interventions, but participates actively in the trading activities which affect results of the schemes. In the two case studies, this implication takes different forms, leading to the invariable hybridization of command-and-control and market-based modes of governance.

Such hybridization crystallizes around the transfer of financial resources. The state not only creates the conditions for an implication of private stakeholders, but it also harnesses the economic mechanisms it institutes to support specific projects within the watershed. The intensity of the state's influence clearly supersedes the influence of other stakeholders and in the case of both South Nation and the Lake Taupo trading schemes, places the state as a primordial actor for the functioning of these programs.

In this context, we argue that the implementation of WQT programs does not correspond to a retreat of the state in the field of environmental governance (Gómez-Baggethun and Muradian, 2015). Therefore, WQT programs cannot be primarily assessed through usual market criteria. Moreover, we argue that WQT can be seen as a novel intervention framework for public authorities in which the state expands its influence to address a broader range of actors and objectives. This novel institutional environment also affects the way public resources are used and distributed.

We demonstrate here that hybridization is a concrete response to the gap between theory and practice in the domain of water quality trading. The presence of hybridized financial and institutional arrangements around WQT suggests the need to understand the dynamic role of the State in these institutional configurations and the challenges of reducing transaction costs. Future investigations are required to assess the effectiveness and efficiency of institutional hybridization on issues of water quality management in relation to command-and-control style regulations for assuring water quality standards and for water provisioning.

Our analysis is based principally on official documentation produced by the programs and on interactions with the administrators of these same programs. In this sense, our consideration has focused primarily on the hybridization of formal institutional structures and arrangements resulting from decision makers' choices during the design and the management of the projects. However, as recent studies have shown in relation to "market-like" ecosystem service programs (e.g. Van Hecken et al., 2018; Jackson et al., 2017; Shapiro-Garza, 2013) other factors can drive hybridization, including political contestation or the reshaping of the initial objectives of a program by particular stakeholders. These more implicit processes, or factors are often under the radar of official program publications by administrators and require further exploration.

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References

Abdalla, C., Borisova, T., Parker, D., Blunk, K.S., 2007. Water quality credit trading and agriculture: recognizing the challenges and policy issues ahead. Choices 22 (2), 117–124.

Boisvert, V., Méral, P., Froger, G., 2013. Market-based instruments for ecosystem services: institutional innovation or renovation? Soc. Nat. Resour. 26 (10), 1122–1136.

Connor, J.D., MacDonald, D.H., Morrison, M., Cast, A., 2009. Evaluating policy options for managing diffuse source water quality in Lake Taupo, New Zealand. Environmentalist 29 (4), 348–359.

Conservation Ontario. (2003). Watershed Economic Incentives Through Phosphorus Trading and Water Quality.

Corbera, E., 2015. Valuing nature, paying for ecosystem services and realizing social justice: a response to Matulis (2014). Ecol. Econ. 110, 154–157.

Corrales, J., Melodie, N.G., Rivero, R.G., Miralles-Wilhelm, F., Bhat, M.G., 2013. Water quality trading programs towards solving environmental pollution problems. Irrig. Drain. 62, 72–92.

Duhon, M., Young, J., Kerr, S., 2011. Nitrogen Trading in Lake Taupo: An Analysis and Evaluation of an Innovative Water Management Strategy. Motu Economic and Public Policy Research. [http://motu-www.motu.org.nz/wpapers/15_07.pdf] (consulted March 9th, 2018).

Duncan, R., 2017. Rescaling knowledge and governance and enrolling the future in New Zealand: a co-production analysis of canterbury's water management reforms to regulate diffuse pollution. Soc. Nat. Resour. 30 (4), 436–452.

Ezzine-De-Blas, D., Wunder, S., Ruiz-Perez, M., Del, P.M.-S.R., 2016. Global patterns in the implementation of payments for environmental services. PLoS ONE 11, 3.

Fisher, J.A., Brown, K., 2015. Reprint of "Ecosystem services concepts and approaches in conservation: Just a rhetorical tool?". Ecol. Econ. 117, 261–269.

Froger, G., Méral, P., Muradian, R., 2016. Vers une prise en compte de la diversité des arrangements institutionnels et des pratiques dans l'analyse des paiements pour services environnementaux. Développement Durable Et Territoires 7.

GAO, 2017. Water Pollution: Some States Have Trading Programs to Help Address Nutrient Pollution, but Use Has Been Limited. [https://www.gao.gov/assets/690/687755.pdf] (consulted March 9th, 2018).

Gómez-Baggethun, E., Muradian, R., 2015. In markets we trust? Setting the boundaries of Market-Based Instruments in ecosystem services governance. Ecol. Econ. 117, 217–224.

Government of Canada, 2006. Les échanges de crédits de qualité de l'eau peuvent-ils contribuer à lutter contre les sources de pollution agricole au Canada?: Rapport de projet. Projet de recherche sur les politiques, Ottawa. [http://publications.gc.ca/collections/Collection/PH4-34-2006F.pdf] (consulted March 9th, 2018).

Goyette, J.-O., Maranger, R., Bennett, E.M., 2018. Low buffering capacity and slow recovery of anthropogenic phosphorus pollution in watersheds. Nat. Geosci. 11 (12), 921–925.

Greenhalgh, S., Selman, M., 2012. Comparing water quality trading programs: what lessons are there to learn? J. Reg. Anal. Pol. 42 (2), 104–125.

Hahn, T., McDermott, C., Ituarte-Lima, C., Schultz, M., Green, T., Tuvendal, M., 2015. Purposes and degrees of commodification: economic instruments for biodiversity and ecosystem services need not rely on markets or monetary valuation. Ecosyst. Serv. 16, 74–82.

Hall, L., Raffini, E., 2005. Water quality trading: where do we go from here? Nat. Resour.

Environ. 20 (1), 38–42.
Horan, R.D., Shortle, J.S., 2011. Economic and ecological rules for water quality trading. J. Am. Water Resour. Assoc. 47 (1), 59–69.
Hu, H., Huang, G., 2014. Monitoring of non-point source pollutions from an agriculture watershed in South China. Water 6 (12), 3828–3840.
Jackson, S., Palmer, L., McDonald, F., Bumpus, A., 2017. Cultures of carbon and the logic of care: the possibilities for carbon enrichment and its cultural signature. Ann. Am. Assoc. Geogr. 107 (4), 867–882.
Kerr, S., Greenhalgh, S., Simmons, G., 2015. The Taupo nitrogen market: The world's only diffuse source trading programme. Motu Economic and Public Policy Research Trust. [https://motu.nz/assets/Documents/our-work/environment-and-resources/nutrient-trading-and-water-quality/Motu-Note-20-Taupo-Nitrogen-Market.pdf] (consulted March 9th, 2018).
King, D.M., 2005. Crunch time for water quality trading. Choices 20 (1), 71–75.
Kusmer, A.S., Bennett, E.M., Goyette, J.-O., Maranger, R., MacDonald, G.K., Bennett, E.M., Withers, P.J.A., 2018. Watershed buffering of legacy phosphorus pressure at a regional scale: a comparison across space and time. Ecosystems 1–19.
Lake Taupo Protection Trust, 2016. Chairman's Report On Trust operations For the Year Ended 30th June 2016. [http://www.laketaupoprotectiontrust.org.nz/file/downloads/pdf/chairmans-report_signed-yr-ended-30.6.16.pdf] (consulted March 9th, 2018).
Lake Taupo Protection Trust, 2017. Statement of Intent 1st July 2017 to 30th June 2018. [http://www.taupodc.govt.nz/our-council/council-organisations/Documents/Statement%20of%20Intent%20documents/LTPT%20Statement%20of%20Intent%202017-2018.pdf] (consulted March 9th, 2018).
Lemos, M.C., Agrawal, A., 2006. Environmental governance. Annu. Rev. Environ. Resour. 31, 297–326.
Mariola, M.J., 2011. The commodification of pollution and a preemptive double movement in environmental governance: the case of water quality trading. Org. Environ. 24 (3), 231–248.
Mariola, M.J., 2012. Farmers, trust, and the market solution to water pollution: the role of social embeddedness in water quality trading. J. Rural Stud. 28 (4), 577–589.
McAfee, K., Shapiro, E., 2010. Payments for ecosystem services in Mexico: nature, neoliberalism, social movements, and the state. Ann. Assoc. Am. Geogr. 100 (3), 579–599.
Milne, S., Adams, B., 2012. Market masquerades: uncovering the politics of community-level payments for environmental services in Cambodia. Dev. Change 43 (1), 133–158.
Muradian, R., 2013. Payments for ecosystem services as incentives for collective action. Soc. Nat. Resour. 26 (10), 1155–1169.
Muradian, R., Gómez-Baggethun, E., 2013. The institutional dimension of "market-based instruments" for governing ecosystem services: introduction to the special issue. Soc. Nat. Resour. 26 (10), 1113–1121.
Muradian, R., Rival, L., 2012. Between markets and hierarchies: the challenge of governing ecosystem services. Ecosyst. Serv. 1 (1), 93–100.
O'Grady, D., 2011. Sociopolitical conditions for successful water quality trading in the South Nation River Watershed, Ontario, Canada. J. Am. Water Resour. Assoc. 47 (1), 39–51.
OECD, 2015. The Lake Taupo Nitrogen Market in New Zealand: A Review for Policy Makers. Environment Policy Papers, no. 4. OECD Publishing, Paris.
Pirard, R., 2012. Market-based instruments for biodiversity and ecosystem services: a lexicon. Environ. Sci. Policy 59–68.
Pirard, R., Lapeyre, R., 2014. Classifying market-based instruments for ecosystem services: a guide to the literature jungle. Ecosyst. Serv. 9, 106–114.
Ribaudo, M.O., Gottlieb, J., 2011. Point-nonpoint trading – can it work? J. Am. Water Resour. Assoc. 47 (1), 5–14.
Ribaudo, M.O., Nickerson, C.J., 2009. Agriculture and water quality trading: exploring the possibilities. J. Soil Water Conserv. 64 (1), 1–6.
Roper, J., Collins, E.M., de Jong, J., 2015. Lake Taupo: a multi-sector collaborative partnership towards sustainable development. J. Public Affairs 15 (2), 143–152.
Sandbrook, C.G., Fisher, J.A., Vira, B., 2013. What do conservationists think about markets? Geoforum 50, 232–240.
Selman, M., Greenhalgh, S., Branosky, E., Jones, C., Guiling, J., 2009. Water Quality Trading Programs: An International Overview. World Resources Institute Issue Brief, Water Quality Trading no. 1.
Shabman, L., Stephenson, K., Shobe, W., 2002. Trading programs for environmental management: reflections on the air and water experiences. Environ. Pract. 4 (3), 153–162.
Shapiro-Garza, E., 2013. Contesting the market-based nature of Mexico's national payments for ecosystem services programs: Four sites of articulation and hybridization. Geoforum 46, 5–15.
Shortle, J., 2013. Economics and environmental markets: lessons from water-quality trading. Agric. Resour. Econ. Rev. 42 (1), 57–74.
South Nation Conservation, 2003. Phosphorus Loading Algorithms for the South Nation River. Clean Water Committee. [http://www.nation.on.ca/sites/default/files/Final%20Phosphorous%20Algorithm%20Report%20phase%20II.Jan%202003.pdf] (consulted March 9th, 2018).
South Nation Conservation, 2005. Clean Water Program 2004 Annual Report. Clean Water Committee. [http://www.nation.on.ca/sites/default/files/SNC%202004%20Clean%20Water%20Program%20Annual%20Report%20EN.pdf] (consulted March 9th, 2018).
South Nation Conservation, 2006. Clean Water Program 2005 Annual Report. Clean Water Committee. [http://www.nation.on.ca/sites/default/files/SNC%202005%20Clean%20Water%20Program%20Annual%20Report%20EN.pdf] (consulted March 9th, 2018).
South Nation Conservation, 2007. Clean Water Program 2006 Annual Report. Clean Water Committee. [http://www.nation.on.ca/sites/default/files/SNC%202006%20Clean%20Water%20Program%20Annual%20Report%20EN.pdf] (consulted March 9th, 2018).
South Nation Conservation, 2010. Clean Water Program 2009 Annual Report. Clean Water Committee. [http://www.nation.on.ca/sites/default/files/SNC%202009%20Clean%20Water%20Program%20Annual%20Report%20EN.pdf] (consulted March 9th, 2018).
South Nation Conservation, 2011. Clean Water Program 2010 Annual Report. Clean Water Committee.
South Nation Conservation, Undated. Total Phosphorus Management (TPM): Annual Summary for 2000–2015. Unpublished document.
Stephenson, K., Shabman, L., 2011. Rhetoric and reality of water quality trading and the potential for market-like reform. J. Am. Water Resour. Assoc. 47 (1), 15–28.
Vaissière, A.-C., Levrel, H., 2015. Biodiversity offset markets: what are they really? An empirical approach to wetland mitigation banking. Ecol. Econ. 110, 81–88.
Van Hecken, G., Kolinjivadi, V., Windey, C., McElwee, P., Shapiro-Garza, E., Huybrechs, F., Bastiaensen, J., 2018. Silencing agency in payments for ecosystem services (PES) by essentializing a neoliberal 'monster' into being: a response to fletcher and Büscher's 'PES conceit'. Ecol. Econ. 144, 314–318.
Van Meter, K.J., Basu, N.B., 2017. Time lags in watershed-scale nutrient transport: an exploration of dominant controls. Environ. Res. Lett. 12, 8.
Vatn, A., 2010. An institutional analysis of payments for environmental services. Ecol. Econ. 69 (6), 1245–1252.
Vatn, A., 2015. Markets in environmental governance. From theory to practice. Ecol. Econ. 117, 225–233.
Vatn, A., 2018. Environmental governance – from public to private? Ecol. Econ. 148, 170–177.
Vilmin, L., Mogollon, J.M., Beusen, A.H.W., Bouwman, A.F., Beusen, A.H.W., Bouwman, A.F., 2018. Forms and subannual variability of nitrogen and phosphorus loading to global river networks over the 20th century. Global Planet. Change 163, 67–85.
Waikato Regional Council, 2003. Protecting Lake Taupo: A long term strategic partnership. Environment Waikato, Hamilton East. [https://www.waikatoregion.govt.nz/assets/PageFiles/7058/strategy.PDF] (consulted March 9th, 2018).
Woodward, R.T., Kaiser, R.A., 2002. Market structures for U.S. water quality trading. Rev. Agric. Econ. 24 (2), 366–383.