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Governing Water Quality Limits In Agricultural Watersheds

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ABSTRACT

The diffuse runoff of agricultural nutrients, also called agricultural nonpoint source pollution (NPS), is a widespread threat to freshwater resources. Despite decades of research into the processes of eutrophication and agricultural nutrient management, social, economic, and political barriers have slowed progress towards improving water quality. A critical challenge to managing agricultural NPS pollution is motivating landowners to act against their individual farm production incentives in response to distant ecological impacts. The complexity of governing the social-ecological system requires improved understanding of how policy shapes farmer behavior to improve the state of water quality. This dissertation contributes both theoretically and empirically to NPS pollution governance by examining the impacts of water quality policy design on farmer nutrient management decision making and behavior.

In the first study, I theoretically contextualize the issue of agricultural NPS pollution in the broader discussion of environmental public goods dilemmas to suggest that an increased focus on the link between policy and behavior can improve sustainable resource management. I propose two empirical approaches to study the policy-behavior link in environmental public goods dilemmas: 1) explicit incorporation of social psychological and behavioral variables and 2) utilization of actor mental models, or perceptions of the world that guide decision making, to identify behavioral drivers and outcomes. In the second and third studies, I then use these approaches to examine how water quality policies for agricultural NPS collectively change farmer behavior to reduce nutrient emissions. The second chapter uses a quantitative, survey-based approach to examine the relationship between mandatory policy design and behavior change in New Zealand. I find that a shift to mandatory policy is not immediately associated with increased adoption of nutrient management practices, but the mandatory policy design is important for potential future behavior change and long-term policy support. In the third study, I combine qualitative methodology with network analysis of qualitative data to examine a spectrum of agricultural NPS pollution policies in Vermont, USA and Taupo and Rotorua, New Zealand. I use farmer mental models to examine behavior change within each of the regions, the perceived drivers of behavior change and perceived outcomes of the policy. In this study, farmers across all three regions cite mandatory water policy as a key behavioral driver, but in each region, policy design interacts with the social-ecological context to produce distinct patterns of behaviors and perceived outcomes. Taken together, this dissertation demonstrates that agricultural NPS pollution policy design must consider the interactions between policy and other social-ecological behavioral drivers in order to achieve long term water quality improvements.

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CHAPTER 1: INTRODUCTION

1.1. Problem Description

Diffuse runoff of the nutrients nitrogen and phosphorus in agricultural lands, also known as nonpoint source (NPS) pollution, is a widespread and persistent challenge to water quality across the globe. Agriculture is the largest source of nitrogen and phosphorus to freshwater systems and nutrient enrichment of rivers and lakes is one of the most common impairments of surface waters (Foley et al., 2005; V. H. Smith & Schindler, 2009). The excessive nutrient loading of surface waters has broad ranging social and ecological impacts. These impacts include damage to fish populations, decreases in biodiversity, economic hardships for businesses and threats to drinking water supplies (Bennett, Carpenter, & Caraco, 2001; Carpenter et al., 1998). Many of these impacts are expected to increase with accelerating global climate change (Intergovernmental Panel on Climate Change, 2015; Zia, 2013), setting up an urgent societal and environmental need to find workable solutions for NPS pollution.

While much is known about the biogeochemistry of NPS pollution, less is known about the social, economic, and political dynamics that contribute to the persistence and expansion of the problem (Carpenter et al., 1998; McDowell et al., 2015; Rissman & Carpenter, 2015). As with many environmental public goods, there are competing individual and community level incentives for the provisioning of water quality (Ostrom, 2005). Farmers across a watershed are incentivized to maximize production and nutrient emissions through many small (or not so small) emissions, over time and across a large geographical area. Any one individual emission may be imperceptible, but scaled up the impacts can be dramatic (L. E. D. Smith & Porter, 2010).

Since Hardin's (1968) classic "Tragedy of the Commons," researchers and practitioners have theorized and debated institutional designs to avoid this social dilemma of collective degradation of a resource (Agrawal, 2003; Baland & Platteau, 1996; Ostrom, 1990, 2005). Institutions, as used here, refer to the formal or informal rules, strategies or norms that constrain human interaction and behavior (North, 1990; Ostrom, 2005). This body of literature highlights the potential for institutional design, whether political, market-based, or normative in nature, to align competing individual and group incentives to create sustainable management regimes (Anderies, Janssen, & Ostrom, 2004; Lemos & Agrawal, 2006; Ostrom, 2005).

Drawing from the perspective of institutional design, a breadth of potential options exist to align individual and community incentives for mitigating agricultural NPS pollution. These range from education and capacity building interventions to incentive payments, to market-based trading instruments, to traditional command-and-control rule-based mechanisms (Drevno, 2016). Institutional design for managing agricultural NPS must also consider the complexity and uncertainty of the spatial and temporal dynamics of a watershed. The transport of land applied nutrients to receiving waters is characterized by stochastic climate events, heterogeneous land and soil characteristics, legacy nutrients within receiving water bodies and time lags in the system (Moss, 2008; Withers, Neal, Jarvie, & Doody, 2014). In addition to this biophysical complexity, agricultural landowners' farm business decisions are governed by broader market trends for agricultural products and individual social and cultural priorities (L. E. D. Smith & Porter, 2010).

Despite the broad range of available tools to address the problem, little progress has been made in improving nutrient impaired waterbodies across the globe (Dowd, Press, & Los Huertos, 2008; Rissman & Carpenter, 2015), suggesting that we lack an understanding of which institutional designs will work in a given watershed context. Specifically, we lack an understanding of two critical institutional interactions for NPS pollution governance: 1) the fit of a policy intervention within its social, economic and environmental context, and 2) the connection between policy design and farmer decision making. In this dissertation I seek to examine these two institutional interactions to advance understanding of governing agricultural NPS pollution through combining theories of institutional design and analysis with social psychological theories of decision making. I will ground the study in watersheds in New Zealand and Vermont, USA. These two regions both feature high levels of farming and are facing similar environmental challenges, but that have distinct and different governance approaches to agricultural NPS pollution. In order to collectively govern individual farm nutrient emissions across a watershed, it is important to gain a better understanding of how institutional designs shape farm management behavior.

1.2. Theoretical Background

Numerous studies have examined governance approaches for agricultural NPS pollution. These approaches have mostly aligned with two theoretical angles: farmer decision making (Baumgart-Getz, Prokopy, & Floress, 2012; Conner, Miller, Zia, Wang,

& Darby, 2016; Knowler & Bradshaw, 2007; Prokopy, Floress, Klotthor-Weinkauf, & Baumgart-Getz, 2008a) and environmental policy (Drevno, 2016; Horan & Ribaudo, 1999; Shortle & Horan, 2013). The first angle seeks to understand motivating factors for individual decision making. This research has relied upon behavioral theories, such as the diffusion of innovations (Rogers, 1962) and the Theory of Planned Behavior (TPB) (Ajzen, 1985; Fishbein & Ajzen, 2011), or econometric studies to identify and define predictive factors for the adoption of water quality practices (Blackstock, Ingram, Burton, Brown, & Slee, 2010; Burton, 2004; Conner et al., 2016; Edwards-Jones, 2006). From this research we know that a wide variety of social, economic and farm system variables are important factors in whether or not a farmer will adopt management strategies that reduce negative environmental impacts, including the degradation of water quality. In a meta-analysis of studies examining farmers adoption of Best Management Practices, Baumgart-Getz et al. (2012) found "access to and quality of information, financial capacity and being connected to an agency or local networks of farmers or watershed groups" to be the strongest determinants of adoption.

The environmental policy approach to examining governance of agricultural NPS pollution focuses on the cost-effectiveness and efficiency of policy interventions in internalizing water quality deterioration negative externalities within agricultural production (Drevno, 2016; Pretty et al., 2001; Shortle, Abler, & Horan, 1998; Shortle & Horan, 2013). This microeconomic perspective models the trade-offs between different institutional designs based on the assumption that farmers are utility-maximizing agents that will change behavior given the appropriate mix of costs and benefits. In this line of research, Shortle and Horan (2013) examine the current state of water quality policy instruments and conclude that, due to the complexity of NPS pollution, second-best institutional designs are required. These second-best designs feature trade-offs in efficiency and equity as compared to theoretically optimally-efficient policies. They do suggest that water quality trading and cap-and-tax institutions show promise for resolving some of the information and transaction cost challenges associated with NPS pollution (Shortle & Horan, 2013). Drevno (2016) also examines the potential for policy tools to address agricultural NPS pollution and concludes that effective water quality institutional design will require a mix of policy instruments, local participation and political will.

While literature examining both farmer behavior and environmental policy have greatly expanded the water quality policy instrument tool kit and our knowledge of the factors farmers balance in their management decisions, there are large gaps in understanding how individuals respond to institutional designs in a given watershed context. From the behavioral and econometric approach, studies have failed to identify a consistent list of predictor variables for pro-environmental farm management (Baumgart-Getz et al., 2012; Knowler & Bradshaw, 2007; Prokopy et al., 2008a). The policy approach appears to offer a similar lack of consensus in the best approach to designing an institutional intervention. Neither perspective takes into account that “farmers’ conservation behaviors are more than individual decisions about isolated practices; they are scale dependent and influenced by issues of space, institutions and time” (Reimer et al., 2014, p. 57A).

There are limited number of studies that have examined the interaction of environmental policy institutional design and farmer decision making. A few studies have focused on the differential response of individuals to voluntary and mandatory water quality regimes (Barnes, Toma, Willock, & Hall, 2013; Barry, King, Larson, Lennox, & others, 2010; Kara, Ribaudo, & Johansson, 2008). The results of these studies show no clear trend and there is a lack of acknowledgement for market-based alternatives. For policy makers to design and implement effective policy solutions, a clear understanding of the interaction between institutional design and behavior is critical.

Institutional analysis provides a vehicle to examine the formal institutional rules of a water quality policy intervention in conjunction with the other formal and informal institutions that govern individual behavior within a watershed. As mentioned above, the nature of agricultural NPS pollution as a social dilemma sets up a scenario in which it is to society's benefit to collectively shift behavior in a way that may not be beneficial at the individual level (Poteete, Janssen, & Ostrom, 2010). The challenge in designing an intentional institutional intervention for this purpose is that for the intervention to achieve the desired outcome (e.g. farm management change to improve water quality), it must fit well with the pre-existing institutions that exist to structure social interaction and behavior in a given setting (Goodin, 1998). As Young highlights, "institutions play a role in both causing and addressing problems that arise from human-environment interactions," hence the fit of the institution to the biophysical context, the interplay of the institution with other existing institutional arrangements, and the scale at which the institution is implemented for the given problem are all important elements in the success of the institutional intervention (Young, King, Schroeder, Galaz, & Hahn, 2008, p. xiiv).

Elinor Ostrom's Institutional Analysis and Development Framework, and its expansion and evolution into the social-ecological systems (SES) framework provide a theoretical basis from which to examine the institutional governance of interactions between actors (Ostrom, 2009, 2011). Typically, in the application of Ostrom's frameworks to understand collective action in natural resource regimes, individual behavior is assumed to be boundedly rational, in that individuals intend to behave rationally but have limited information, cognition and attention processing abilities (Ostrom, 2011; Poteete et al., 2010; Simon, 1972). In cases like agricultural NPS pollution where there are high degrees of uncertainty in resource dynamics, which makes measurement, monitoring and enforcement of policy institutional interventions difficult, there is an increased need to understand individuals' internal decision-making processes.

1.3. Dissertation Overview

In this dissertation, I further the understanding of SES governance through examining the role and impact of institutional design on farmer nutrient management decision making and behavior through an integrated institutional analysis and social psychological approach. First, I do this theoretically in the second chapter through building the case for an expansion of Ostrom's (2007, 2009) SES Framework to facilitate the study of environmental public goods dilemmas, like declining water quality from agricultural NPS pollution. Then in the third and fourth chapters I build on the theoretical approaches laid out in the second chapter to empirically examine farmer decision making and behavior across a number of agricultural NPS pollution policy regimes. In this section I highlight the key topics, questions and approaches used in each chapter of the dissertation.

In the second chapter I contextualize the issue of agricultural NPS pollution in the broader discussion of environmental public goods dilemmas and the need for greater analysis of these dilemmas to lead to their sustainable management. Water quality decline from agricultural NPS pollution is used as an example case throughout the first chapter to define the challenges to analyzing these types of regimes, as well as potential paths forward. I suggest that Ostrom's (2007, 2009) SES framework provides a foundational structure for this type of analysis. However, the SES framework has yet to fill this analytical need for environmental public goods dilemmas. I propose that a critical gap in applications of the framework lies in the treatment of actor decision making, and in particular the lack of attention paid to how institutions shape behavior. I conclude by proposing two potential pathways for increasing attention paid to the institution-behavior link in applications of the SES framework. These analytical pathways are: 1) through explicitly incorporating social psychological and behavioral variables into the analysis of environmental public goods dilemmas and 2) by studying actor mental models to identify the most salient components to actor behavior and perceived outcomes.

In my third and fourth chapters, I then pursue these two analytical pathways to examine how water quality policy institutions for agricultural NPS collectively change farmer behavior and reduce nutrient emissions in a given watershed context. The third chapter takes a quantitative, survey-based approach to compare farmer decision making and behavior across agricultural NPS pollution policy regimes in New Zealand. This study examines the relationship between policy design and behavior change to evaluate potential for water quality improvement in the future. Further, this study incorporates the social psychological Theory of Planned Behavior (Fishbein & Ajzen, 2011) to examine alignment between farmer decision making and their values and beliefs as a basis for evaluating potential for long term policy support.

In the fourth chapter I use the SES framework as the basis to examine farmer mental models within a spectrum of agricultural NPS pollution regimes in Vermont, USA and Taupo and Rotorua, New Zealand. Here, I use farmer mental models to examine behavior change within each of the regions, perceived drivers of behavior change and perceived outcomes of the policy. The qualitative, interview-based study allows for an in-depth examination of the fit of each policy within the biophysical context in terms of behavior change and the interplay of the policy with existing social and ecological dynamics in the watershed. I examine the distinct pattern of behaviors and outcomes that emerge in each policy context to draw conclusions for agricultural NPS pollution policy design.

Finally, in the fifth chapter, I offer concluding thoughts on the results of the dissertation as a whole and insights to pursue for future research. Ultimately, through increasing our knowledge on the contextual and psychological drivers of farmer response to water quality policies, this dissertation seeks to reduce barriers to the management of agricultural NPS pollution and inform effective policy design. Furthermore, this dissertation aims to inspire other researchers to do likewise in the study of environmental public goods dilemmas more broadly guided by an expanded SES Framework that incorporates a greater focus on actor decision making and behavior.

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CHAPTER 2: STRENGTHENING THE INSTITUTION-BEHAVIOR LINK IN THE SES FRAMEWORK TO FACILITATE ANALYSIS OF ENVIRONMENTAL PUBLIC GOODS DILEMMAS

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2.1. Abstract

Many environmental challenges take the form of environmental public goods dilemmas, including climate change, water quality deterioration and biodiversity loss. There is a great need for analysis of these challenges to better inform the design of governance institutions for sustainable resource management. The social-ecological systems (SES) framework provides a foundational structure for analyzing the sustainability of complex, multi-scale environmental challenges. However, in application, the SES framework has struggled to facilitate analysis of environmental challenges beyond common-pool resource (CPR) regimes and the emergence of community-based governance institutions. In this paper, I propose that one way to facilitate the application of the SES framework to environmental public goods dilemmas is to incorporate a greater focus on the link between institutions and behavior.

After introducing the SES Framework, I examine attributes of environmental public goods dilemmas that differentiate them from CPR regimes. These include the lack of a behavior-reinforcing link, multi-actor and multi-resource system dynamics, higher levels of uncertainty and complexity, and lack of built-in social capital. Then I suggest that these attributes also increase the need to study a broader suite of potential governance institutions. I propose that one way to address both of these challenges is to

incorporate the study of the psychological drivers of individual behavior and decision-making into the SES Framework. I link the attributes of environmental public goods with the need for an increased focus on actor decision making and behavior. Then I explore a sampling of psychological and behavioral concepts to show their potential to improve our understanding of system dynamics within environmental public goods dilemmas. Finally, I propose revisions to the SES Framework to facilitate this increased focus on the institution-behavior link. Incorporating psychological and behavioral theory into the SES framework to strengthen the institution-behavior link is a promising approach to allow for the study of institutional interventions for environmental public goods. Ultimately, a better understanding of which institutions promote behavior change within and across environmental public goods regimes can improve the sustainability of these systems.

2.2 Introduction

Many of the regional and global environmental challenges we face are environmental public goods dilemmas, including climate change, ocean acidification, declining water quality, and biodiversity loss (Rockström et al., 2009; Shortle & Uetake, 2015). Because of the scale and persistence of many environmental public good dilemmas, there is a critical need to improve our understanding of how institutions can support sustainable resource regimes in environmental public goods dilemmas. To improve our understanding of these systems we need analysis of environmental public good dilemmas to identify generalizable trends or design principles for robust management regimes (Ostrom, 2005). The social-ecological systems (SES) framework provides a foundational structure for this type of analysis, specifically for analyzing and improving the sustainability of complex environmental dilemmas (Ostrom, 2007, 2009). The framework acknowledges the context-specific nature of human decisions and behavior within environmental dilemmas, and the existence of influences and feedbacks between the ecological and the social (Ostrom, 2011). However, the SES framework has yet to fill this analytical need for environmental public goods dilemmas. I propose that a critical gap in applications of the framework lies in relying on behavioral assumptions about actor decision making, in particular the lack of attention paid to how institutions shape decision making and behavior.

In an effort to inspire transdisciplinary analysis of environmental public goods dilemmas using the SES framework, I propose to improve the link between governance institutions and actor behavior within the framework. Thus far, applications of the SES framework have been limited to the study of common pool resource (CPR) regimes and the conditions that lead to the emergence of community-based natural resource management (Thiel, Adamseged, & Baake, 2015). In this paper, I will suggest that the attributes of environmental public goods dilemmas, in particular those that differentiate them from CPR dilemmas, increase the relevance of actor behavior and decision making for social-ecological outcomes compared to the role of actor behavior in CPR regimes. I identify these attributes as the lack of a behavior-reinforcing link, multi-actor and multi-resource system dynamics, higher levels of uncertainty and complexity, and lack of built-in social capital.

An expanded focus on the link between governance institutions and behavior within the SES framework will allow analysts to examine how institutions shape social-ecological outcomes in environmental public goods dilemmas, in light of their unique attributes. Methodologically, the expanded SES framework that I am proposing for environmental public goods dilemmas includes 1) designing research questions around the institution-behavior link, 2) incorporating new variables into the SES framework on drivers, influences and psychological components of actor decision-making, and 3) utilizing actor mental models to identify the salient components of the social-ecological dilemma. The expanded SES framework allows the analyst to draw from the literature of social psychology, cognitive psychology and behavioral economics to investigate behavior under different institutions rather than rely on strong behavioral assumptions. This approach allows for the examination of diverse types of institutional arrangements in a broader range of environmental resource dilemmas, including environmental public goods.

In section one, I begin by reviewing the vision behind the SES framework and outline its current constraints. Then, in the second section, I explore the specific challenges in the management of environmental public goods for implementation of the SES framework. In section three I build on the exploration of environmental public goods to suggest the need for examining diverse institutional arrangements with the SES framework to motivate collective action. In section four I establish the importance of the institutional-behavioral link to address these challenges. Finally, in section five, I propose revisions to the SES framework to strengthen researchers' ability to examine the institutional-behavioral link in public goods dilemmas using the framework.

2.3. SES Framework Vision & Constraints

The seemingly simple question of which institutions promote sustainability under which social-ecological contexts is hugely complex. Variation in scale, scope, resource attributes, community attributes, market forces, and governance regimes, among other factors, makes drawing concrete conclusions and proposing solutions challenging. Furthermore, researchers analyzing these systems from different disciplinary perspectives use different terminology, use different scales of analysis and focus on different variables, which makes drawing system-wide transdisciplinary conclusions difficult (Agrawal, 2003). The SES framework was proposed as a solution to this problem, following the success of a research program on CPR regimes (Poteete et al., 2010). The framework provides a theoretical basis from which to examine interactions between ecological resource dynamics, underlying biophysical systems, governance regimes and human behavior (see Figure 2-1 below) (Ostrom, 2009, 2011). These first-order variables, and the second- and third- order variables nested below them, are organized to guide research design and data collection so that analysts can communicate across cases and begin to form theories about how SES work (for more detailed introduction to the SES framework see Ostrom (2007, 2009)). The long-term goal of the SES Framework is to enable research that can recognize "which combination of variables tends to lead to relatively sustainable and productive use of particular resources systems operating at specific spatial and temporal scales and which combination tends to lead to resource collapses and high costs for humanity" (Ostrom, 2007, p. 15183).

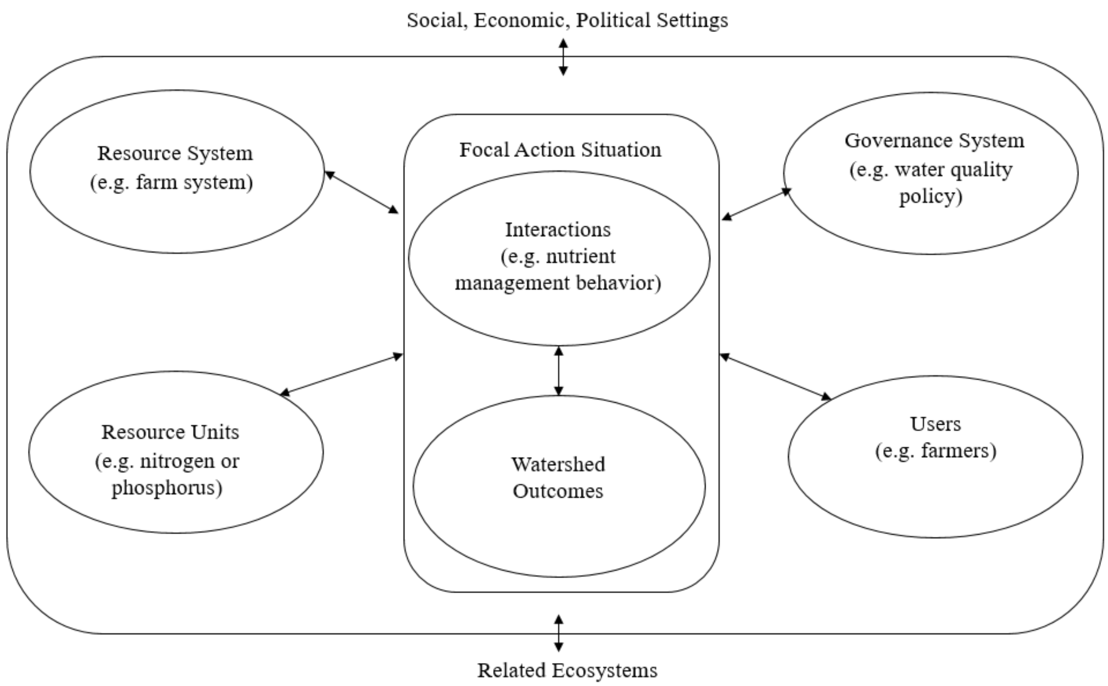

Figure 2-1. The SES framework with example elements of watershed agricultural nonpoint source pollution dilemma adapted from McGinnis and Ostrom (2014)

Thus far, the SES framework has struggled to live up to this initial vision. Applications of the SES framework still lie mostly within the realm of CPR regimes (Thiel et al., 2015), despite the intention for the framework to branch out to different types of resource regimes (McGinnis & Ostrom, 2014). Additionally, the framework has been applied primarily in community-based natural resource management contexts, such as when and under what conditions will resource users self-organize to address resource degradation or overharvesting (Thiel et al., 2015). Yet, the framework has the potential to examine a much wider breadth of governance questions.

Theoretically the SES Framework centers around individual behavior and the "conscious choices" made by individuals or collaborative groups (McGinnis & Ostrom, 2014, para. 5). The SES framework “does not dictate a particular model of decision-making; instead it prompts the analyst to explicitly identify what participants value; what resources, information, and beliefs they have; what their information-processing capabilities are; and what internal mechanisms they use to decide on strategies” (Ostrom, Cox, & Schlager, 2014, p. 274). However, in application, very few studies explicitly identify actor perceptions that drive behavior and how actors perceive costs and benefits (Thiel et al., 2015). This may be in part because, as Ostrom identifies, “accurate and reliable measures of users’ perceived benefits and costs are difficult and costly to obtain, making it hard to test theories based on users’ expected net benefits” (Ostrom, 2009, p. 420). Therefore, in applications of the SES Framework, analysts tend to overlook individual perceptions and values that drive decision-making, despite the fact that these lie theoretically at the core of the framework. This relates to a broader challenge for the SES Framework, which lies in the lack of a common understanding in what it means to apply the SES Framework (Ban & Cox, 2017).

In the following section, drawing from the vision and constraints laid out here, I explore the attributes of environmental public goods dilemmas that present challenges for applications of the SES framework.

2.4. Environmental Public Goods Dilemmas

In the disciplines of economics and political science, public goods are often defined as non-subtractable (e.g. one person’s use of the good does not subtract from another person’s) and non-excludable (e.g. it is difficult or impossible to exclude others from accessing the resource) (Ostrom, 2005). Another related way to consider environmental public goods dilemmas is that they are, at their core, environmental externalities. Environmental externalities occur when a behavior in a specific domain results in an output outside or external to the domain in question. This external output results in the deterioration or degradation of an environmental good shared by all. One example of an environmental public good dilemma, which I will draw on for illustrative purposes throughout this paper, is water quality deterioration from agricultural nonpoint source (NPS) pollution. In this dilemma, farmers spread nutrient fertilizers on their fields to increase agricultural yield, but as a result, these added nutrients may runoff into nearby waterbodies and decrease water quality of rivers and lakes. Environmental public goods, such as water quality, differ from the traditionally studied common-pool resource regimes, such as irrigation networks, fisheries and forests, on a few important characteristics. These are: 1) a lack of a clear resource-behavior reinforcing link and 2) they typically feature larger geographic scales, greater complexity and more uncertainty.

2.4.1. Public Goods Dilemmas Lack of Behavior-Reinforcing Link

CPR dilemmas also feature externalities at their core, but with an important distinction. Within CPR dilemmas, overuse of resource results in degradation of that same resource for all. Therefore, an individual who overharvests, say overfishes in a vulnerable fishery, will ultimately see reductions in their own ability to fish because of aggregate overfishing. As shown in Figure 2-2 below, this can be conceptualized as a negative reinforcement mechanism. Hardin described this situation in his classic *Tragedy of the Commons* paper: “each pursuing his own best interest” will bring “ruin to all” (Hardin, 1968, p. 1244).

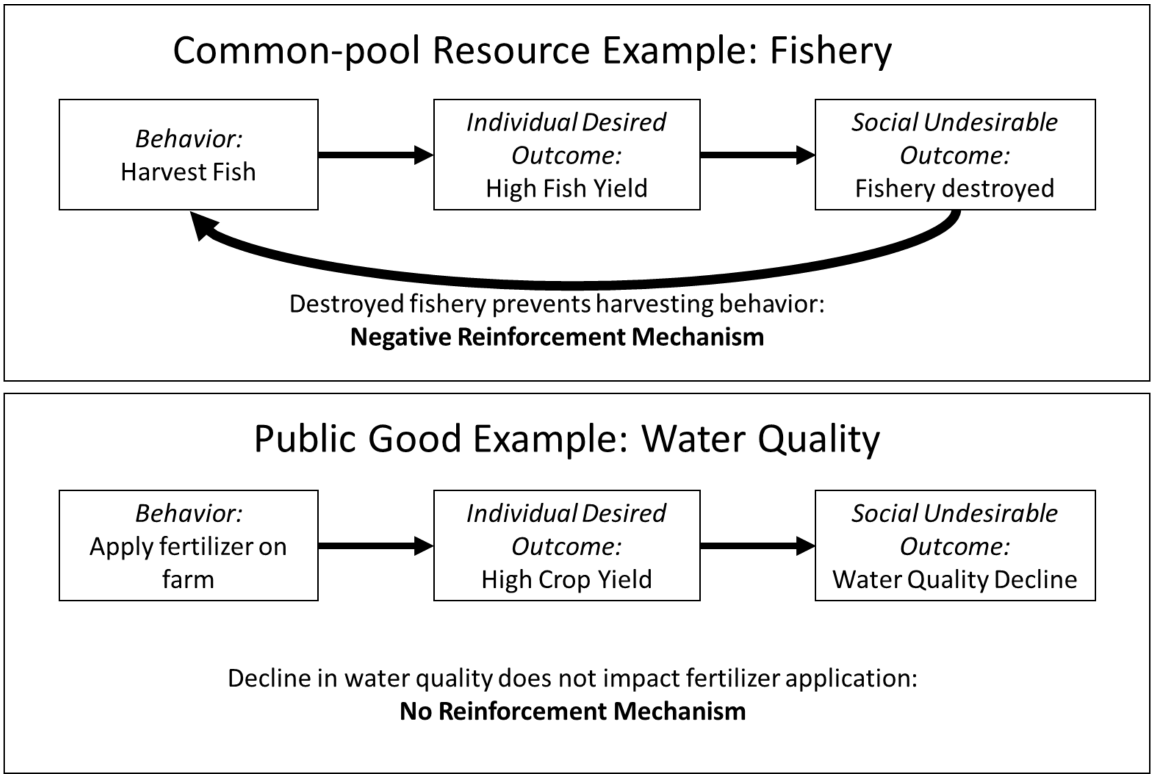

Figure 2-2. Resource system and resource use relationships in common-pool resource and environmental public good. Note the lack of feedback between undesirable outcomes in public good example.

This feedback link, in which the behavior in question ultimately affects the ability to engage in that same behavior in the future, is not present with environmental public goods, as show in Figure 2-2. Rather, environmental public goods dilemmas often feature many different types of actors using or exploiting the same resources for different purposes (Young, 2002). In the water quality example, farmers use nutrients to produce agricultural products, and citizens more broadly enjoy water quality for recreation, aesthetics or drinking water, as shown in Table 2-1. Importantly, the decline in water quality, in and of itself, will not limit a farmer's ability to apply fertilizer on the farm. This is true even if a farmer is a part of the population that also enjoys water quality.

This lack of a behavior-reinforcement link creates challenges for characterizing the resource system within the SES Framework because it is unclear which resource system dynamics drive behavior and at which scales. Environmental public goods dilemmas generally do not feature the one-to-one resource system-resource unit link that is characteristic of most CPR regimes (e.g., Resource unit: Fish; Resource system: Fishery). Hinkel et al.’s (2015) diagnostic approach for identifying the resource units, resource system, and provisioning and/or appropriation problem using the SES Framework is not as clear cut for a public goods dilemma without this one-to-one link. Environmental public goods dilemmas typically feature at least two nested resource systems, and often many more.

Table 2-1 shows the relevant action situation for the example case of declining water quality in agricultural watersheds. Connected to this action situation are two distinct levels of resource system, resource units, activities, benefits and actors. The first resource system is that of the focal behavior: the farm in which a farmer is applying fertilizer to produce agricultural products. The second resource system is the higher-level system that absorbs the negative externality of the behavior in the first system: the watershed, which receives nutrients from the land into local waterbodies. Similarly, the resource units are related, but distinct. One is units of nitrogen and phosphorus, and the other is the nutrient capacity of the waterbody in the watershed. Additional units of nitrogen and phosphorus added to farms will overwhelm the nutrient capacity of the waterbody but will not prevent farmers from adding additional nutrients to their farms in the future.

Table 2-1. Characterization of appropriation and provisioning action situations for agricultural watersheds. Structure adapted from Hinkel et al. (2015).

Actors	Benefits	Activity	Stock of Resource Units (RU)	Subtractability	Resource System (RS)	Action situation (s)
Farmers	Sale of crops/ products	Extracting nutrients from soil and adding nutrients through fertilizer/feed	Nitrogen and Phosphorus	No	Farm system	Addition of nutrients at the farm scale creates a water quality provisioning problem at the watershed scale
Rural and Urban Citizens	Water quality	Aesthetics, Recreation, drinking water, local economic	Nutrient assimilative capacity of the waterbody	Yes	Watershed (biogeochemical processes)	

Importantly, what I am characterizing here as an environmental public goods dilemma could also be described as a number of other types of environmental dilemmas depending on perspective and context. As Young (2002, p. 142) suggests, "environmental problems are socially constructed in the sense that there are almost always a number of plausible ways to think about them, and the choice of conceptualizations is likely to have significant consequences for the interests of one or more members of the relevant group." For example, the issue of declining water quality in agricultural watersheds also bears elements of a CPR regime: the nutrient capacity of the waterbody can be viewed as a CPR that farmers and other landowners use (and overuse) for disposing of wastes (e.g., excess nutrients applied to fields or sewage). Here again, Young (2002, p. 142) suggests that "the extent to which any given environmental concern is properly construed as a CPR problem is likely to be more a matter of how we look at it than a fact of life."

2.4.2. Complexity and Uncertainty in Public Goods Dilemmas

Environmental public goods dilemmas tend to be larger scale, featuring greater levels of complexity and uncertainty than small-scale CPR regimes. All SES share elements of complex systems, including feedbacks, nonlinear dynamics and emergent system properties (Meadows & Wright, 2008). Yet, in larger scale systems, with multiple interacting resource systems and multiple user groups, greater levels of complexity can further complicate the search for sustainable resource management regimes, by complicating our ability to understand system dynamics and measure system outcomes.

To illustrate the complexity and uncertainty typical of public goods dilemmas, I return to the example case of water quality deterioration in agricultural watersheds. The biogeophysical movement of NPS nutrient pollution throughout a watershed is dependent on both deterministic factors, such as land use and soil composition, and random, weather-related processes. Phosphorus and nitrogen molecules, whether originating from agricultural, urban storm water, or streambank erosion, are extremely difficult to differentiate at the watershed scale (Moss, 2008). Because of this, it is very difficult and costly to attribute nutrient pollution to a source (Horan & Ribaudo, 1999). The measurement of pollution is generally done at the watershed scale as farm scale models and measurements have high degrees of uncertainty (Moss, 2008). Yet, even at the watershed scale, modeling of diffuse nutrient pollution involves combining hydrological, geological, meteorological, land cover classification and other data sources across a complex, heterogeneous landscape, with trade-offs in specificity and uncertainty.

Typically, at the watershed scale, government agencies and researchers use a variety of modeling techniques to estimate and attribute NPS pollution contributions to individual sectors, such as agriculture. Management strategies within or across polluting sectors then rely on proxy measurements such as ambient water quality, or production-related measures, such as input-use or practice implementation (Horan & Ribaudo, 1999). Furthermore, at the watershed scale, the transport of nutrients from farms to waterbodies may face significant time lags in the system, again resulting in a high degree of uncertainty and unpredictability (Meals, Dressing, & Davenport, 2010). These attributes of the agricultural NPS pollution, while unique to this specific problem, are representative of the broader challenges of uncertainty and complexity that make many environmental public good dilemmas more difficult to address than small-scale CPR regimes.

The challenges outlined here, namely the multi-resource, multi-actor, highly complex and uncertain nature of public good dilemmas, make them difficult to characterize within the SES Framework. In particular, it is difficult to identify which elements of the system are important to examine for motivating collective action, and how to portray these systems given multiple potential ways to conceive of them. Here I suggest, and will further describe in the fourth section below, the importance of focusing on the actors within the system, drawing on their perceptions of the system to define the relevant elements driving behavior and collective action. Before describing this proposal, I first need to consider another important and related gap within the applications of the SES Framework: the need to apply the SES Framework to examine a broader range of institutional interventions for SES.

2.5. Examining Diverse Institutions to Motivate Collective Action

Many, if not most, SES issues are collective action problems. In collective action problems individuals' pursuit of their own self-interested welfare leads to collective suffering. In other words, all individuals would be better off if they worked together. The collective action problem in agricultural nonpoint source pollution can be defined as: each farmer's individual pursuit of a maximum yield, realized through excessive nutrient inputs, results in poor water quality that is shared by all farmers (and other residents of the watershed). Overcoming collective action problems requires motivating individuals to pursue the collective welfare (Olson, 1971; Ostrom, 1990). In the literature on community-based natural resource management, collective action is often linked with self-organized community management. This body of work, led by Ostrom and others, aimed to suggest that community-based, self-organized governance systems are a viable, potentially sustainable form of natural resource management. More broadly, community-based natural resource management, or self-organized management of resource systems, is just one type of institutional arrangement that can motivate collective action. Other institutional arrangements for addressing collective action problems in SES include market-based strategies, state-based strategies, or any combination of these options with community-based strategies. According to Ostrom, institutional arrangements should be context specific, hence the formation of the SES framework to guide analysis of which institutions promote sustainable system outcomes under specific conditions (Ostrom, Janssen, & Anderies, 2007).

The focus thus far on the emergence of community-based management using the SES framework is just a narrow slice of the potential institutional arrangements that could effectively manage resource systems. More broadly, there is a need to examine a diversity of potential institutional arrangements in environmental dilemmas. This is especially the case within the study of environmental public goods dilemmas, where community-based management strategies may not be the most effective or the most efficient means to address the issue. Indeed, the traditional economics perspective dictates that the state should intervene in the provision public goods because individuals face incentives to freeride off the contributions of others (Singh et al., 2013). Characterizing environmental public goods as dual- or multi-resource system dilemmas, as I do above, illustrates an additional reason for this need: when compared to small-scale CPR regimes, the structure of environmental public good dilemmas does not lend itself to the emergence of social capital.

Small-scale CPR regimes typically consist of "individuals who observe on a daily basis each other's behavior and the impact of their actions on the resource" and, furthermore, "the resource users and the public infrastructure providers are the same individuals" (Anderies et al., 2004, para. 43). In environmental public goods dilemmas, by contrast, these conditions that lead naturally to the building of social capital, such as norms and trust, are not necessarily present. Social capital refers to the "idea that social bonds and norms are important for people and communities" (Pretty, 2003, p. 1913). In public goods dilemmas, resource users are not often the same as the public infrastructure providers. Resource users may not be observing each other's behavior on a daily basis. Finally, it may be impossible to see the impact of each other's behavior on the broader resource system. Therefore, reciprocity, trust, norm creation, and repeated interactions may not be feasible mechanisms to create sustainable resource management regimes.

Take, again, the example of water quality declines in agricultural watersheds: a farmer's fertilizer use and nutrient management behavior takes place on her farm in isolation. It is difficult for other farmers to observe her nutrient management actions. Additionally, public infrastructure providers, such as employees of government water resources agencies, are typically not farmers and do not interact with farmers on a regular basis. It may be difficult for farmers to make the connection between regular nutrient applications on their farm and broader water quality issues at the watershed-scale because of the complexity challenges outlined in the previous section. Furthermore, water quality issues may be less salient to those farmers who farm higher up in a watershed when they don't experience or witness water quality issues firsthand. Therefore, the rule and norm creation, trust, reciprocity, and shared understanding may not exist amongst the farming community, making self-organized collective action on water quality very difficult. This suggests that there may be a place for other types of institutional interventions, such as regulatory or market-based policies, to encourage or require collective farmer behavior change to improve water quality. I propose that to investigate diverse institutional arrangements using the SES framework, it is important to more closely examine this institution-behavior link. This focus on how and why institutions shape behavior and decision-making is what is needed to improve our understanding and management of environmental public goods.

2.6. Expanding the Institutional-Behavior Link

An increased focus on actor decision making within the SES Framework, and in particular, on the link between institutions and behavior, can facilitate its application to both environmental public good dilemmas and a broader diversity of institutional arrangements. As described in the previous two sections, environmental public goods dilemmas differ from CPR regimes, the archetypal application of the SES Framework, by a number of factors, including the lack of a behavior-reinforcing feedback, multiple resource systems and actor groups, complex and uncertain biophysical dynamics, and a lack of key interactions that build social capital. These elements of environmental public goods dilemmas increase the importance of understanding actor decision making and behavior. In this section, I will first describe how an increased focus on decision-making can improve the applicability of the SES Framework to environmental public goods dilemmas and diverse institutional arrangements. Then I will describe a sampling of social-psychological and behavioral theories of decision-making to demonstrate how pulling from theory and models in these fields can improve our understanding of SES system outcomes through incorporation into the SES Framework. In the last section of this paper, I outline how to incorporate these theories and models into the SES Framework.

2.6.1. The Critical Role of Actor Decision Making in SES

The SES Framework is designed around actor decision-making, but the decision-making processes, or at least actors perceptions of costs and benefits, themselves are typically not empirically analyzed (Thiel et al., 2015). Actor decision-making and behavior are important components of any SES because ultimately, actor behavior is a key driver of both social and ecological outcomes, and moreover, one of the major leverage points that humans have to intervene in SES. However, I propose that the attributes of environmental public goods dilemmas, as compared to CPR dilemmas, make actor decision-making and behavior even more relevant for SES system outcomes.

As described above, public goods dilemmas lack the behavior-reinforcing link present in CPR dilemmas as illustrated in Figure 2-2. This link in CPR dilemmas serves as leverage to change self-interested actors' behaviors. It is possible to design incentives around this self-interest to motivate a behavior shift towards long-term individual (and social) payoffs. This is, of course, not a simple shift, and much research has been dedicated to designing incentives to solve this difficult problem (Ostrom, 1990; Ostrom et al., 2002; Poteete et al., 2010). However, the shift to sustainable resource management for public goods dilemmas, which lack this behavior-reinforcing link, can be even more difficult. Without this self-interested mechanism to motivate behavior change, there must be another value-based motivator. A few possibilities include altruism, stewardship, and deterrence from fees or penalties. Drawing again from the example of water quality and agriculture, when water quality declines, there is nothing physically preventing farmers from applying nutrients to their farms. It is possible that informing a farmer of the impact of nutrient applications on the lake could inspire behavior change due to a farmer identifying with stewardship values. Whether or not this is the case would have implications for designing effective policy. Identifying and understanding what motivates collective behavior in context-specific environmental public goods dilemmas is important for the design of institutional interventions to change behavior.

The difficulty in defining behavioral motivation and incentives is further exacerbated by the multi-resource, multi-actor nature of many environmental public goods dilemmas. With different actors, using a resource, or multiple-related resources systems for different purposes, it is hard to decipher what the breadth of motivators are for distinct actor groups/resource uses. Moreover, individual actors understanding of the SES is likely to vary actor to actor. The way in which an actor perceives the SES and their role in it is likely to influence their decision-making process and behavior. Ostrom highlighted the importance of actors' mental models and knowledge of the SES on system outcomes by designating these as variables in the framework (McGinnis & Ostrom, 2014). These variables are likely to be of increased importance in environmental public goods dilemmas. Here again, understanding the drivers, perspectives and values that comprise actors' mental models and knowledge of the SES that underlie the decision-making process can help with identifying behavioral interventions.

In environmental public goods dilemmas, SES are often larger scale, more complex, and more uncertain. This poses a challenge for designing sustainable governance solutions because often it is impossible to accurately measure ecological system outcomes. With water quality decline in agricultural watersheds, due to time lags in the movement of nutrients from farms to waterbodies, it may take decades for collective behavior change to result in water quality improvement (Meals et al., 2010). In these cases, we often use models to project future ecological outcomes based on land use behavior. Therefore, behavior change itself becomes the proxy for ecological outcomes. The central focus on behavior change in these systems suggests that understanding the drivers of behavior to then change behavior is the most direct pathway to improve ecological outcomes.

Finally, in environmental public goods dilemmas the lack of built-in processes for building social capital amongst actors calls for greater attention to how specific institutional interventions influence decision-making. The lack of built-in processes for building social capital suggest that there is less likelihood for the emergence of community-based collective action (Pretty, 2003). This is not to say that trust, reciprocity, norms, and shared rules do not play a role in shaping behavior, but it does suggest that greater emphasis is required to understand where and how they play a role.

In making the case for the relevance of decision-making and behavior in the analysis of environmental public goods dilemmas, it is important to note that the SES framework is compatible with a wide range of decision-making and behavioral theories. Within the SES framework, McGinnis and Ostrom (2014, para. 5) suggest that "choice processes are not required to comport to any specific model of decision-making or policymaking, nor are all outcomes observed required to have been intended by participants in the process." This flexibility means that we can use a variety of decision-making and behavioral theories to better understand SES actor behavior and outcomes. However, so far, this flexibility has been underutilized.

Ostrom and her colleagues were aware of the importance of incorporating a broader understanding of human behavior into the study of SES. Poteete et al. (2010), in their book on methods for studying collective action, identify this as one of the key next steps for the field. Rather than using a single model to describe behavior, such as bounded rationality, Poteete et al. (2010, p. 222) suggest that it "is more productive to posit broad theoretical attributes of human behavior that can help explain why individuals act in particular ways in one situation versus another." To do this, I suggest, requires drawing on a broad range of psychological and behavioral theories to empirically examine the conditions and contexts that drive decision making and behavior with SES.

Next, I will highlight a few psychological and behavioral concepts that may be particularly relevant for the study of environmental public goods dilemmas. This is not meant to be an exhaustive list, but rather a sampling to suggest the utility of this approach (see Singh et al. (2013) and Schlüter et al. (2017) for additional reviews of decision-making theories of relevance to understanding environmental dilemmas).

2.6.2. Promising Decision-making Concepts and Theories for Environmental Public Goods Dilemmas

A number of decision-making and behavioral models exist that could prove useful for incorporation within the SES framework for the study of environmental public goods and beyond. The body of research on collective action and common pool resource dilemmas, including SES Framework applications, has typically relied upon the behavioral assumptions of bounded rationality to explain individual behavior, as suggested in Section 2 above (Ostrom, 2005). This approach models decision-making as dependent upon limited information, cognitive processing, and attention in shifting individual cost-benefit analysis of potential actions (Poteete et al., 2010). Bounded rationality offers insight into the heuristics and biases that shape individual behavior, such as a greater aversion to losses than gains, anchoring on a given value rather than intrinsic values, or habit-formation (Gsottbauer & van den Bergh, 2011). Within the SES Framework, these aspects of decision-making may have important implication for institutional design, such as whether to design incentives to motivate behavior or sanctions, or what level to set a baseline incentive offer.

Social psychology also offers a number of decision-making models and theories, which are not mutually exclusive with bounded rationality. Theories such as the Theory of Planned Behavior (Fishbein & Ajzen, 2011), the Value-belief-norm theory (Stern, Dietz, Abel, Guagnano, & Kalof, 1999), and the Norm-Activation theory (Schwartz, 1977) model individual behavior as embedded in individual's beliefs and perceptions of the world. As a complement to bounded rationality, individuals' beliefs and perceptions are grounded in an individual's worldview and experience, as opposed to full information about any given decision-making situation. These social psychological theories suggest that constructs such as an individual's attitudes toward a behavior, subjective and personal norms surrounding the behavior, and perceived behavioral control, or self-efficacy in engaging in a behavior are important predictors of how an individual will behave (Bandura, 2000; Fishbein & Ajzen, 2011; Stern et al., 1999). Klöckner's (2013) comprehensive action determination model combines elements of the theory of planned behavior, norm-activation theory and bounded rationality in an integrated decision-making model and has shown strong predictive power across a number of domains of environmental behavior.

In environmental public goods dilemmas, where individuals are faced with high levels of uncertainty and ambiguity, social psychological decision-making theories can help identify the way in which individuals are making decisions in these highly variable conditions (e.g. based on other's actions, their own level of understanding, what they think is right, etc.). Furthermore, these theories can help to identify types or typologies of actors that value different types of information and assistance. This stands in stark contrast to an institutional rational choice model which assumes individuals to be self-interested and motivated by utility maximization (in practice mainly profit maximization).

As a proof of concept, I will suggest a few psychological and decision-making concepts that may be particularly helpful in examining actor behavior in environmental public goods dilemmas and describe their potential contribution. These are: self-efficacy and perceived behavioral control, experience and personal norms, and attitudes.

2.6.3 Self-Efficacy and Perceived Behavioral Control

When considering actor behavior in collective action dilemmas, autonomy, or an individual's capacity to make their own decisions, is an important concept. Autonomy is closely aligned with the concept of self-efficacy, for motivating behavior change. According to Bandura, "unless people believe that they can produce desired effects and forestall undesired ones by their actions, they have little incentive to act" (Bandura, 1986, 2000, p. 75). Another closely related psychological concept is perceived behavioral control, which is an element of the psychological Theory of Planned Behavior (Ajzen, 1985). Perceived behavioral control refers to "a general sense of personal competence or perceived ability to influence events" (Fishbein & Ajzen, 2011, p. 153). Beliefs of self-efficacy strongly inform an individual's confidence in their ability to perform a behavior and it is predicted that those with higher levels of perceived behavioral control with respect to a specific behavior or action would be more likely to adopt the behavior

(Ajzen, 1991). There is a strong link between individual self-efficacy, individual action and collective action. Individual's hold beliefs about collective efficacy within themselves, as opposed to some external representative. Therefore examining individual's beliefs about perceived behavioral control may be an important component of actor decision making and behavior in SES (Bandura, 2000). Furthermore, different institutional arrangements intended to motivate collective behavior change in SES may impact actor self-efficacy and perceived behavioral control in different ways. This could have important consequences for overall SES system outcomes.

2.6.4. Experience and Personal Norms

Exposure or experience with a policy can be through participation in town hall meetings, planning committees, or public hearings, as well as measurement, monitoring or enforcement exercises can shape individual decision-making. Edward-Jones (2006, p. 788) highlighted this as an important area for future research, in the light that engaging in a behavior due to policy requirements could "have a positive feedback on behavior such that the policy aims would continue to be met after the formal end of the policy". This is further in line with Krosnick et al.'s (2006) Attitude, Certainty and Existence (ACE) model which includes personal experience and informant's messages as predictors of general public support for a policy agenda. Throughout a policy process and through engaging in target behaviors, individuals may be exposed to information that updates belief sets and norms to reinforce the target behavior. It is possible that exposure to a policy process activates personal pro-environmental norms. Personal norms are a component of the Norm-Activation theory (Schwartz, 1977) and Value-Belief-Norm theory (Stern, 2000) which suggest that given awareness of a behaviors consequences and personal ascription of responsibility for a given outcome, personal norms for a behavior will be activated and increase the likelihood that an individual will engage in the behavior.

2.6.5. Attitudes

Attitudes are a central concept to many psychological models of decision-making, including the Theory of Planned Behavior (Ajzen, 1991). According to Fishbein and Ajzen, attitudes are the "latent disposition or tendency to respond with some degree of favorableness or unfavorableness to a psychological object" (2011, p. 76). Attitudes can be seen as an evaluation, on a scale from negative to positive, of a given action or behavior. In the context of actor behavior in environmental public goods dilemmas, actors may hold attitudes toward specific behaviors of interest that may influence whether or not they engage in the behavior. According to the Theory of Planned Behavior, one would expect an individual with positive attitudes towards an action to be more likely to engage in that action (Fishbein & Ajzen, 2011).

I propose that incorporating the study of actors' attitudes, experience and personal norms, and self-efficacy and perceived behavioral control, along with other psychological theories, into the study of environmental public goods dilemmas using the SES can improve our ability to design institutions to promote sustainability in these systems.

2.7. Incorporating the Institutional-Behavior Link into the SES

What would it look like to expand the institutional-behavior link in the SES Framework to apply it to environmental public goods dilemmas and to examine diverse institutional arrangements? Given the flexibility of the SES framework towards decision-making and behavioral theories, the incorporation can take many different forms. Here I recommend two potential approaches to strengthen the institution-behavior link in the SES framework. The first approach is to add social-psychological variables to the suite of actor attribute variables to test and explore the role of relevant psychological and behavioral theories in driving outcomes in SES. The second is to examine actor mental models within environmental public goods dilemmas to redefine SES framework categories to capture the relevant actor motivations and drivers of behavior. These recommendations complement each other and ultimately, a mixed methods approach combining both recommendations would be the most beneficial to improving our ability to identify elements of institutional design that lead to robust environmental public good regimes.

The first recommendation, to add social-psychological variables to the SES Framework, methodologically begins with framing research questions around the connection between institutions and actor behavior. For example, in the context of declining water quality due to agricultural activities, a potential set of institution-behavior questions could be: Are farmers more likely to adopt water quality best management practices in mandatory or voluntary policy regimes? Do farmer feelings of self-efficacy explain the difference in behavioral response to these policies? These questions would then drive the application of the SES Framework to a series of cases to be compared. In Table 2-2, I demonstrate the application of the SES Framework to these example questions by listing the variables that could be used in defining and testing the relationship of interest. First, one would define the independent variables of interest, shown as red variables in Table 2-2. The first independent variable is the institutional variable: GS6 Rules-in-use, which is defined in this example as being either mandatory or voluntary. Then the second independent variable, "A10 Actor(s) values and motivations," is a new second tier variable that I am proposing to add to the framework under the first tier Actor category. This new variable is where theories from psychology and behavioral economics, such as those reviewed above, can be incorporated into the framework as shown in Table 2-2 below. Drawing from the sampling of theories reviewed in the previous section, some potential third tier variables under "A10 Actor(s) values and motivations" are personal norms, attitudes and self-efficacy. In the example case, self-efficacy can be included as an actor attribute, falling on a spectrum from high to low.

The relationship of interest is the interaction of these two variables, and their effect on the dependent variable "I1* Resource use levels of diverse users," defined here as adoption of water quality best management practices. In order to better accommodate environmental public goods dilemmas, I also propose including this revised label category for I1 ("Resource use") as opposed to the previous label for the category "Harvesting levels of diverse users", since not all resource use behavior within an SES is harvesting behavior. Furthermore, I suggest explicitly adding a variable to examine public good provisioning behavior: "I9* Public good provisioning levels." This variable could be another dependent variable of interest in the example case, defined as ambient water quality levels.

Table 2-2. Example application of a revised SES framework to the case of declining water quality due to agriculture. Additions or revised categories are marked with an asterisk (*). Highlighted variables: red are the example independent variables, gold are example dependent variables, blue are covariates and bold black are held constant. Adapted from McGinnis & Ostrom (2014)

Social, economic and political settings (S): S1 Economic development, S2 Demographic trends, S3 Political stability, S4 Government resource policies, S5 Market incentives, S6 Media organization

Resource systems (RS)	*Governance systems(GS)*
RS1 Sector: watershed	GS1 Policy area
RS2 Clarity of system boundaries	**GS2 Geographic scale of governance system: state/region**
RS3 Size of resource system: large	GS3 Population
RS4 Human-constructed facilities	GS4 Regime type
RS5 Productivity of system	**GS5 Rule-making organizations: state/regional**
RS6 Equilibrium properties: declining water quality	GS6 Rules-in-use: voluntary or mandatory
RS7 Predictability of system dynamics	**GS7 Property-rights systems: private**
RS8 Storage characteristics	GS8 Repertoire of norms and strategies
RS9 Location	GS9 Network structure
	GS10 Historical continuity
Resource units (RU)	*Actors (A)*
RU1 Resource unit mobility	A1 Number of relevant actors: few to many farmers
RU2 Growth or replacement rate: continued nutrient applications	A2 Socioeconomic attributes: small to large farms
RU3 Interaction among resource units	A3 History or past experiences
RU4 Economic value	A4 Location
RU5 Number of units	A5 Leadership/entrepreneurship
RU6 Distinctive markings	A6 Norms (trust-reciprocity)/social capital: existence of farmer group
RU7 Spatial and temporal distribution: history of nutrient enrichment	A7 Knowledge of SES/mental models
	A8 Importance of resource (dependence)
	A9 Technologies available
	A10* Actor(s) values and motivations: high or low self-efficacy
Interactions (I) ->	*Outcomes (O)*
I1* Resource use levels of diverse users: adoption of practices	O1 Social performance measures
I2 Information sharing among users	O2 Ecological performance measures
I3 Deliberation processes	O3 Externalities to other SESs
I4 Conflicts among users	
I5 Investment activities	
I6 Lobbying activities	
I7 Self-organizing activities	
I8 Networking activities	
I9* Public good provisioning levels: ambient water quality	

Related ecosystems (ECO): ECO1 Climate patterns; ECO3 Flows into and out of focal SES; ECO2 Pollution patterns

With the independent and dependent variables of interest defined, the framework can then be used to guide case selection, by selecting cases that have similar resource systems, resource units, governance systems and actors. This is demonstrated by the resource system, resource unit and governance system variables in bold black text in Table 2-2. These variables would define the criteria that all cases must meet to be included in the analysis. Alternatively, or within the same analysis, some variables could be allowed to vary to examine covariates of the institution-behavior link of interest. An example for these is given by the variables in blue text, including farm size for socioeconomic attributes (A2) and existence of a farmer group for social capital (A6). This approach, as defined here, lends itself to a quantitative analysis in which the relationship between the dependent variable (e.g. behavior or system outcomes) and the independent variables (e.g. policy type and covariates) is measured using a regression model. Agent-based modeling also offers an promising complementary approach for exploring the institution-behavior link in environmental dilemmas, as described in Schlüter et al.(2017).

The key element to incorporating this new social-psychological second tier variable (A10) is data collection, as well as agreement on standardized constructs and validated questions. Data will need to be collected from actors within the system of interest, either from surveys, interviews, experimental games or any other number of methods (see Poteete, Janssen and Ostrom (2010) for a review of methods for studying collective action problems). In doing so, it is important that a core set of psychological constructs are include and questions are asked in the same way to provide internally valid comparisons. One potential example that can be informative for this is the New Ecological Paradigm, a standardized, broadly used, internally valid questionnaire to measure environmental concern (Dunlap & Van Liere, 1978; Dunlap, Van Liere, Mertig, & Jones, 2000; Stern, Dietz, & Guagnano, 1995). This quantitative approach is one way that we can begin to better understand trends in how institutional design shapes decision making, behavior and ecological outcomes in environmental public goods dilemmas.

The second recommendation for strengthening the institution-behavior link within the SES Framework is to draw upon actor mental models to define the relevant system attributes in environmental public goods dilemmas. Mental models of actors are acknowledged to play an important role in SES outcomes and are included in the framework (see variable A7 in Table 2-2) and in many applications of the framework (Thiel et al., 2015). Mental models are individuals' "internal representations" of the world and are made up of concepts linked together, and it is these relationships between concepts that are used to make meaning of the world (Carley & Palmquist, 1992, p. 602). In environmental public goods dilemmas it is important to look to actors to define the concepts/variables that they perceive to be important influences on their behavior. Again, actor behavior is important because ultimately it is actor behavior that policy-makers and society in general are looking to change to improve social-ecological outcomes.

Examining actor mental models lends itself to a qualitative methodologies, much like the in-depth case studies Ostrom and others pursued in the early work on CPR regimes (Ostrom, 1990). Interviews, focus group, and other ethnographic approaches can be used to elicit actors' perceived motivations, interactions and system outcomes within an environmental public good dilemma. The analyst can then using qualitative coding techniques such as grounded theory (Strauss & Corbin, 1994) or other forms of content analysis (Saldaña, 2015) to identify the salient or relevant aspects of the system according to actors. These elements can then be merged with the SES framework, either falling under existing second tier variables, or adding new ones as needed to better define the environmental public goods dilemma context. Working up from actor perceptions of their own behavior and experience to the system level will allow analysts to identify institutions and contextual variables shaping system outcomes in environmental public goods dilemmas.

Ultimately these two recommended approaches to strengthening the institution-behavior link can be used in conjunction, or iteratively to improve our understanding of institutional design in environmental public goods dilemmas.

2.8. Conclusion

The study of environmental public goods dilemmas and of diverse institutional arrangements can help us to identify design principles to improve the sustainability of these regimes. The SES framework was designed with the ambition to fill this need and facilitate the study of all types of SES. However, in application, the SES Framework has struggled to facilitate the study of SES beyond CPR regimes and community-based natural resource management institutions. The same attributes of environmental public goods dilemmas that differentiate them from CPR regimes, namely the lack of a behavior-reinforcing link, the multi-actor and multi-resource system dynamics, higher levels of uncertainty and complexity, and lack of built-in social capital, also increase the need to understand how a broader suite of institutions govern these systems. I have proposed that one way to address these linked challenges within the SES Framework and facilitate the application of the SES to these types of systems is to expand the framework's focus on the institution-behavior link. I suggest that this can be done through incorporating decision-making and behavioral models from psychology and behavioral economics into the SES framework and through examining actor mental models to define relevant system attributes. Both of these recommendations will improve the ability of the SES framework to accommodate the analysis of more diverse resource regimes and facilitate the design of context-specific institutional interventions to support sustainable resource management.

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CHAPTER 3: FROM WATERSHED LIMITS TO FARM-SCALE DECISIONS: THE IMPACT OF MANDATORY WATER QUALITY POLICY ON FARM MANAGEMENT BEHAVIOR AND DECISION MAKING

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3.1. Abstract

Nutrient runoff from agricultural lands is a challenge for agricultural watersheds across the globe. As decades of voluntary programs to address nonpoint source (NPS) pollution have failed to improve water quality, regional governments are turning to mandatory policies in an effort to achieve water quality goals. This recent policy shift highlights a need for insight on the effectiveness of mandatory water quality policy design to limit agricultural NPS pollution. We analyze a national survey of 1,917 New Zealand farmers to compare farmer nutrient management behavior and decision making under three different policy types: mandatory practice-based policy, which requires farmers to adopt specific practices; mandatory performance-based policy, which requires farmers meet a modeled farm nutrient limit; and no current mandatory policy. To compare the success of policy types, we examine behavior change as a proxy for future water quality improvements, and we use the social psychological Theory of Planned Behavior to evaluate potential for farmers' long-term policy support. We run logistic and Poisson mixed effects models to examine differences in the presence and extent (e.g. number of related practices or strategies) of nutrient management plan (NMP) adoption, and for non-adopters, intention to adopt an NMP between policy groups. In our series of

models, farmers in performance-based policies are almost four times more likely to intend to adopt an NMP than the no policy group, which is not the case for farmers in the practice-based group. However, we find that policy type is not predictive of actual NMP adoption or extent of adoption, suggesting that neither type of mandatory policy is associated with increased nutrient management behavior when compared to the no policy group. On the policy support side when we compare predictors of extent of adoption and intention to adopt NMPs, we see perceived behavior control and attitudes are significant predictors of nutrient management behavior in the performance-based policy group and the no policy group, but not the practice-based policy group. Combined, these results suggest that performance-based mandatory policies send a stronger policy signal to farmers in that they are associated with greater intended adoption of NMPs, as well as increased potential long-term policy support.

3.2. Introduction

Globally, declining water quality from the agricultural runoff of nitrogen and phosphorus is an increasing challenge for local, regional and national governments. This diffuse form of pollution, also known as agricultural nonpoint source (NPS) pollution, has broad ranging social, ecological and economic impacts (Bennett et al., 2001; Carpenter et al., 1998). Managing agricultural NPS pollution is challenging due to the difficulty of attributing the diffuse pollution to a source. Management is further confounded by variation in nutrient loss rates due to ecological and climatological characteristics (Carpenter et al., 1998; Ghebremichael, Veith, & Watzin, 2010), the contribution of legacy nutrient loads in the watershed (Sharpley, 2016; Wironen, Bennett,

& Erickson, 2018) and potential decades-long time lags between agricultural management changes and resulting water quality improvements (Meals, 1996; Meals et al., 2010). Agricultural NPS pollution has traditionally been approached through voluntary programs and policies, such as funding for conservation practice adoption through the United States Department of Agriculture and New Zealand's former emphasis on non-regulatory approaches such as education, advice and incentives (Quinn, Wilcock, Monaghan, McDowell, & Journeaux, 2009; Shortle, Ribaudo, Horan, & Blandford, 2012). To date, voluntary programs have made little progress in improving nutrient impaired waterbodies across the globe (Dowd et al., 2008; Rissman & Carpenter, 2015). Governments are beginning to implement mandatory, rules-based approaches to achieve water quality improvements (McDowell et al., 2015). This recent policy shift highlights a need for insight on the effectiveness of mandatory water quality policy design in addressing agricultural NPS pollution.

With mandatory approaches to agricultural NPS pollution, policy makers must make difficult decisions about who bears the burden of paying for water quality improvements, and how to measure and monitor rule compliance (Drevno, 2016). These policy decisions can be controversial, which may impact the ability of the policy to achieve its overall goal of water quality improvement by instigating resistance, non-compliance or policy rejection. Two major rules-based approaches have emerged for regulating nutrient exports from farms that are the focus of this study: practice-based and performance-based policies. Both mandatory practice-based and performance-based policies regulate nutrients flowing off the farm, as opposed to more upstream policies that regulate farm inputs through quotas or taxes (Drevno, 2016). The two approaches, practice and performance, differ in terms of what farmer behavior is allowed or required under the policy, and therefore the farmer experience and behavior under each policy may vary significantly.

Practice-based rules require farmers to adopt a specific practice or set of practices to reduce nutrient exports from the farm. This approach is based on the assumption that various practices are “proven” to reduce nutrient emissions from the farm, although in reality there is wide variety of practice effectiveness (e.g. Zhang et al. (2010) and Dodd and Sharpley (2016)). In a mandatory practice-based policy regime a farm is in compliance if the practices are in place. Conversely, in a mandatory performance-based policy, rules specify a numeric limit for units of nitrogen or phosphorus that leave the farm system. The numeric limit for the farm system can be set through a number of different allocation strategies, including allocation based on historical levels of nutrient use, farm type, physical quality of the land or nutrient vulnerability (Daigneault, Greenhalgh, & Samarasinghe, 2017). Then, performance-based policies typically use a farm system model to calculate whole farm nutrient balances and compare these to the numeric limit to demonstrate compliance. A popular farm system model used in performance-based policies in New Zealand is Overseer®, which calculates nitrogen and phosphorus exports from a farm based on the geographical and ecological characteristics of the farm as well as the farm system type, including the management practices and infrastructure on the farm (Wheeler et al., 2003). To comply with the mandatory performance-based policy, farmers can employ any practice or strategy they choose to achieve their numeric limit and be in compliance.

To improve water quality in an impaired watershed, both practice- and performance-based mandatory NPS pollution policies require patience and prolonged policy support. First patience is required to see results: due to time lags in the movements of nutrients from land to water, the results of management changes on the land today will most likely not be seen for decades (Meals et al., 2010; Morgenstern et al., 2015), though this varies by soil type and landscape. Additionally, internal nutrient cycling in lakes can impede the alleviation of eutrophication symptoms once external nutrient loads are reduced (Carpenter et al., 1998; Roy, Martin, Irwin, Conroy, & Culver, 2010). Second, prolonged support is required to ensure that behavior changes endure to provide sustained improvements in water quality in the future. This suggests that two different elements of policy success are particularly important for the long-term success of agricultural NPS pollution policy: achievement and maintenance of the desired outcome and attracting support for the goals of the policy and means of achieving them to ensure long-term viability (McConnell, 2010).

Given the difficulty in measuring NPS pollution, the best proxy for measuring whether policy is achieving the desired goal (i.e. improvements in water quality in the long term) is changes in farmer behavior. However, if changes in behavior are achieved at the expense of support for the policy and means of achieving them, it is possible that long term water quality improvements will not materialize if adoption is short-term or sporadic. This second aspect of policy success calls for examination of the social psychological impacts of policy on land management decision making. Research has shown that past policy experiences can have lingering negative impacts on farmers' environmental beliefs (Niles, Lubell, & Haden, 2013) and theories of the policy process and social movements suggest that value alignment is a key component of policy support (Jenkins-Smith, Nohrstedt, Weible, & Sabatier, 2014; Stern et al., 1999). Therefore, it is probable that a policy that allows for decision making that aligns with farmer values and beliefs, is more likely to be associated with sustained policy support from farmers.

While much social science research has attempted to understand farmer's voluntary adoption of conservation behaviors, including nutrient management behavior related to water quality (Baumgart-Getz et al., 2012; Conner et al., 2016; Knowler & Bradshaw, 2007; Pannell et al., 2006; Prokopy et al., 2008a; Ranjan et al., 2019), much less work has examined farmer behavior within mandatory policy setting regimes. A few studies have focused on the differential response of individuals to voluntary and mandatory water quality regimes, but the results of these studies show no clear trends. There is evidence for higher levels of adoption of nitrogen testing within mandatory regimes (Bosch, Cook, & Fuglie, 1995), evidence for higher levels of adoption of water quality management techniques in voluntary regimes (Barnes et al., 2013), and evidence for mixed effects of regulation on adoption of different conservation practices (Kara et al., 2008). One relevant case study-based paper examined two types of water quality regulation in Tomales Bay, California and Lake Taupo, New Zealand (Barry et al. 2010). The authors found that farmers in Lake Taupo's performance-based cap-and-trade policy faced more negative economic and social impacts to farm sustainability than Tomales

Bay's practice-based policy, in large part due to the availability of financial assistance in Tomales Bay for on farm practice changes (Barry et al., 2010). For policy makers to design and implement effective policy solutions, a clear understanding of the interaction between policy design and behavior is critical.

In this study, we draw on a natural water quality policy experiment across New Zealand to examine the success of mandatory practice- and performance-based agricultural NPS pollution policy in comparison to regions without mandatory water quality policies. Our focal behavior is adoption of nutrient management plans (NMP), which entails creating and following a plan to manage and control nutrient dynamics on the farm. In practice this means adopting strategies or building farm structures to control nutrient runoff and nutrient applications beyond land and crop requirements. In New Zealand some of these strategies and structures include applying fertilizer at agronomic rates, precision irrigation, fencing permanent waterways, and adjusting the number of livestock units on the farm to match nutrient capacity. Theoretically, engaging in nutrient management planning and adopting an NMP allows a farm to maximize economic benefits (if cost savings are possible through reduced input use) and minimize environmental harm (Beegle, Carton, & Bailey, 2000). Regardless of type of policy, nutrient management planning serves as an important gateway to improving nutrient dynamics on the farm.

We address the following three core research questions to examine the role and impact of mandatory NPS pollution policies:

1. Are mandatory policies associated with higher levels of adoption of NMPs?

2. For those that have adopted NMPs, is policy type related to the extent of adoption of nutrient management practices?
3. For those that have not adopted NMPs, is policy type related to intention to adopt NMPs?

3.3. Material and Methods

3.3.1 Study location

To address our three research questions, we utilize a cross-sectional sample of farmers in a diversity of water quality policy regimes across New Zealand. New Zealand is an ideal study location because there is a high level of variation in regional policy approaches for agricultural NPS pollution, including practice-based, performance-based and no policy regions. The National Policy Statement for Freshwater Management of 2011 & 2014 requires all regional governments to put in place water quality limits for all watersheds across the country by 2025 (NPSFM, 2014). Moreover the National Policy Statement requires regions to create policy to achieve reductions to meet water quality limits where they are unmet, and importantly, these limits can be met through any policy approach. As a result, there is great variation in water quality policies across the country, including a number of regions without policy yet in place (see Appendix 1 Table 5-1 for policy descriptions by region). In essence, the National Policy Statement, prior to 2025, has enabled a natural experiment to examine the impact of water quality policy on farmer behaviors related to NMPs and nutrient management practices.

3.3.2 Policy support and the Theory of Planned Behavior

To evaluate the potential for prolonged policy support, we employ the Theory of Planned Behavior (TPB) (Fishbein & Ajzen, 2011) to examine the predictors of nutrient management behavior amongst farmers both within and outside of mandatory practice- and performance-based water quality policy regimes in New Zealand, as shown in Figure 3-1. We use the TPB to examine evidence for value alignment between theorized social psychological predictors of behavior change and drivers of reported behavior change within a policy context. Existence of value alignment suggests greater potential for prolonged policy support (Jenkins-Smith et al., 2014; Stern et al., 1999).

The TPB predicts that intention to engage in a behavior is explained by an individual's attitudes, subjective norms and perceived behavioral control beliefs regarding the behavior in question (Ajzen, 1985). In the TPB, attitudes are defined as the tendency for an individual to respond with a degree of favorableness towards a behavior (Fishbein & Ajzen, 2011). Subjective norms are the degree to which an individual perceives social pressure to behave in a certain way regarding the behavior of interest. Finally, perceived behavioral control is a "general sense of personal competence or perceived ability to influence events" (Fishbein & Ajzen, 2011, p. 153). It has also been suggested that a fourth component, a moral norm, can improve the predictive validity associated with the TPB for certain behaviors that have a moral dimension (Beck & Ajzen, 1991; Fishbein & Ajzen, 2011). Since nutrient management behavior may have an environmental moral component, we include a variable for environmental stewardship in our application of the TPB. The TPB is one of the most widely researched psychological theories of behavior and has been shown to have consistent predictive power of individual behavior across behavioral domains, including health, political and environmental behavior (Armitage & Conner, 2001; Fishbein & Ajzen, 2011).

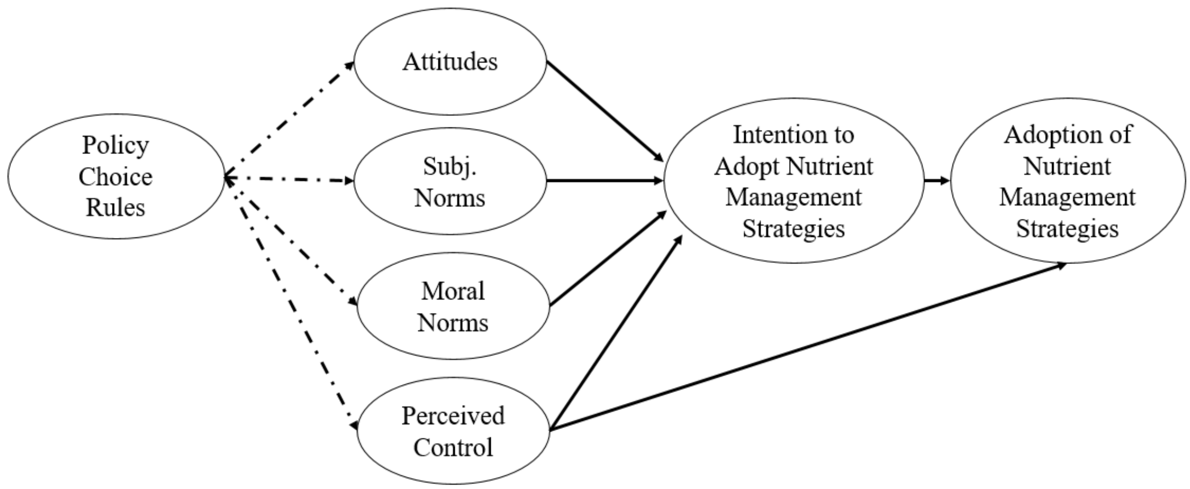

Figure 3-1. Adaptation of Ajzen's (1985) Theory of Planned Behavior (TPB) to test the influence of variation in institutional choice rules on intention and actual adoption of nutrient management strategies by farmers. The dashed arrows represent the hypothesized existence of a relationship between policy choice rules and components of the TPB in a farmer's decision making process on nutrient management planning adoption.

As described above, farmers under practice- and performance-based regulations may have different experiences under each policy type due to differences in rule structure. It is possible that policy design could interact with all four of the TPB psychological pathways for nutrient management plan adoption decisions. For practice-based policies, the clear designation of nutrient management practices that need to be in place may shape social norms within the farming community, attitudes towards practices, control beliefs regarding the practices or moral norms to adopt nutrient management planning. Likewise, in performance-based policies, the requirement to measure and monitor nutrient export from the farm may shape norms, attitudes and perceived behavioral control. However, without the clear regulatory signal for specific practices, performance-based policies may shape norms, attitudes and control beliefs through a farmers' learning, exposure and experience of meeting a nutrient limit for their particular farm system. In the case that any of the TPB predictors are found to be positive and significant predictors of NMP adoption, extent of NMP adoption or intention to adopt NMP, we take this as evidence for value alignment between decision making and a policy. This value alignment suggests that farmers are making decisions about NMPs within a policy context that align with their internal values and beliefs.

3.3.3 Survey and sample description

The data for this study are drawn from a national survey of New Zealand farmers, the Survey of Rural Decision Makers (SRDM) undertaken by Maanaki Whenua – Landcare Research. The SRDM was fielded between July and December 2015 (Brown, 2015). The SRDM is a national, internet-based survey of commercial farm owners and managers. The SRDM sampling strategy consisted of contacting farmers via email through farmer industry lists and databases, circulating invitations to participate through industry and sector groups, and sending mail invitations to farmers in the Statistics New Zealand business frame (for a full description of the sampling strategy, see Brown (2015)).

The SRDM featured 288 questions covering ownership, farm structure, land use, livestock, land management, technology adoption, values, norms, preferences, farming objectives, profitability, demographics, and education (Brown, 2015). Also included in the survey are questions reflecting the TPB that address farmers' attitudes, subjective norms, perceived behavioral control and environmental stewardship related to NMP (see

Appendix 1 Table 5-2 for description of TPB related questions). The focus of the present work is farmers' behavior toward managing nutrients, which is addressed through three questions: 1) has the farmer adopted a nutrient management plan (NMP), 2) if yes, what nutrient management practices has the farmer adopted (e.g. extent of adoption) and 3) if no, does the farmer intend to adopt an NMP in the next 2 years? Extent of NMP adoption is a count of seven NMP-related practices that a farmer has adopted, including reduced stocking rates, changed cropping patterns, changed timing of fertilizer applications, constructed/maintained wetlands, reduced fertilizer applications, fenced waterways and an optional "other" category defined by the respondent. It is important to note that there was a skip pattern built into the survey such that farmers who answered yes to question 1 (i.e. have adopted an NMP), only received question 2 and not question 3. The opposite was also true, such that farmers who answered no to question 1 (i.e. have not adopted an NMP), only received question 3 and not question 2 (See Appendix 1 Figure 5-1 for survey skip pattern structure). Our analytical approach to these questions, as discussed below, reflects the structure of the survey.

The 2015 survey featured a sample of 2,342 commercial farmers which represents 3.90% of the farming population (according to the NZ Ag Census 2012 farm totals). Survey representation varies across territorial authorities in New Zealand (New Zealand's sub-regional geographic unit), from representing 0.60% of the farming population in Tauranga to 16.67% of the Kawerau district farming population (for survey sample by territorial authority see Appendix 1 Table 5-1). Due to missing data, we dropped 425 commercial farmers from the sample, leaving us with a subset of 1,917 farmers to use in analyses. The descriptive statistics of participants are shown in Table 3-1 and represent the subset of 1,917 farmers used in the analyses (for descriptive statistics broken down by policy group, see Appendix 1 Table 5-3). With regard to the key behavioral and decision making variables of interest in our study, adoption of nutrient management planning, we see that 40.53% of the full sample of farmers has adopted an NMP (*NMP adoption*). Of those 777 farmers that have adopted an NMP, they have adopted on average 2.64 nutrient management strategies (*NMP extent adoption*). Alternatively, of those 1,139 farmers who have not adopted an NMP, we see that 21.51% state that they intend to adopt an NMP in the next two years.

Table 3-1 also lists mean response and percentages for the TPB variables included in the study. Two of the TPB constructs, subjective norms and attitudes, are index variables built from aggregating multiple survey questions relating to the construct, as shown in Appendix 1 Table 5-2. Subjective norms questions asked farmers about the expectations from family, the farming community and the New Zealand public for running the farm in an environmentally friendly way. Similarly, attitudes questions asked farmers about how they perceive adopting an NMP has or would impact financial, environmental and farming lifestyle performance of the farm. Cronbach's alpha were used to assess the internal reliability of the attitude and subjective norm latent constructs amongst the measured variables. Both measures were found to have high internal reliability with an alpha of 0.74 for both attitude and subjective norms, which is above the generally accepted 0.70 cutoff for internal reliability (Nunnally, 1978).

The third TPB construct, perceived behavioral control is a count variable of the number of perceived behavioral control-related constructs selected as factors that led to, or kept a farmer from, implementing an NMP. The perceived behavioral control related constructs include successful demonstration, trialing, reversible in nature, having the necessary skills, receiving advice, and availability of financial resources. Respondents could tick up to three of factors. We examine perceived behavioral control as four distinct levels from 0 to 3, reflecting increased perceived behavioral control as more items were selected. We include perceived behavioral control as a categorical variable in our analysis, comparing each level to the base level of "0" or no reported perceived behavioral control. To capture an environmental moral norm, we separated out one of the potential factors included with the perceived behavioral control constructs, "environmental stewardship," to include separately as a binary variable. It is also important to note that some of the TPB questions, specifically the perceived behavioral control and stewardship, were framed differently for NMP adopters and non-adopters. Therefore, we keep these separate and designate the difference using a "_no" for those variables that were asked of non-adopters.

Table 3-1. Farmer sample descriptive statistics

	All (n = 1917)	
Continuous variables	mean	sd
farm size (thousand hectares)	0.37	1.24
age	56.47	11.60
attitude (n = 1018)	6.41	1.31
norms (n = 1830)	21.32	4.79
nmp_adopt_extent (n = 773)	2.64	1.34
Categorical variables	count	%
NMP (yes)	777	40.53
NMP intention to adopt (yes, n = 1139)	245	21.51
profitable (yes)	935	48.77
farm type		
farm type: other	457	23.84
farm type: dairy	425	22.17
farm type: sheep & beef	920	47.99
farm type: grazing support	115	6.00
education		
education: secondary school or less	700	36.52
education: certificate/diploma	544	28.38
education: bachelor's degree	367	19.14
education: advanced degree	287	14.97
education: other	19	0.99
N (nmp extent adoption model only)	*423*	*100*
0. perceived behavioral control	128	30.26
1. perceived behavioral control	163	38.53
2. perceived behavioral control	106	25.06
3. perceived behavioral control	26	6.15
stewardship (yes)	220	52.01
N (nmp intention model only)	*596*	*100*
0. perceived behavioral control_no	239	40.10
1. perceived behavioral control_no	207	34.73
2. perceived behavioral control_no	108	18.12
3. perceived behavioral control_no	42	7.05
stewardship_no (yes)	94	16.93

3.4 Policy coding

The regional policy context of farmer survey respondents was used to explore farmer behavior across different policy contexts, including mandatory practice-based (n =

268), mandatory performance-based (n = 583), or no current mandatory policy (n = 1048). We utilized farmers' reported territorial authority to match farmers to water management zones and identify the existing water quality rules for each territorial authority (NPSFM, 2014). In most cases territorial authority and water management zones overlap significantly or are the same. To categorize territorial authorities as mandatory performance-based policy, mandatory practice-based policy, or no current mandatory policy, we referenced regional environmental policy documents and policy reviews (Greenhalgh & Murphy, 2017), consulted with officials in regional policy offices, and relied on the expertise of co-author S. Greenhalgh in water quality processes throughout New Zealand. The map in Figure 3-2 shows the application of the policy codes by territorial authority across New Zealand.

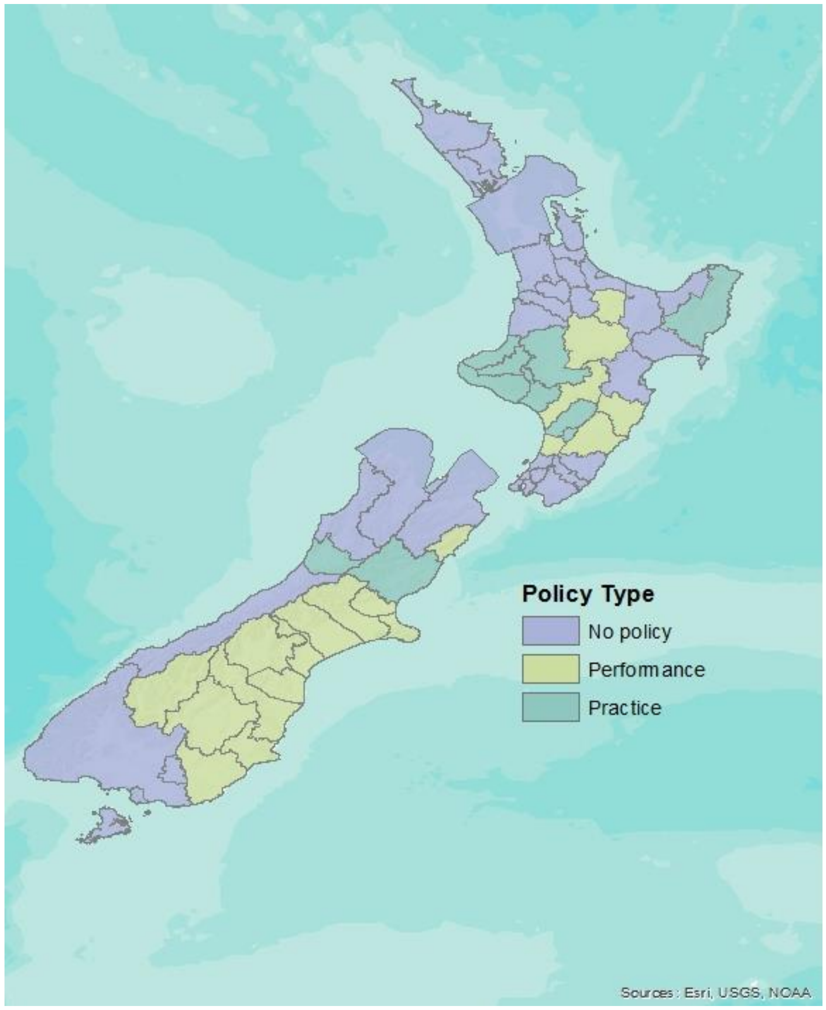

Figure 3-2. Water quality policy types as of 2015 by territorial authority across New Zealand (Statistics New Zealand, 2015).

3.3.5 Data Analysis

We use three mixed effects regression models to investigate the relationship between mandatory water quality policy and farmer behavior for each of the three behavioral outcomes (i.e. adoption, extent of adoption, and intention to adopt). We run logistic mixed effects regression models for NMP adoption and intention to adopt NMPs and a Poisson mixed effects regression model for the extent of NMP adoption. In each of the models we include a random effect at the level of territorial authority to control for unobserved heterogeneity at the district level (Albright & Marinova, 2015). We would expect farms within a region to experience similar trends, both social, market and ecological, and we use the random effect term to control for this in our comparison of behavioral predictors.

Additionally, for each of the three models, we run one full sample and then three group-wise runs by policy type, breaking the sample into no policy, mandatory practice-based policy and mandatory performance-based policy groups to examine intergroup differences in predictors of nutrient management plan behavior. We would like to note a limitation of these policy group sub-models in that they vary in terms of sample size. The practice-based sub-model in particular has relatively low sample sizes for extent of adoption (n=52) and intention to adopt (n=76). In each of the mixed effects models we include farm size, farm type, farmer age, farmer educational attainment and farm profitability as controls. These variables have been found to be important in farmer decision making and conservation behavior (Baumgart-Getz et al., 2012; Conner et al., 2016; Prokopy et al., 2008a). To determine model structure we compared the results of many different model types, including simple single level regressions, single level regression with clustered errors, and mixed effects with and without survey weights. We decided upon the mixed effects models without survey weights as they were the most conservative, although the variation between models did not result in major changes. Statistical analysis was performed in Stata 15 (StataCorp, 2017).

3.4. Results

3.4.1. NMP adoption

The results of the mixed effects logistic regression model examining the predictors of NMP adoption are shown in Figure 3-3 below with the model coefficients represented with odds ratios (for table of odds ratios and standard errors see Appendix 1 Table 5-4). There is no statistically significant effect of policy type (either practice or performance) on rate of NMP adoption. Dairy farms were nine times more likely to have adopted an NMP compared to the other farm type category, which includes deer, pig, poultry, vegetable and horticultural farms. Sheep and beef farms and grazing support were each about half as likely as the other farm type category to have adopted an NMP. A shift from not profitable or breakeven to profitable farms was associated with a 1.35 times increased likelihood of adopting an NMP. Farm size, education and age were not significant predictors of NMP adoption. The Likelihood Ratio Test (LR) for the significance of the random effect of territorial authority on NMP adoption was non-significant (χ^2 (1) = 0.72, p = 0.20).

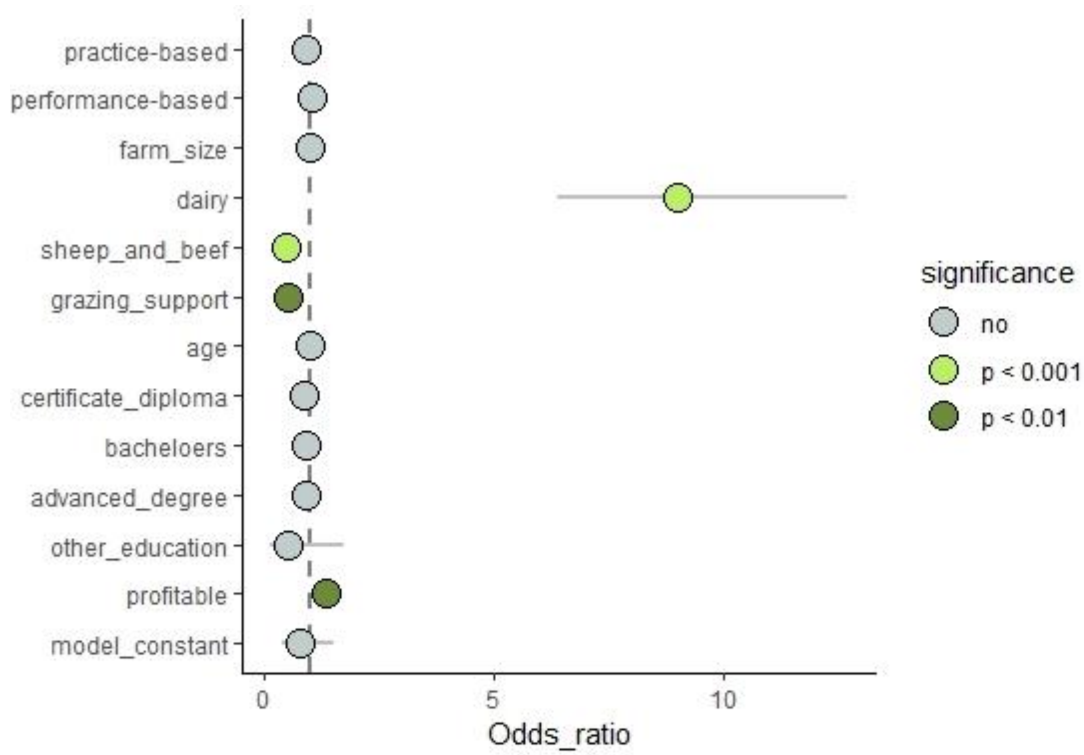

Figure 3-3. Coefficient plot of NMP Adoption mixed effects logit model (n=1917). Coefficients are presented as odds ratios. For table of odds ratios and standard errors see Appendix 1 Table 5-4.

3.4.2 Extent of NMP adoption

Figure 3-4 shows the results of the Poisson model predicting farmer extent of NMP adoption. The betas associated with significant predictors can be interpreted as the number of nutrient management practices associated with a one unit increase in the predictor variable. For extent of NMP adoption we again see no effect of policy type on rate of adoption. With regard to the TPB variables, perceived behavioral control does significantly, and positively, predict adoption at two levels: the second level of perceived behavioral control ($\beta = 0.21$, $p < 0.05$) and the third level of perceived behavioral control ($\beta = 0.31$, $p < 0.05$), as compared to the lowest (base) level of perceived behavioral control, but attitudes and norms do not. The second and third levels of perceived behavioral control represent the second highest and highest belief strength, respectively, of perceived ability to engage in nutrient management planning. Of the TPB constructs, environmental stewardship (β= 0.21, $p < 0.01$) does significantly predict extent of NMP adoption. In addition, farm size (β= 0.06, $p < 0.05$) and operating a dairy farm (β= 0.48, $p < 0.000$) compared to other farm types both significantly and positively predict extent of NMP adoption. The random effect for territorial authority on extent of NMP adoption for the model was estimated to have a coefficient of zero.

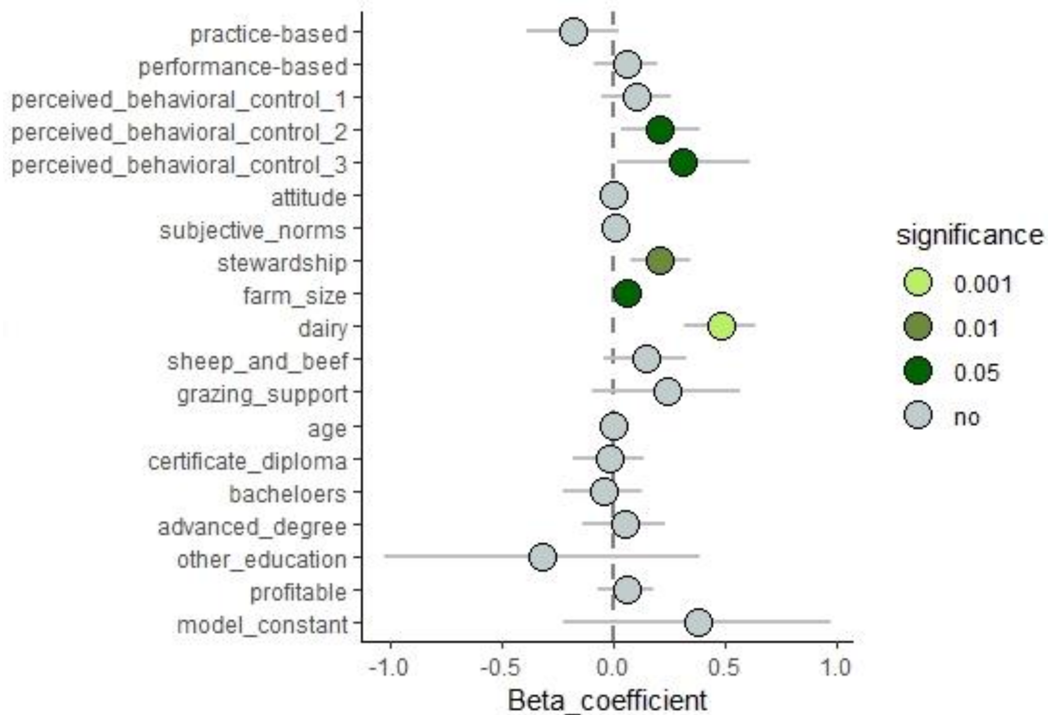

Figure 3-4. Coefficient plot of NMP Extent of Adoption mixed effects Poisson model (n=401). Coefficients are presented as Beta coefficients. For table of coefficients and standard errors see Appendix 1 Table 5-5.

Broken down by policy type we see that the three policy types are associated with different factors related to extent of NMP adoption. The no policy group, shown in Figure 3-5, results align closely with the full model: perceived behavioral control of 3 (β=

0.44, $p < 0.05$), environmental stewardship ($\beta = 0.22$, $p < 0.05$), farm size ($\beta = 0.17$, $p < 0.05$) and operating a dairy farm ($\beta = 0.47$, $p < 0.000$) all significantly and positively predict NMP extent adoption. In the practice-based model, shown in Figure 3-6, only operating a dairy farm ($\beta = 0.68$, $p < 0.05$) is a significant predictor of extent of NMP adoption. Although, we would like to reiterate here the low sample size (n=52) for the practice-based model, which may limit the ability to interpret these results. In the performance group, shown in Figure 3-7, only the second level of perceived behavioral control ($\beta = 0.33$, $p < 0.05$) is a significant predictor of NMP extent adoption. The random effects for territorial authority on extent of NMP adoption in all three policy sub-group models were estimated to have a coefficient of zero

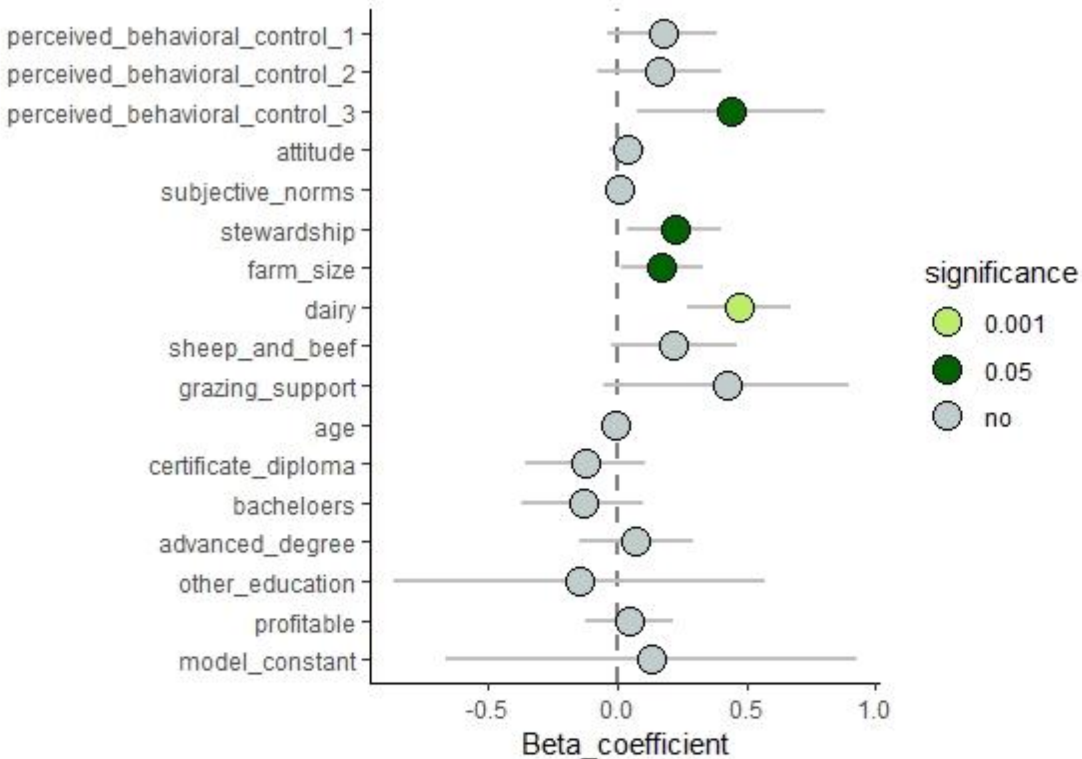

Figure 3-5. Coefficient plot for no policy group (n = 230) NMP Extent of Adoption mixed effects Poisson model. Coefficients are presented as Beta coefficients. For table of coefficients and standard errors see Appendix 1 Table 5-5.

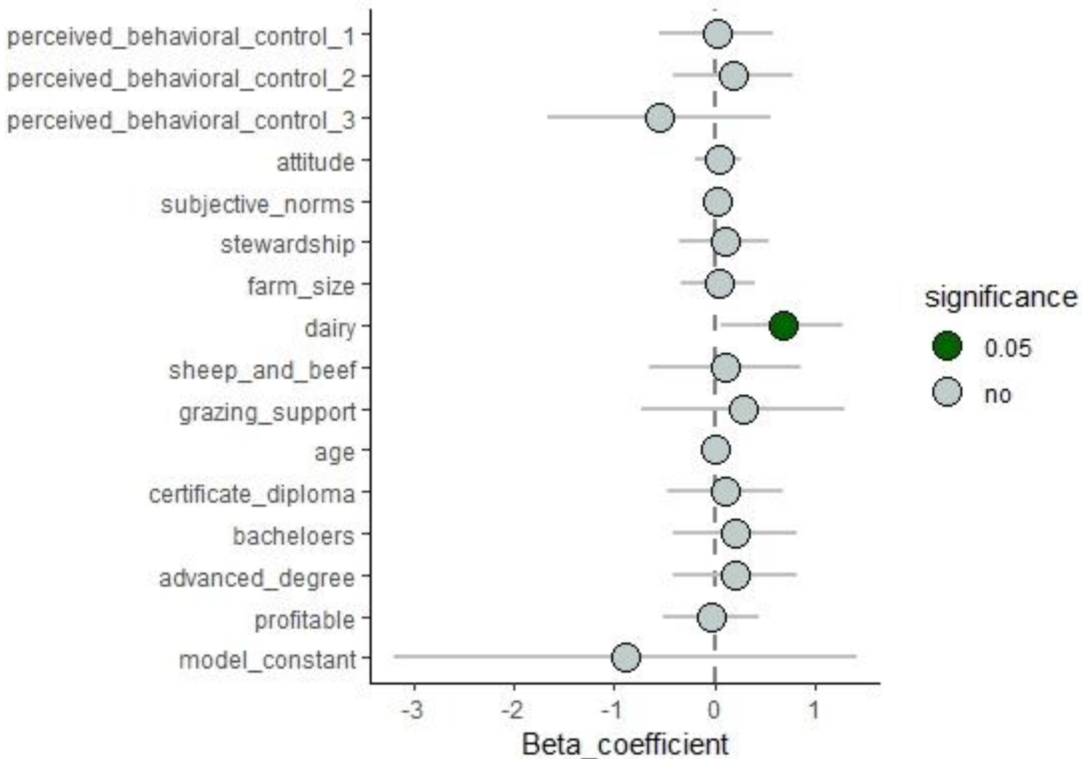

Figure 3-6. Coefficient plot for practice-based group (n = 52) NMP Extent of Adoption mixed effects Poisson model. Coefficients are presented as Beta coefficients. For table of coefficients and standard errors see Appendix 1 Table 5-5.

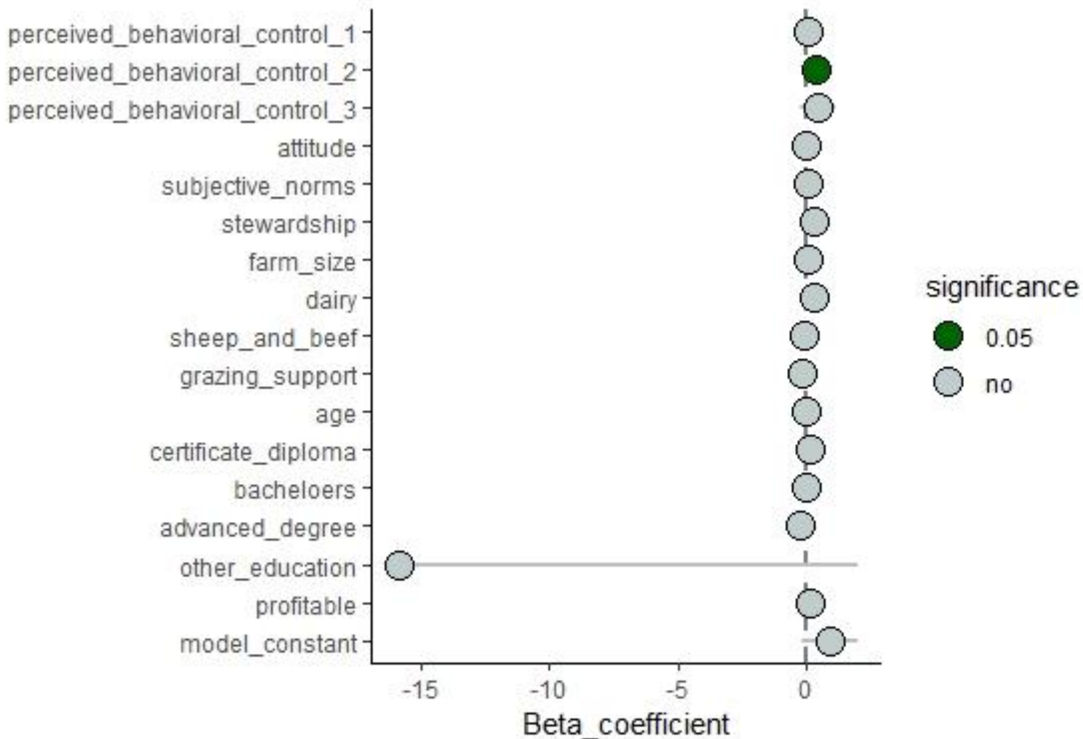

Figure 3-7. Coefficient plot for performance-based group (n = 119) NMP Extent of Adoption mixed effects Poisson model. Coefficients are presented as Beta coefficients. Note that we present a truncated left hand confidence interval for other education in this plot. For table of coefficients and standard errors see Appendix 1 Table 5-5.

3.4.3 Intention to adopt nutrient management plan

The results of the logistic mixed effects model examining predictors of the intention of non-adopters to adopt an NMP, with coefficients presented as odds ratios, are shown in Figure 3-8. In the full model, farmers in a performance-based policy are almost four times more likely to intend to adopt an NMP than farmers in the no policy group (OR = 3.96, $p < 0.001$). Amongst the TPB variables, attitudes (OR = 1.56, $p < 0.000$) and norms (OR = 1.08, $p < 0.01$) both significantly and positively predict intention to adopt an NMP, but perceived behavioral control is not statistically distinguishable from zero. In addition, operating a sheep and beef farm (OR = 2.212, $p < 0.01$), operating a grazing support farm (OR = 3.042, $p < 0.05$) and having a bachelor's degree (OR = 2.19, p <

0.05) are all positive and significant predictors of intention to adopt an NMP. Age (OR = 0.97 p < 0.01) is a significant negative predictor of intention to adopt an NMP, meaning older farmers are less likely to adopt a NMP. The LR test for the significance of the random effect of territorial authority on intention to adopt NMP was non-significant (χ^2 (1) = 0.05, p = 0.41).

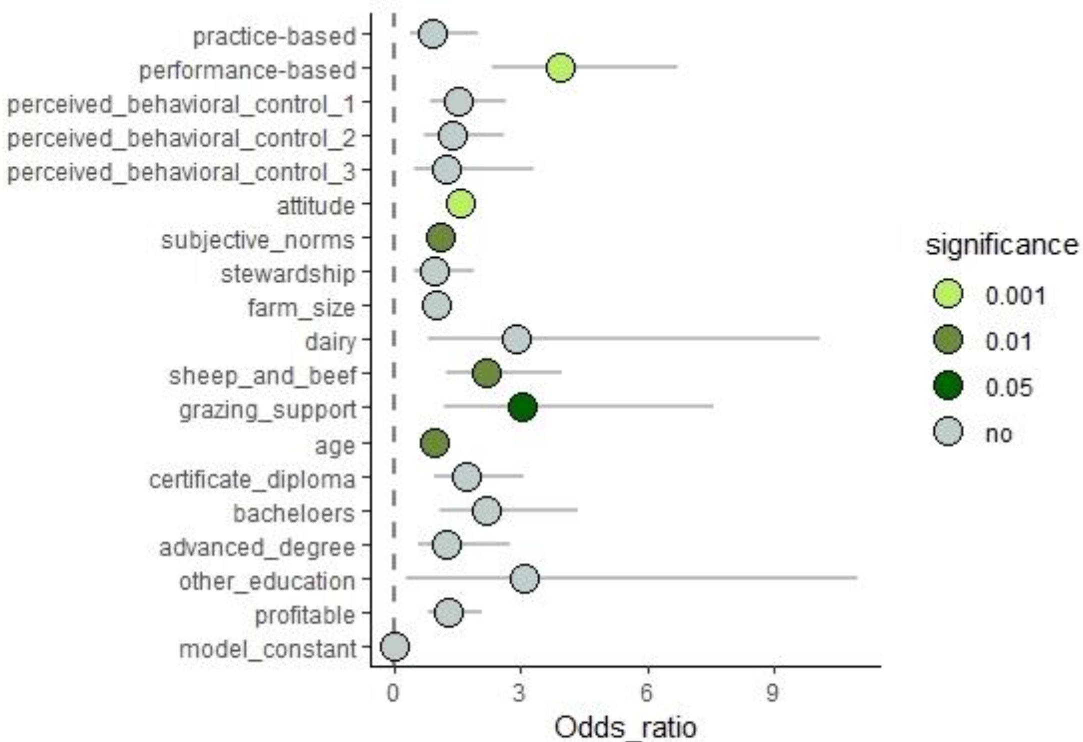

Figure 3-8. Coefficient plot of Intention to Adopt NMP mixed effects logit model (n=536). Coefficients are presented as odds ratios. Note that we present a truncated right hand confidence interval for other education in this plot. For table of odds ratios and standard errors see Appendix 1 Table 5-6.

Comparing policy group models, again we see the policy types are associated with different factors related to intention to adopt NMP. In the no policy group model, shown in Figure 3-9, attitudes (OR = 1.98, p < 0.01), norms (OR = 1.14, p < 0.05) and operating a sheep and beef (OR = 5.23, $p < 0.05$) significantly and positively predict intention to adopt. For the practice-based group model, shown in Figure 3-10, farm size (OR = 114.5, $p < 0.01$) is associated with a very large increased likelihood of NMP intention to adopt, whereas sheep and beef farms (OR = 0.0134, $p < 0.05$) and age (OR = 0.899, $p < 0.05$) are associated with a very low likelihood of NMP intention to adopt. Amongst the performance group, shown in Figure 3-11, attitudes (OR = 1.35, $p < 0.05$) is a positive and significant predictor of NMP intention to adopt and so is operating a grazing support farm type (OR = 4.40, $p < 0.05$). The LR test for the significance of the random effect of territorial authority on intention to adopt NMP was non-significant for the no policy group (χ^2 (1) = 0.40, $p = 0.26$) and the coefficient was estimated as zero for the practice-based and performance-based groups.

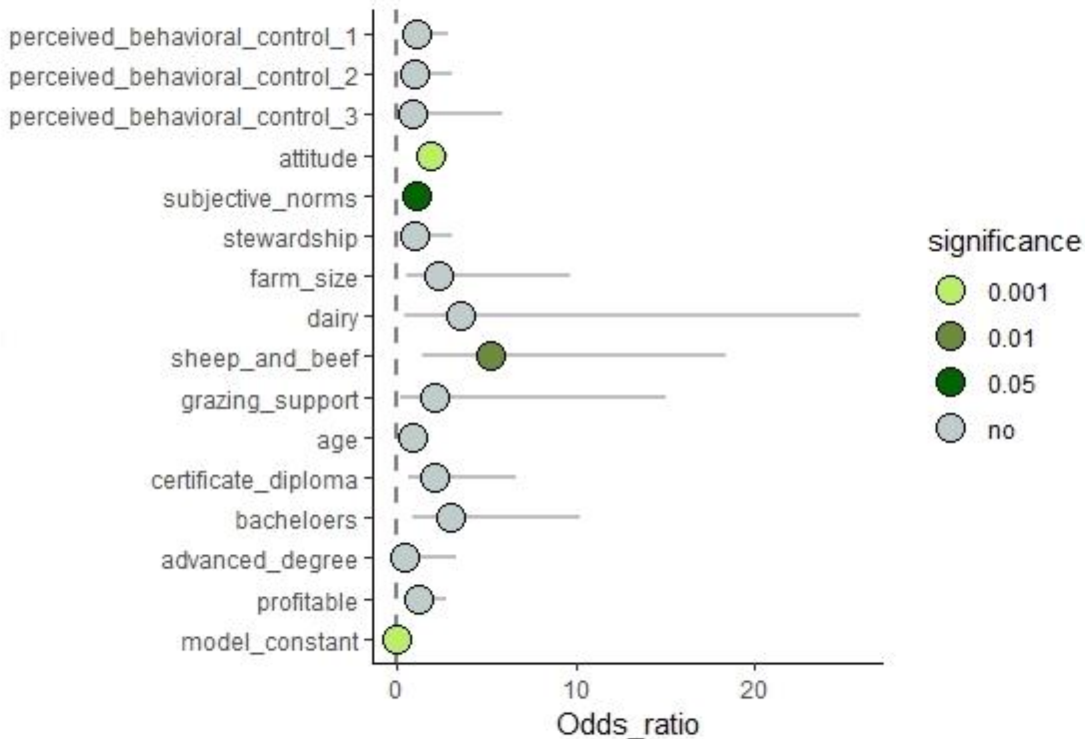

Figure 3-9. Coefficient plot for no policy group (n=271) Intention to Adopt NMP mixed effects logit model. Coefficients are presented as odds ratios. For table of odds ratios and standard errors see Appendix 1

Table 5-6.

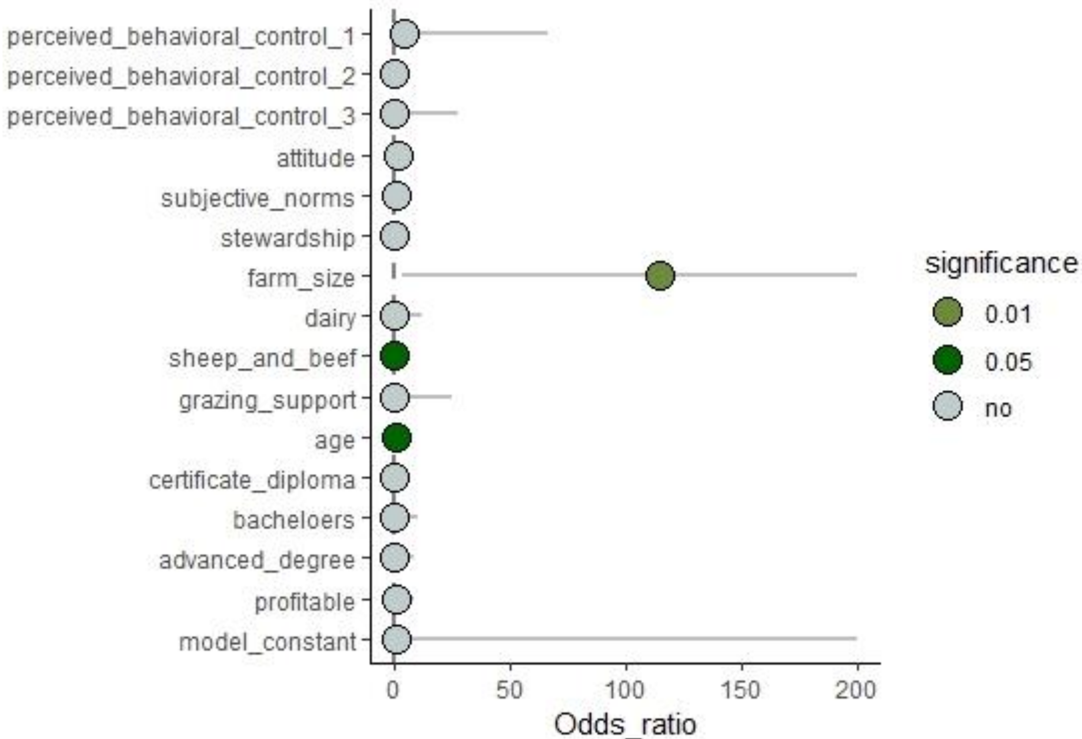

Figure 3-10. Coefficient plot for practice-based group (n=76) Intention to Adopt NMP mixed effects logit model. Coefficients are presented as odds ratios. Note that we present a truncated right hand confidence interval for farm size and model constant in this plot. For table of odds ratios and standard errors see Appendix 1

Table 5-6.

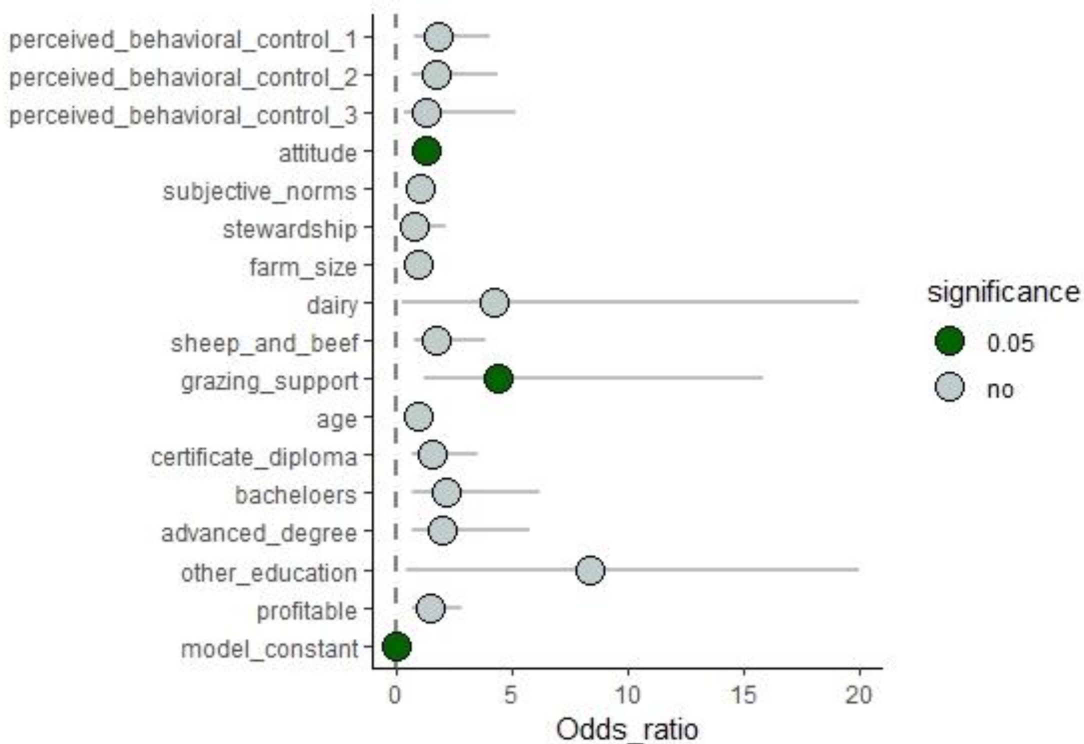

Figure 3-11. Coefficient plot for performance-based group (n=186) Intention to Adopt NMP mixed effects logit model. Coefficients are presented as odds ratios. Note that we present a truncated right hand confidence interval for dairy and other education in this plot. For table of odds ratios and standard errors see Appendix 1

Table 5-6.

3.5. Discussion

3.5.1. Do mandatory policy choice rules matter for behavior change?

According to our first two models in Figure 3-3 and Figure 3-4, mandatory water quality policy is not associated with an increase in NMP adoption or extent of adoption. This suggests that, at least in the time period captured by the SRDM survey, mandatory policy is not (yet) changing behavior. There are a couple potential reasons for this no effect. The first is that in 2015, of the 29 territorial authorities with mandatory policies, 12 territorial authorities had policies that were not yet operational. This means that rules had been defined, but in 2015 farmers were not yet required to meet practice or performance standards. For those policies that were not yet operation, the policy process provided a policy signal that alerted farmers to near future rules, which would require forward planning and action. Importantly, this differs from the "no policy" regions where no rule-making was occurring or if it had begun, no decisions had been made towards the structure of future water quality rules (i.e. practice-based or performance-based). However, despite these distinctions, it may be too early in the policy process to detect differential levels of adoption. It is possible that in five years we may see a difference in nutrient management behavior between policy groups.

Another potential explanation for the lack of higher NMP adoption rates under mandatory policy is that overall adoption of NMP is high across the country (e.g. in mandatory policy and no policy groups) possibly due to a combination of public pressure and regulatory pressure. Public pressure on farmers to clean up their impact on New Zealand's waters may be driving adoption of NMP across all policy types in the country. For example a 2015 newspaper article in the New Zealand newspaper Scoop written by dairy industry group DairyNZ said that New Zealand farms "need to evolve new farming systems" in response to the challenge of nutrient limits (DairyNZ, 2015). In addition, national level policy signal from the National Policy Statement for Freshwater Management that requires that, eventually, all regions must implement water quality limits and rules (NPSFM, 2014). Therefore, even farmers in the no policy regions may see adoption of NMP as an inevitable regulatory requirement. The final potential rational for the lack of nutrient management behavior differences between policy groups is that mandatory policy does not change farmer NMP behavior. If this is the case, water quality improvements will likely not be realized in the future. Given the potential implications of a lack of behavior change, future research should continue to monitor farmer nutrient management behavior across policy regimes.

Turning to other predictors of NMP adoption, the positive relationship between farm profitability and adoption of NMPs suggests that profitability can drive environmental stewardship. NMPs are often framed as a win-win for farming in that they can save farmers money by allowing them to maximize the economic benefits from nutrient inputs and reduce environmental impacts (Beegle et al., 2000). This result could suggest two things: profitable farms could be drawn to NMPs as a strategy to increase farm economic efficiency or farms that have adopted NMPs are able to maximize their economic returns and are therefore more profitable. Given the correlational nature of our study, we are unable to discern whether one or both of these are occurring. However, the positive relationship between profitability and NMP adoption does suggest that framing NMP benefits in economic terms is a good strategy to promote adoption, even within regulatory contexts. This result aligns with much of the literature on voluntary farm conservation practice adoption (Baumgart-Getz et al., 2012; Conner et al., 2016; Prokopy, Floress, Klotthor-Weinkauf, & Baumgart-Getz, 2008b). In their meta-analysis on farmer adoption of conservation practices, including nutrient management practices, Baumgart-Getz et al. (2012) found a farm’s financial capital, or investment into the farm, as having one of the largest impacts on adoption. This suggests that with regard to the practice of nutrient management planning, regardless of differing regulatory environments, farm financials relate to behavior change.

The role of farm type in driving NMP adoption may have more to do with increased industry support and initiatives in New Zealand for dairy farms versus other farm systems (grazing support, sheep and beef and other categories) than the particulars of the farm system, as we see dairy farms show a strong likelihood to adopt NMP, whereas other farm types show a decreased likelihood. However, in the intention to adopt models, sheep and beef farms and grazing support farms are more likely to intend to adopt than dairy. This is likely due to the fact that most dairy farms have already adopted NMPs, over 80% in the sample, compared to much fewer sheep and beef farms and grazing support farms, 23% and 24% respectively. It is likely that industry pressure and support for dairy has led to dairy NMP adoption, whereas the relatively lower pressure on sheep and beef and grazing support farms has resulted in less motivation for sheep and beef and grazing support farms actually adopt NMP.

The dairy industry in New Zealand had been under heightened public pressure to clean up its impact on water quality following the “Dirty Dairying Campaign” led by an environmental NGO in the early 2000s (Edgar, 2008; Holland, 2015). Dairy farming has a greater nutrient impact per unit of production on the land compared to other pasture-based farm types (Monaghan, Hedley, et al., 2007; Monaghan, Wilcock, et al., 2007), and so it has been targeted the New Zealand public as a polluter of the country’s waterways (Holland, 2015). As a result, Fonterra, the dominant dairy cooperative in New Zealand and DairyNZ, the dairy industry research and support group, have promoted the adoption of NMPs as a way to budget farm nutrients to reduce water quality impacts (Quinn et al., 2009). Thus far there has not been the same public pressure on other farm types throughout the country, which suggests that industry and public pressure play an important role in motivating behavior change.

While our results show no evidence of differences in reported levels of nutrient management behavior between groups, we do see that performance-based policy is associated with an increased intention to adopt NMP. If indeed the lack of behavior change is due to policy phase-in periods as suggested above, the increased intention to adopt NMP in performance-based policies suggests promise for future behavior change in performance-based policies. However, we know that intention to change can be quite distinct from actual behavior change. For example, Niles et al. study of New Zealand farmers intended versus actual adoption of climate change mitigation and adaptation strategies showed that intended adoption did not correlate well with actual behavior change (2016). In order to encourage this shift from intention to actual behavior change we can look to the results of our first model again to suggest that profitability, public pressure and industry support may help motivate farmers who intend to adopt an NMP to follow through with actual adoption. Additionally, in mandatory policies, enforcement of the policies may also help shift intention to actual adoption. Regardless, the increased intention to adopt NMP in performance-based policies suggest that they are more likely to be associated increased levels of behavior change in the future, relative to mandatory practice-based policies and no policy regions.

3.5.2 Do policy choice rules impact decision making and does this have implications for policy support?

Across the full sample, in the extent of adoption model (Figure 3-4) and the intention to adopt model (Figure 3-8), we see evidence that all four TPB variables, attitudes, subjective norms, moral norms (i.e. environmental stewardship) and perceived behavioral control are significant, positive predictors of NMP behavior. This suggests, as would be expected by the literature, that values and beliefs are an important component of NMP behavior (Fishbein & Ajzen, 2011; Stern et al., 1999). When the sample is broken down into policy sub-groups, for both extent of adoption and intention to adopt, there is greater evidence for value alignment in the no policy group than both of the mandatory groups, suggesting that values and beliefs may play lesser roles in adoption of NMP in regulatory contexts than in non-regulatory contexts. Environmental stewardship and subjective norms are only significant predictors of extent of adoption and intention to adopt, respectively, in the no policy sub-group model. This suggests that, subjective norms and stewardship moral norms may only be relevant to behavior outside of regulatory environments.

However, perceived behavior control and attitudes are both positive and significant predictors of adoption behavior in both the no policy group and performance-based group's extent of NMP adoption and intention to adopt NMP models respectively. According to Fishbein & Ajzen, the role of perceived behavioral control is expected to both moderate the impact of social norms and attitude on intention and the impact of intention on actual behavior (2011, p. 181). Logically, one would assume that once a farmer has already adopted NMPs as a practice then attitudes and norms would play less of a role in determining which nutrient management strategies or structures are implemented. Instead, as we see here, we would expect the farmers' capabilities and their farm system dynamics to drive adoption. However, this result is not observed amongst farmers in the practice-based policy group. In the practice-based group, operating a dairy farm was the only significant predictor of extent of nutrient management plan adoption.

The significance of attitudes and norms in the full sample intention to adopt NMP model is also in line with what one would expect from the TPB, as Fishbein and Ajzen suggest, it is not anticipated that one would see a strong relationship between perceived behavioral control and intention because "the fact that I am capable of performing a behavior does not necessarily imply that I will intend to do so" (2011, p. 181).

For both extent of NMP adoption and intention to adopt an NMP, when broken down by policy group, we see that no TPB variables are correlated with farmers' adoption or intention decisions in a practice-based policy. Instead, in practice-based policies, farm and farmer characteristics appear to drive adoption and intention. However, for farmers in performance-based policies, we see perceived behavioral control and attitudes play a role in adoption extent and intention to adopt (respectively). In practice-based policies, were farmers are required to adopt specific practices, it appears that an individual farmer's level of perceived behavioral control doesn't matter. However, in performance-based policies, where farmers' have the autonomy to determine how to achieve a benchmark, perceived behavioral control is important. This indicates that fostering perceived behavioral control amongst farmers in performance-based policies can help to capitalize on their increased likelihood to intend to adopt NMP and motivate actual NMP adoption.

Furthermore, this seems to imply that there is more room in performance-based policies for farmers to make adoption decisions that align with their internal values and beliefs. Additional evidence for this lies in the fact that farmers in performance-based policies TPB drivers align with the TPB drivers for farmers in the no policy group. We interpret this in terms of policy success to say that farmers in performance-based regimes show greater potential for prolonged policy support. According to social movement and public policy theory, value alignment between a policy and on farm management is more likely to result in policy support than value misalignment (Jenkins-Smith et al., 2014; Stern et al., 1999).

3.6. Limitations

Before concluding, we would like to acknowledge a few limitations of the study. First, the practice-based versus performance-based categorization system for water quality policies employed in the policy coding for this paper is a simplification of the nuances of each unique policy. For example, not all farms under a policy may be subject to the practice or performance standards of the policy and there are often farms that because of size (e.g. small commercial farms) or type (e.g. forms of low input agriculture such as some varieties of horticulture and vegetable farms). However, this is likely to be a small number of our commercial farm sample and these farms would have most likely been exposed to the policy discussion and policy signal.

We would also like to acknowledge some limitations in the application of the TPB in the study. Other implementations of the TPB often use sets of paired questions to compute the attitude, subjective norms and perceived behavioral control components which includes both the participant's evaluation of the impact of the element on the behavior and the participant's assessment of the importance of the element to themselves (Fishbein & Ajzen, 2011; Willcox, Giuliano, & Monroe, 2012). Due to question restrictions, we were unable to ask participants to evaluate the strength of importance of the TPB elements and therefore our measures may be seen as partial representations of the constructs. Additionally, we use a proxy behavior for nutrient management planning for the subjective norms question in this study (i.e. environmentally friendly farming), on the survey to represent subjective norms towards NMP. As NMPs are a tool to farm at agronomic rates and described by both industry and regulations to reduce the environmental impact of a farm system, we see this as an appropriate proxy. However, it would be preferable for this question to have been asked explicitly about NMP (Fishbein & Ajzen, 2011). Finally, it is likely that the stringency (e.g. amount of reduction required and/or precision of monitoring and compliance) of each of the water quality policies plays a role in driving behavior change. Analyzing the stringency of each policies was out of the scope of this study, but future research should investigate how stringency interacts with values and beliefs and behavior change.

3.7. Conclusion

Agricultural NPS pollution is a challenging environmental issue to manage and a growing concern for watersheds across the globe. As regions seek certainty in attaining long term water quality improvements, it is likely that more will turn to mandatory, rules-based policies. The results of this study suggest that a switch to mandatory policies is not assured to increase nutrient management behavior change. However, our results do suggest that mandatory performance-based policies are associated with an increased likelihood of future behavior change compared to mandatory practice-based policies and no mandatory policy. Furthermore, performance-based policies show greater potential for prolonged policy support from farmers due to better alignment with farmer decision making values and norms compared to practice-based policies. Given the complexity of agricultural NPS, achieving water quality goals requires both behavior change on the landscape and sustained policy support to maintain behavior change over a long period of time. It is likely that any form of mandatory policy will incur a degree of cost and resistance amongst the farming community as compared to a voluntary policy. However, if mandatory policy is necessary to achieve water quality results, our results suggest that performance-based policy increases the likelihood of attaining water quality goals and may be more palatable to farmers in that it allows them autonomy and flexibility in running their farm system. Long term monitoring of farmer nutrient management behavior is needed to better understand whether mandatory policies will result in increased nutrient management behavior and therefore increased water quality improvements.

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CHAPTER 4: A SOCIAL-ECOLOGICAL SYSTEMS APPROACH TO UNDERSTANDING FARMER NUTRIENT MANAGEMENT BEHAVIOR IN A SPECTRUM OF MANDATORY WATER QUALITY POLICIES

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4.1. Abstract

Water quality policy for agricultural lands strives to improve water quality through changing farmer behavior across the landscape. Understanding what farmers are doing on their land and the drivers that influence these behaviors are signals of whether water quality will improve and if behavior is changing in the intended direction. This study utilizes farmer behavior and mental models to qualitatively examine the fit of water policy within its social-ecological context and the interplay of the water quality policy within existing institutional dynamics, each of which contribute to the ability of the policy to achieve the overall goal of increased water quality. We investigate farmer behavior in three mandatory agricultural NPS pollution regimes in similar contexts in Vermont, USA and Taupo and Rotorua, New Zealand that vary by policy design and degrees of implementation. Vermont, USA has implemented mandatory practice-based rules that require farmers to enact a specific set of practices to improve water quality. Whereas Taupo and Rotorua both have mandatory-performance based policies that require farms to stay below a nutrient leaching limit, but give farms the flexibility to achieve the limit how they see fit. Vermont and Taupo’s policies are operational and

Rotorua's policy had been formalized by the Bay of Plenty Regional Council (i.e. the formal rules had been written and released to the public) but not yet operational.

We interviewed 38 farmers across the three regions to examine farmers reported behavior change, perceptions of the drivers causing those behaviors and perceived individual and watershed outcomes. We then used the social-ecological systems (SES) framework to inform content analysis of each interview. Coding was aggregated by region to produce group mental model networks, consisting of farmers reported links between drivers, behaviors and outcomes. Each region's mental model network was analyzed using simple network analysis techniques to identify influential elements in each network. Our results show that farmers report behavior change across the three regions, with Vermont farmers reporting the highest number of changes per farmer, followed by Taupo and then Rotorua. We also see different patterns in types of behavior changes with dominance of structural changes in Vermont (e.g. fencing or buffers) and system changes in Taupo (e.g. switch from dairy to cattle farm system), and no dominance in Rotorua. Farmers report that the water quality policy is a key driver of behavior change across all three regions, but we see the interplay between the water quality policy and existing institutional dynamics contributes to the different behavioral patterns, as well as perceived outcomes. Farmers in Vermont's practice-based policy reported greater behavior change and practice adoption, but farmers in Taupo's performance-based policy reported greater levels of system change which ultimately may be associated with higher nutrient reductions. We conclude by suggesting that driver-behavior-outcome dynamics should be considered carefully in future policy design to achieve the desired water quality outcomes.

4.2. Introduction

Water quality policy targeting agricultural nonpoint source (NPS) pollution strives to improve water quality through changing farmer behavior across the landscape. Despite the pervasive impact of agricultural NPS pollution to freshwater systems around the globe, little is known about the social, economic, and political dynamics that contribute to the persistence of the problem, including the role of mandatory NPS pollution policy in changing farmer behavior (Carpenter et al., 1998; McDowell et al., 2015; Rissman & Carpenter, 2015). What farmers are doing on their land and the drivers that influence these behaviors are signals of whether water quality will improve and if behavior is changing as intended. The mental models farmers hold with respect to the motives for their nutrient management behavior can help identify underlying mechanisms driving behavior (Saldaña, 2015). Mental models are “internal representation of external reality that people use to interact with the world around them”(Jones, Ross, Lynam, Perez, & Leitch, 2011, para. 1). Understanding farmers’ mental models can in turn shed light on the interplay between a water quality policy, the broader watershed context, and social, economic and ecological outcomes.

History is littered with examples of policy interventions gone wrong, in which the intended behavior is not achieved, or worse yet, the opposite of the social objective of the policy is realized (Goodin, 1998). For water quality policy to achieve the desired outcome (e.g. farm management change to improve water quality), it must fit well with the pre-existing institutions that structure social interaction and behavior in a given setting (Goodin, 1998). As Young highlights, "institutions play a role in both causing and addressing problems that arise from human-environment interactions," hence the fit of the institution to the biophysical context and the interplay of the institution with other existing institutional arrangements are important elements in the success of the institutional intervention (Young et al., 2008, p. xiiv). Institutions, as used here, refer to the formal or informal rules, strategies or norms that constrain human interaction and behavior (North, 1990; Ostrom, 2005). Due to challenges in measuring and monitoring agricultural NPS pollution (Meals et al., 2010), it is important to look for other avenues to understand what is driving NPS pollution trends. Farmer behavior and mental models are a promising alternative that can be used to qualitatively assess the fit and functioning of an agricultural NPS policy regime.

This study utilizes interviews and network analysis to examine farmer nutrient management behavior in a water quality policy context, thereby integrating farmers' individual decision-making processes and the influence of the broader watershed social, economic, political and ecological context. We investigate farmer behavior in three agricultural NPS pollution policies in similar contexts in Vermont, USA and New Zealand that vary by policy choice rules and degrees of implementation.

Within these policy frameworks, farmers have a set of "choice rules", which specify what a farmer "must, must not, or may do" (Ostrom, 2005, p. 200). The mandatory policy regimes under consideration represent two different types of choice rules: practice-based and performance-based. Under a practice-based policy, as is the case in Vermont, farmers must implement a series of practices or structures to be in compliance. In a performance-based regime, as is the case in both New Zealand regions, farms are required to stay under a performance limit for modeled nutrient leaching from the farm, but they can choose any suite of strategies to achieve the standard. The Lake Taupo policy has been operation since 2011, Vermont since 2016 and the Rotorua process is yet to be implemented and therefore represents a policy signal, i.e. requirements for policy known but no enforcement.

Through examining farmer perceptions and behavior in a spectrum of agricultural NPS pollution policy regimes, this study will contribute to an understanding of how policy influences and interacts with nutrient management behavior. We address three key research questions to explore policy performance, policy fit and policy interplay across the three policy contexts: 1) what types of nutrient management behavior changes do farmers report making, if any? 2) What do farmers perceive as the drivers of their nutrient management changes? And 3) what are the perceived individual and watershed outcomes of behavior changes and the NPS pollution policy?

4.3. Theoretical Framework

Elinor Ostrom's social-ecological systems (SES) framework provides a theoretical basis from which to examine the institutional governance of interactions between actors within natural resource regimes (Ostrom, 2009, 2011). Typically, in the application of Ostrom's framework to understand collective action, individual behavior is assumed to be boundedly rational, in that individuals intend to behave rationally but have limited information, cognition and attention processing abilities (Ostrom, 2011; Poteete et al., 2010; Simon, 1972). In cases like agricultural NPS pollution where there are high degrees of uncertainty in resource dynamics which makes measurement, monitoring and enforcement of policy institutional interventions difficult, there is an increased need to understand individuals' mental models and internal decision making processes (see chapter 2).

This study seeks to build on the literature in applying the SES framework to explore the institutional drivers of nutrient management behavior within a policy context through farmers' mental models. Ostrom's SES framework (2009) considers the interactions between governance systems (e.g. water quality policy), users (e.g. individual farmer decision making processes), resource systems (e.g. farm systems), resource units (e.g. nutrient dynamics) and system outcomes (e.g. water quality) as shown in Figure 4-1. The SES framework focuses on the way in which these interactions exist within broader social, economic, political and ecological dynamics. The framework in particular, building on Ostrom's work with the Institutional Analysis and Development framework, seeks to understand the workings of "action arenas," in which actors interact in the context of the broader system to produce outcomes, e.g. improved water quality (Ostrom, 2005). The focus of this study is on nutrient management decision making and behavior, in which the agricultural NPS pollution water quality policy rules interacts with individual behavior, the community and the biophysical world (Ostrom, 2005).

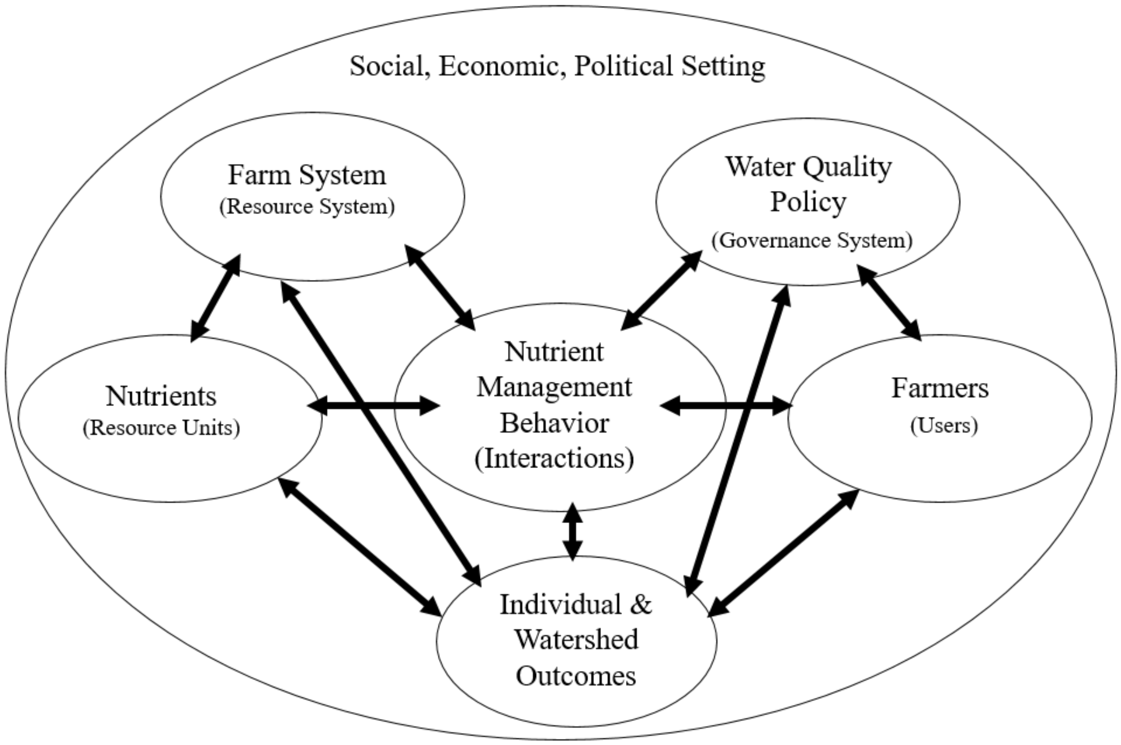

Figure 4-1. Adaptation of the SES Framework to Agricultural NPS pollution, adapted from Ostrom (2009) and revised from Hammond Wagner et al. (forthcoming) (chapter 2 of this dissertation).

Typically in applications of the SES framework researchers use a diversity of metrics and indices (Cox, 2014; Leslie et al., 2015; McGinnis & Ostrom, 2014), but rarely include perspectives of individuals within the system. Here we present a novel application of the framework, drawing on farmers' internal perceptions of dynamics in the SES (i.e. mental models) to identify the most salient aspects of the system to individual farmers' behavior and decision making. Each farmer in the watershed is operating based on their own understanding of their situation and the broader context. Farmers, like all people, filter and store information through their mental models and, as Jones et al. (2011, para. 4) suggest, mental models are "limited and unique to each individual…context-dependent and may change according to the situation in which they are used." Therefore, exploring farmer mental models within the context of a water quality policy can provide important insight into how farmers are evaluating alternatives, framing discussions and making decisions that ultimately impact water quality (Carley & Palmquist, 1992).

A mental modeling approach, i.e. eliciting actor mental models, has been employed to understand a broad range of environmental behavior and decision making, including irrigator water-use decisions in a water stressed basin (Douglas et al., 2016), farmer definitions of sustainable agriculture (Hoffman, Lubell, & Hillis, 2014), organic farmers' weed management decisions (Jabbour et al., 2014), and the public's climate change beliefs (Zia & Todd, 2010). Furthermore, mental models can be aggregated or grouped to examine "collective knowledge and understanding of a particular domain held by a specific population of individuals" (Hoffman et al., 2014, p. 36). These group mental models are the focus of this study, in that we group individual farmer mental models within each of the three water quality policy regions to examine and compare collective understanding of nutrient management in each social-ecological context.

4.4. Methods

We employ qualitative interviews and network analysis to examine farmer mental models in three water quality SES's that have mandatory policy to curtail agricultural NPS pollution.

4.4.1 Study Site Descriptions

The three focal agricultural NPS pollution policy contexts of this study are: Rotorua, Bay of Plenty region and Taupo, Waikato region, both in New Zealand, and Vermont, USA. As noted above, these regions differ in terms of policy choice rules, i.e.

practice-based versus performance-based, and degree of implementation. These regions have each implemented agricultural NPS pollution policy that regulates nutrients coming off of farms, as opposed to more upstream regulation that targets nutrient import to the farm. The three regions are all agriculturally dominated landscapes that have seen agricultural intensification in the last few decades which has been associated with decreases in water quality (Mcdowell, Larned, & Houlbrooke, 2009; Quinn et al., 2009; Rutherford, Pridmore, & White, 1989; Smeltzer, 2015; Smeltzer, Shambaugh, & Stangel, 2012). Table 4-1 gives a description of each of the three case study regions using the high level SES categories shown in Figure 4-1.

Before describing the specifics of each region, it is important to note some general differences between the New Zealand and Vermont social, economic and political settings. Agriculture in the United States is highly subsidized (Kirwan, 2009), which includes millions of dollars in cost-share for farmers to adopt conservation agricultural practices (Baylis, Peplow, Rausser, & Simon, 2008). In sharp contrast, New Zealand abolished all agricultural subsidies in 1984 and is export-based, meaning that farmers are exposed to international market dynamics (Quinn et al., 2009). While Vermont exports most of its agricultural products outside of the state (Wironen et al., 2018), it is partially protected from market exposure due to national subsidies. Another important difference is the dominance of pastoral agriculture across New Zealand, compared to the semi- and full-confinement systems for animal agriculture in Vermont.

Table 4-1. SES description of the three case study regions

Case study policy regions	Taupo, Waikato Region, New Zealand	Rotorua, Bay of Plenty Region, New Zealand	Vermont, United States
Resource units	Nitrogen	Nitrogen	Phosphorus
Resource system	Mostly extensive pasture-based beef and sheep farms with some dairy operations	Mixture of pasture-based dairy operations and sheep and beef operations	Mixture of full and semi-confinement dairy, semi-confinement cattle, vegetable and other diversified farm systems
Governance System	Variation 5: performance-based cap-and-trade	Rule 11 and Proposed Plan Change 10: performance-based cap-and-trade	Act 64 and the Required Agricultural Practices: practice-based regulation
Users	Farmers	Farmers	Farmers
Social, economic, political setting	*No subsidies for agriculture (Quinn et al., 2009) *International export-based market (Quinn et al., 2009) *Public pressure on agriculture, and dairy in particular, to reduce water quality impacts (Holland, 2015) *National policy focus on improving water quality across New Zealand (NPSFM, 2014) *Taupo first in country to take a stringent regulatory approach (Yerex, 2009)	*No subsidies for agriculture (Quinn et al., 2009) *International export-based market (Quinn et al., 2009) * Public pressure on agriculture, and dairy in particular, to reduce water quality impacts (Holland, 2015) *National policy statement for freshwater in 2011/2014 mandates water quality limits across country by 2025 (NPSFM, 2014) *Rotorua early adopter of water quality regulation (behind Taupo and some other regions)	*Lots of subsidies for agriculture, including incentives and programs to adopt conservation practices (McDowell et al., 2015) *Most agricultural products are sold out of state, but less exposure to international markets than NZ farmers (Wironen et al., 2018) *Public finger pointing at dairy as the problem for water quality in Lake Champlain and other waterbodies throughout the state (Flagg, 2015; J. M. Smith, Parsons, Van Dis, & Matiru, 2008)

Taupo, New Zealand

The Lake Taupo watershed is located in the center of the North Island of New Zealand and is the country’s largest lake. The watershed is dominated by pastoral agriculture consisting of approximately 120 farms, mainly extensive sheep and cattle farms, with a few dairies. With evidence for declining water quality and algal blooms in the early 2000s, the Waikato Regional Council proposed “Variation No. 5 – Lake Taupo Catchment” in 2005 to clean up Lake Taupo (Waikato Regional Council, 2011), which became operational in 2011. The policy is a performance-based cap-and-trade for nitrogen, the main nutrient of concern in the lake, and features three core aspects. First, farm nitrogen leaching was capped at current levels (i.e. prior to the proposed policy) and each farm was given a "nitrogen discharge allowance" based on historical levels of nitrogen use (Waikato Regional Council, 2011). Second, a trust was endowed with 80 million New Zealand dollars of government funds to reduce 20% of the nitrogen in the catchment to align the nitrogen load with estimates of the catchment's sustainable nitrogen load. Third, the policy set up a nitrogen market to allow farmers to trade nitrogen discharge allowances between each other to allow for increases or decreases in individual farms' nitrogen leaching, while maintaining the overall basin level. Farms are monitored through annual modeling of the farm system to ensure compliance with their nitrogen discharge allowance and are required to pay an annual fee (Waikato Regional Council, 2011).

Rotorua, New Zealand

Lake Rotorua watershed is also located in central North Island, New Zealand and is about 80 km northeast of Lake Taupo. Similar to the Lake Taupo, the Lake Rotorua watershed is dominated by pastoral agriculture, with a similar number of farms to Taupo, but including a stronger presence of dairy farms. As a result of declining water quality in the Rotorua Lakes region, the Bay of Plenty regional council passed Rule 11 in 2005 which, similar to Taupo's Variation 5, capped farm nitrogen emissions at their current levels. This policy was meant to stop agricultural intensification in the region. Further rules, Proposed Plan Change 10, were proposed to reduce the overall amount of nitrogen leaching in the watershed. Proposed Plan Change 10 was notified in February, 2016 (Bay of Plenty Regional Council, 2016). Proposed Plan Change 10 is also a performance-based cap-and-trade for nitrogen, including a nitrogen discharge allowance for each farm. Similar to Taupo, the policy features an incentives board with 40 million New Zealand dollars of government funding to remove nitrogen from the catchment and the potential for farm-to-farm trading of nitrogen. Unlike Taupo, Rotorua farmers must make mandatory reductions in their nitrogen leaching rates to achieve the required 42% reduction in the watershed's nitrogen load. Farms must reach their required load reductions before they can trade nitrogen. Once operational, farmers will need to pay an annual fee and be monitored annually for compliance with their nitrogen discharge allowance (Bay of Plenty Regional Council, 2016).

Vermont, United States

The state of Vermont is located in the northeastern United States on the border with Canada. While Vermont's policy is state-wide, it was motivated by the need to address the phosphorus-driven eutrophication of Lake Champlain, a watershed shared by Vermont, New York State, and the province of Quebec, Canada. Similar to the New Zealand watersheds, the Lake Champlain Basin has seen declining water quality for decades due primarily to agricultural intensification and urban development (USEPA, 2016). Vermont's agricultural industry includes dairy, cattle, and vegetable farms, with dairy dominating agricultural land use and economic output (Vermont Dairy Promotion Council, 2015). In 2015, the Vermont legislature passed Act 64 to enact new regulations for managing phosphorus on farms, as well as rules for other sources of phosphorus (Act

64: An Act Relating to Improving the Quality of State Waters, 2015). Under Act 64, farms are required to comply with the Required Agricultural Practices (RAPs) which include mandatory practices, such as writing nutrient management plans, requirements for cover cropping on highly erodible soils, winter manure and flood plain spreading bans, and 25 foot (7.5 meter) buffers between farm fields and surface waters (Vermont Agency of Agriculture, Food & Markets, 2018). It should be noted that some of these practices were already required for medium and large farms before Act 64. Under the new rules, farms must register with the state, pay an annual fee and are monitored for compliance with the RAPs at a rate dependent on farm size: every year for large farms (> 700 dairy cows or equivalent, e.g. 1000 beef cattle), every three years for medium size farms (<700 and >200 dairy cows or equivalent) and every seven years for small farms (<200 dairy cows or equivalent).

Phosphorus and Nitrogen Dynamics

As shown in Table 4-1, the case study sites differ in their focal nutrient of concern: Vermont's rules are written to reduce phosphorus runoff from farms and Taupo's and Rotorua's rules target reductions in nitrogen leaching from farms.

In freshwater systems phosphorus tends to be the limiting nutrient for cyanobacteria or algal blooms because the phosphorus cycle lacks external atmospheric inputs, unlike nitrogen (Schindler, 1977). However, in the Lake Taupo and Lake Rotorua watersheds there are naturally high occurring levels of phosphorus, so the limiting nutrient for cyanobacteria in these lakes is considered to be nitrogen (Edgar, 1999; Rutherford et al., 1989). There is debate as to whether a nitrogen-only management strategy is appropriate (see Morgenstern et al. (2015), Abell et al. (2016) and Smith et al. (2015) for commentary on this debate), but the current policies are written only to address nitrogen leaching from farms. It should be noted, however, that Rotorua's Proposed Plan Change 10 does address phosphorus mitigation in the watershed, but not as a part of the rules for farmers (Bay of Plenty Regional Council, 2016, p. 10).

The differences in the nitrogen and phosphorus cycles do have implications for nutrient management behavior on farms that should be taken into account when comparing the impact of policy on behavior between these three regions. The primary difference, from a management perspective, is that phosphorus' main transport pathway off the farm is through soil erosion and overland water flow, whereas nitrogen's primary transport pathway off the farm is through sub-surface flow, such as leaching into groundwater (Carpenter et al., 1998; Mcdowell et al., 2009). In both cases, managing fertilizer inputs and timing is an important mechanism for managing nutrient loses form the farm system. However, nutrient management behaviors that target transport factors from farm systems will have differential impacts on nitrogen leaching and phosphorus runoff.

4.4.2 Data Collection

We completed a total of 38 semi-structured interviews with farmers as shown in Table 4-2. New Zealand interviews were completed between June and August, 2016 and Vermont, USA interviews were completed between February, 2017 and September, 2018. It is important to note that while the number of interviews between each region is fairly balanced, the number of farmers interviewed in Vermont represents a much smaller proportion of the farming population in Vermont compared to the proportion represented by our sample in Taupo and Rotorua. An interview protocol was used as a basis for the semi-structured interviews. Farmers were asked about their farm system, any changes they have made to managing nutrients on their farm in the last 5-10 years, the drivers of those changes, and their perceptions of the broader water quality and policy context in the watershed (see Appendix 2 Table 5-7 for interview protocol). Interview duration ranged between 30 minutes and 3 hours and were conducted by the lead author. Each transcript was recorded and transcribed. Prior to conducting interviews, we received an exempt certification for the research from the University of Vermont's Institutional Review Board.

Table 4-2. Interview sample across regional policy contexts

		Region		
Farmers interviewed	All	Vermont	Taupo	Rotorua
Total	38	16	11	11
By farm type				
Dairy	23	11	3	9
Beef, cattle or deer	15	5	8	2
Vegetable	1	1	0	0
By farm size				
Small	11	11	0	0
Medium	12	4	4	4
Large	15	1	7	7

Farmer participants were selected using maximum variation sampling to purposely interview participants that represented a diversity of farm systems types (e.g. dairy, beef cattle, sheep, vegetable) and farm sizes (e.g. small, medium, large following Vermont's farm size categories referenced above) in an effort to capture the breadth of experiences (Morse, 2010). To recruit participants, we worked with key individuals in each region, including agricultural extension agents and regional government employees to identify an initial list of potential participants. Following this initial contact list, we used snowball sampling to recruit additional participants and, in Vermont only, reached out to the agricultural community to recruit participants through the Vermont Agency of Agriculture, Food and Market's monthly newsletter and the Vermont Farm Bureau.

4.4.3 Data Analysis

Interview Coding

Interview transcripts were analyzed using directed (i.e. theory-driven) qualitative content analysis (Hsieh & Shannon, 2005) in NVivo 12 (QSR International Pty Ltd, 2018), followed by network analysis of codes and their relationships to identify themes (Pokorny et al., 2018). We use the SES Framework (Ostrom, 2009) to examine the interactions between nutrient management drivers, including governance dynamics, farmer attributes, farm system dynamics and nutrient dynamics, as shown above in Figure 4-1. The interaction of interest for this study is the farmers' nutrient management behavior. We also examined how drivers and behaviors relate to farmers' perception of individual and watershed level outcomes.

We used del Mar Delgado-Serrano and Ramos' (2015) definition of variables in the SES Framework as a starting point for the content analysis. From there the content analysis proceeded as an inductive and deductive process, identifying behaviors, drivers and outcomes and the relationships between them for each interview. We also allowed for sub-categories to emerge in the coding process that were not present in del Mar Delgado-Serrano and Ramos' (2015) articulation of the SES framework to capture the full range of relevant drivers, behaviors and outcomes. For example, we differentiated between individual-level and watershed-level outcomes, a distinction not made in Ostrom (2009) or del Mar Delgado-Serrano and Ramos' (2015) use of the SES framework. Differentiating between levels of outcomes allowed us to capture variation in individual's own personal experience of the policy and their perception of community outcomes. Following the SES Framework, we differentiate between social, economic and ecological outcomes. We also coded outcomes according to the farmer's stated or implied valence of the outcome. See Appendix 2 Table 5-8 for the full codebook used in the analysis, description of codes, and representative quotes.

To capture farmers' nutrient management behavior we coded any self-reported change in nutrient management behavior in the last 5-10 years or concrete, planned changes to occur in the next two years. We categorized nutrient management behavior change into one of three categories: management changes, structural changes, or system changes, as defined in Table 4-3. Our constructed categories reflect a spectrum in capital expense and time commitment required to make the changes, as well as the reversibility of the changes (e.g. management changes are generally less capital/time intensive and more reversible compared to structural, and structural are generally less so than system). The spectrum also captures variation in the potential change in nutrient loss that one would expect to see from a nutrient management change.

Management changes can be very impactful in achieving nutrient reductions as they can represent a direct reduction in the amount of nutrients mobilized in a watershed, for example through reducing nutrient inputs in fertilizer amounts. However, management changes are likely to hit a limit in potential nutrient reductions without changing other farm dynamics due to farm production needs. Structural changes, such as riparian buffers, water detainment berms, or new manure pits reduce nutrient inputs mainly through mitigating nutrient runoff or leaching. For example, riparian bank buffers work by capturing phosphorus before it enters the stream ecosystem. However, research has shown that it is possible for buffers over time to become saturated with phosphorus and actually transition to a source of phosphorus entering streams (Dodd & Sharpley, 2016). In most cases, structural changes adjust nutrient pathways on the farm and not the overall amount of nutrients used. System changes, conversely, usually impact the overall quantity of nutrients used on the farm through changing the amount required for farm production needs and therefore represent the highest potential for nutrient reduction.

Table 4-3. Categories of nutrient management behavior changes on farms

Category	Definition	Examples of changes in category
Management	Changes that effect crop or animal types, plus anything else related to soil and animal management	Includes changes in timing and amount of fertilizer application, timing and types of cropping, stocking rate of animals, type and amount of feed, and wintering animals on or off
Structural	Physical or infrastructure changes to farm	Includes installation of buffers on the side of fields, fencing out animals, new milking parlor, new effluent system, water retention bunds, and animal stand-off pad
System	Change in overall farm system dynamics, including type of animal/product and expansion or contraction of land base	Includes transition in farm type between dairy, beef and sheep, sheep milking, forestry, other types, transition to organic or grass-based system, land retirement, purchase of new land, and sale of land

As discussed above, the distinction between managing nitrogen and phosphorus is important in that it suggests a different set of management or structural practices will be relevant for each nutrient. However, the categorization of behaviors used here should capture a range of behaviors appropriate for both nitrogen and phosphorus management.

In other words, managing options for nitrogen and phosphorus on farms both include management, structural and system changes, and we'd expect the trends of capital intensity, reversibility and potential nutrient reduction associated with the different categories of nutrient management changes to hold true regardless of nutrient.

Network Analysis

We grouped coded interviews by region (Taupo, Rotorua and Vermont) and used NVivo 12's matrix query tool to export aggregate, weighted, nondirectional (symmetrical) adjacency matrices for each region. Following methods adapted from Hoffman et al. (2014) and Pokorny et al. (2018), adjacency matrices for each region were imported into R version 3.5.1 (R Core Team, 2018) and analyzed as group mental model network graphs using the igraph package (Csardi & Nepusz, 2006).

The adjacency matrices report the co-occurrence of drivers, behaviors and outcomes in the grouped interviews for a region. To co-occur, two or more codes must have been assigned to the same portion of text. In the aggregate matrices for each region, the weight of the relationship between codes represents the number of farmers in that region that reported a connection between two concepts. When translated into a network graph, each node represents a concept (i.e. SES driver, behavior or outcome), the link between them represents a connection between those concepts and the weight of the link represents the number of participants in a region who made the connection between the two concepts.

Regional group mental model networks were analyzed using simple network node statistics, again following Hoffman et al. (2014) and Pokorny et al. (2018). Each node in the network graph is evaluated by occurrence probability and strength. The occurrence probability of a node represents the likelihood that a node is included in the network. It is calculated, following Hoffman et al. (2014) as the ratio of farmers that mentioned the node to the total number of farmers in a region's sample. In our analysis, this represents the extent to which a node resonates across a regional sample. Strength represents a combination of the occurrence probability of a node and the number of nodes that a node is connected to (i.e. the "degree" in network statistics). Strength represents both the breadth and prominence of influence of a node. It is the sum of the weights of links for all links connected to a node (Csardi & Nepusz, 2006). We analyzed each of the regions' group mental models separately and below interpret themes and results using representative quotes from interviews. Further, to examine which SES subcategories were most influential in driving nutrient management behavior, we analyzed a subset graph with only drivers and behaviors (i.e. no outcomes) to isolate the connections between drivers and behaviors. In this subset graph, we then ranked drivers in each region by node strength and report on driver rankings. The network visualizations for each of the three regions, including a network with just high-level SES categories and a more detailed network with SES subcategories are in Appendix 2 Figure 5-2 to Figure 5-7.

4.5. Results

4.5.1. Behavior Changes

Farmers across all regions reported making a number of behavior changes relevant to nutrient dynamics on their farms. As shown in Table 4-4, on average, farmers in Vermont made 5.81 behavior changes each, farmers in Taupo made 4.55 behavior changes each and farmers in Rotorua made 3.64 behavior changes each. Farmers across all three regions made management changes, but Taupo farmers also favored system changes (versus structural changes), whereas Vermont farmers favored structural changes. Rotorua farmers do not show a preference for structural versus system changes.

Table 4-4. Count of nutrient management changes and average number of behavior changes per person by Region

	Taupo (n = 11)		Vermont (n = 16)		Rotorua (n = 11)	
Behavior change	Count	Average	Count	Average	Count	Average
Management changes	33	3.00	46	2.88	19	1.73
Structural changes	4	0.36	40	2.50	14	1.27
System changes	19	1.73	10	0.63	11	1.00
Total changes	50	4.55	93	5.81	40	3.64

We examined counts of specific changes by behavior category as described below. Some behaviors are specific to each region and agricultural systems. These practices include soil sampling (VT), no-till (VT), manure spreading (VT), putting in a new barn or updating barn structures to mitigate runoff (VT), and grazing animals off of pasture or farm for a period time to reduce nutrient leaching (NZ).

Management Changes

The top two management categories for all three regions are seeding varieties/ cropping changes and fertilizer changes as shown in Figure 4-2. Reduced animal stocking rate was a relatively common management change in Taupo and Rotorua, but no farmers in Vermont reduced animal numbers on their farm. Only Vermont farmers and one Rotorua farmer started nutrient management planning and soil sampling. Across all three regions we see a small number of farmers engaging in learning or pursuing nutrient management knowledge. All of the behaviors noted thus far would be considered behaviors in the intended direction, i.e. leading to reductions in nutrient use or intensity. We do, however, see two categories of management behavior change with increased nutrient use: increased fertilizer use and increased stocking rate. In Taupo and Vermont, one and two farms respectively increased fertilizer use, and just two farms in Vermont also increased the stocking rate, i.e. the number of animal units on their farm.

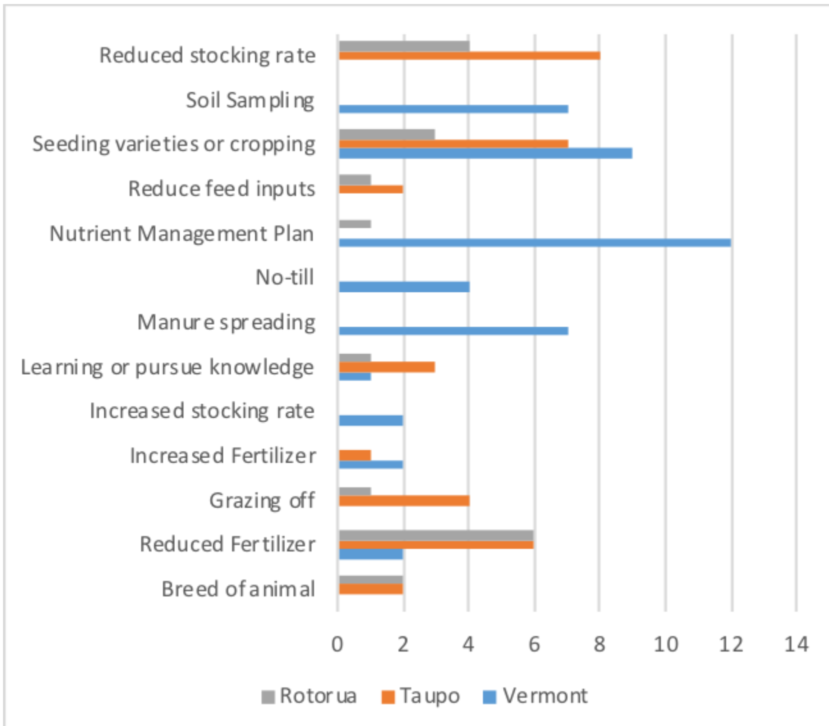

Figure 4-2. Number of Management changes by region

Structural Changes

As shown in Figure 4-3, Vermont farmers made the most structural changes. The structural changes in common across the three regions are fencing and purchasing new equipment (e.g. more efficient irrigator). The top structural changes for Vermont were buffers and setbacks, manure pit or pad upgrades, leachate systems and water flow control structures. In Rotorua, manure pits or pad upgrades was the top structural change.

In Taupo, relatively few structural changes were made. Those that were made included milking parlor upgrades (one farmer), equipment upgrade (one farmer) and fencing (two farmers).

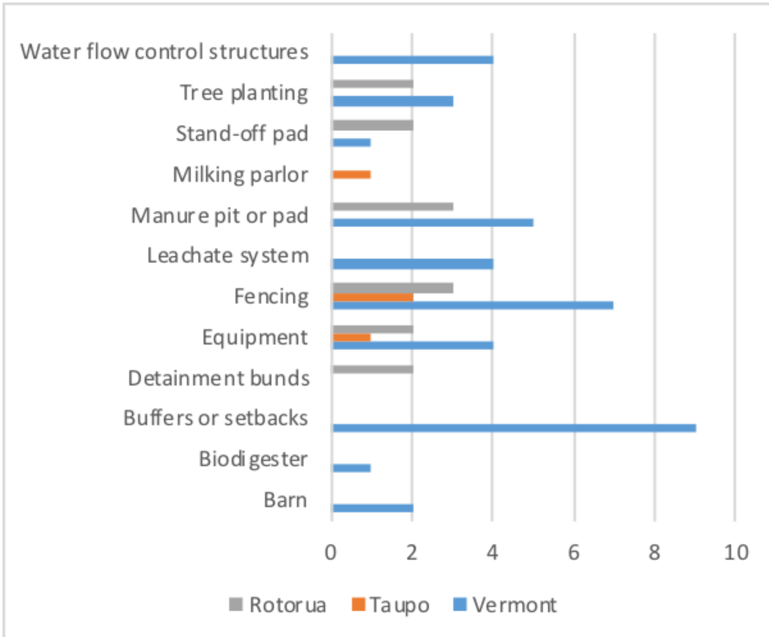

Figure 4-3. Number of Structural Changes by Region

System Changes

The top system changes across all three regions were switching to a lower intensity farm system and the purchase or lease of new land. In Vermont, three farmers transitioned to lower intensity, i.e. lower nutrient input, grass-fed and organic dairies. In Rotorua, four farms retired land into forestry or transitioned to sheep and cattle from dairy grazing. Finally, in Taupo, six farms retired land into pine plantation or native plantings or transitioned to beef finishing systems from dairy support or cattle breeding operations. Figure 4-4 shows the counts of system changes reported by farmers in each of the three regions in the study. Taupo and Rotorua farmers report the sale and ceasing of leasing land, but Vermont farmers do not. Although it should be noted that two of the farmers that sold land in Taupo also purchased land in the watershed, so they do not represent an exit from farming in the watershed. Importantly, there are three instances where farmers shifted to a higher intensity farm system in Rotorua and Taupo including transitions to dairy, sheep milking and cattle breeding operations. Similarly, in Vermont there were two cases in which a farmer transitioned land from forestry into agricultural production. These transitions represent an increase in potential negative water quality impacts via nutrient runoff and leaching.

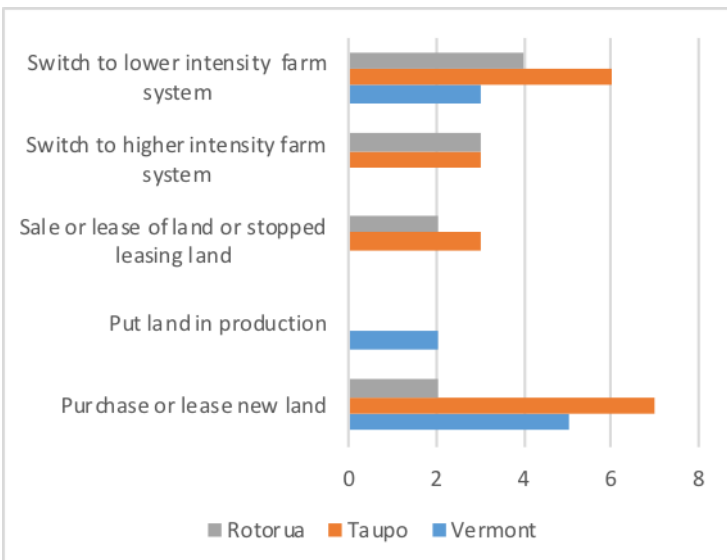

Figure 4-4. Number of Systems Changes by Region

4.5.2. Behavioral Drivers

Overall, Taupo and Vermont farmers referenced 19 different SES sub-categories as behavioral drivers, whereas Rotorua farmers referenced 16 (see Appendix 2 Table 5-9 for full list of driver nodes by region and Appendix 2 Table 5-10 for a list of ranked driver nodes by region). As such, not all SES subcategory drivers were present in each of the regions. However, in general, farmers in each region referenced many of the same drivers. Table 4-5 lists the key SES drivers across all three regions and their node statistics in each region. We define key drivers as those drivers that ranked in the top five drivers by strength in at least one region.

Table 4-5. Key behavioral driver node statistics. Key drivers are those that are ranked by strength in the top five of drivers in at least one of the three regions. Strength captures both the number of other nodes a node is connected to in the network and the number of individuals that mentioned each connection. Occurrence probability represents the proportion of individuals in a region that mentioned a node. Lack of statistics for a node in a region means that a node was not mentioned in the region.

	Node description	Node statistics	Taupo	Vermont	Rotorua
Water quality policy (governance)	The specific water quality policy in each region (i.e. Taupo's Variation 5, Vermont's Act 64 and the RAPs and Rotorua's Rule 11 and Proposed Plan Change 10)	Rank	1	2	1
		Strength	88	58	42
		Occurrence probability	100%	94%	100%
Government assistance (governance)	Technical or financial assistance from a government agency/entity	Rank	10	1	4
		Strength	9	74	14
		Occurrence probability	18%	88%	45%
Economics (actor)	Any considerations tied to a farm or farmer's economic situation, e.g. income, debt and economic efficiency of farm	Rank	2	5	2
		Strength	49	21	2
		Occurrence probability	91%	50%	64%
Ecological (resource system)	Existence, mitigation or prevention of erosion, runoff, drought, flooding etc.	Rank	5	4	3
		Strength	31	31	17
		Occurrence probability	45%	44%	55%
Nitrogen market (social, economic, political setting)	Purchase or sale of nitrogen in Taupo's nitrogen market or future purchase or sale in Rotorua's nitrogen market	Rank	3	-	10
		Strength	42	-	2
		Occurrence probability	82%	-	9%
NGOs or other organizations (governance)	Interactions with non-governmental entities including extension, watershed programs, land trusts, and research organizations and universities	Rank	11	3	6
		Strength	7	48	6
		Occurrence probability	9%	75%	36%
Economics and markets (social, economic, political setting)	Broader market and economic dynamics including prices, market access and competition	Rank	4	8	8
		Strength	40	9	5
		Occurrence probability	82%	44%	9%
Nitrogen and phosphorus attributes (resource units)	Attributes of nitrogen and phosphorus and the movement of these nutrients in the landscape and farm system	Rank	8	12	5
		Strength	16	2	11
		Occurrence probability	27%	6%	27%

Governance Drivers

Water quality policy is the top ranked behavior driver in Taupo and Rotorua, and the second in Vermont. In both Taupo and Rotorua, the occurrence probability is 100%, which means that every farmer interviewed referenced water quality policy as a driver of behavior. In Vermont, similarly, we see a very high occurrence probability of 94%. The following three quotes, one from each region, demonstrate the influence of each region's water quality policy on behavior:

> *"Some of my land, I'm on the early spreading ban. Due to the new RAPs I got to hit [by] them in the midsummer, so we're changing the way we got to do things, a little bit. We'll see in a few years. Hopefully, it'll benefit."* – Vermont Farmer

> *"But when Rule 11 came in… we [got rid of] 230 cows and 2 full time jobs. That was a result of [the water quality policy]. Because we were leasing land. We were leasing land and then with the [the water quality policy] we needed to get out of the catchment, which we've done*." – Rotorua Farmer

> "*We bought the farm and farmed it for a couple of years and through consultation process, it was pretty obvious that it was going to be capped, and it might be worse than that, we weren't sure what was going to come*

out of that…So we decided after a lot of soul-searching that we would sell." – Taupo Farmer

In Vermont, instead of water quality policy, government agency assistance has the highest driver strength rating for nutrient management behavior change in the group mental model and an occurrence probability of 88%. In Rotorua, government agency assistance is also relatively influential, ranked 4th amongst behavior drivers with an occurrence probability of 45%, however, in Taupo, it is ranked 10th, with an occurrence probability of only 18%. Farmers in Vermont reported government agency assistance mainly from the US Department of Agriculture's (USDA) Natural Resources and Conservation Service (NRCS) programs that give financial assistance for adopting, upgrading or installing new practices/structures on the farm, as well as technical assistance and advice form NRCS agents. In Rotorua, farmers referenced some financial assistance from the Bay of Plenty Regional Council to install physical structures on their farms such as fencing or water detainment berms, as well as funding to write farm management plans. The following quote represents the strong influence that NRCS played in driving behavior change for many Vermont farmers in the sample:

"So, [NRCS agent] just stopped in one day and they're non-regulatory. It was just a total social visit and I said, "Well, I've got some concerns"…. So, we sat down and he said, "Well, let's go around and just look at things if you want. No commitment." …So, when I started explaining the

> *concerns of the stream bank erosion and stuff and you know he had always been a supporter of conservation stuff anyway. So, he really listened to me and said, "Yeah, let's go for it. Let's do it." So, [the USDA NRCS' Environmental Quality Incentives Program] project is maxed out at $250,000.00 at the time. Well, we maxed it out."* – Vermont Farmer

NGOs and other organizations ranked third amongst behavioral drivers in Vermont, sixth in Rotorua and eleventh in Taupo. Seventy five percent of farmers in Vermont referenced technical assistance from the University of Vermont (UVM) agricultural extension and organic certification programs, or financial assistance from watershed programs and land trusts as drivers of their nutrient management behavior changes. One Vermont farmer noted a sentiment about UVM extension, that was shared by many in the Vermont farmer sample, in regard to beginning to take soil samples: "*I went to Extension yesterday…They're really, really helpful."* In Rotorua, only 27% of farmers cited NGO and other organizations as behavior change drivers, but they included similar categories of organizations, such as land trusts, research organizations like AgResearch and industry extension like DairyNZ. The other two governance nodes - other government policies and participation in a farmer group - were not listed in the top five of behavioral drivers in any region.

Actor Drivers

Actor economics was an important driver across all three regions. This node encompasses any considerations tied to a farm or farmer's economic situation as opposed to broader market considerations like price. Other actor sub-category behavior drivers, representing different attributes of the individual farmers interviewed, were not listed amongst the top five behavioral drivers in each region, although some still varied quite considerably in their influence between regions. These other actor drivers include ethic, flexibility, leadership or entrepreneur, lifestyle, past experience, social attributes and technology.

Actor economics, in terms of node strength, ranked second in Taupo, second in Rotorua, and fifth in Vermont. However, occurrence probability did vary quite significantly between the regions, with 91% of the farmer sample in Taupo citing actor economic drivers compared with only 64% and 50% of the farmer samples in Rotorua and Vermont. Actor economic drivers were phrased in similar language across all three regions. For example, in Vermont, one farmer noted in reference to transitioning forested land into agricultural land, "*really, for me the biggest driver is getting the most out of every dollar*." Similarly, in Rotorua, when explaining the reason for reducing the use of nitrogen fertilizer, a farmer stated, "I *mean, it was just around maximizing profit.*" Finally, in Taupo, one farmer described their reason for leasing out their land as *"three things, money, money and money*."

Resource System and Resource Unit Drivers

Ecological drivers, such as drought, flooding and erosion, were in the top five of behavioral drives across all three regions. In Rotorua ecological drivers were ranked 3rd, including protecting native species, minimizing runoff, and reducing erosion. In Vermont, ecological drivers were ranked 4th including soil health, minimizing runoff, stabilizing streambanks, concerns over water quality and controlling erodible soils. Lastly, In Taupo, ecological drivers were ranked 5th, with many farmers noting multiple years of drought as driving behavior. Farm production needs were not listed as a key behavioral driver in any of the three regions.

Nitrogen and phosphorus attributes were ranked relatively higher in Rotorua (5th) and Taupo (8th) than Vermont (12th). Only one farmer interviewed in Vermont referenced attributes of nitrogen and phosphorus as driving behavior (i.e. not the policies treatment of nitrogen and phosphorus, but the specifics of the nutrients cycling), corresponding to a 6% probability of occurrence in the sample. Whereas, a small subset of farmers in Rotorua and Taupo demonstrated a sophisticated understanding of nitrogen or phosphorus dynamics and cited this as a driver of behavior change. For example, one Taupo farmer said: "*we have also learned that we stop leaching here below the root zone about the middle of October. So we put no fertilizer on until after that date. We do not use any nitrogen fertilizer. We fertilize to grow clover, and clover is fixing according to scientists and according to overseer modeling, we are fixing between 250 and 300 kg of nitrogen per hectare per annum*."

Social, Economic, and Political Setting Drivers

The nitrogen market sub-category is very influential as a behavioral driver in Taupo, but practically non-existent as a driver in Rotorua and not present as a driver for Vermont. This code was specific to the existing nitrogen market in Taupo that existed as a part of the water quality policy as a voluntary nitrogen trading market. The nitrogen market is ranked 3rd as a behavioral driver in Taupo, with an occurrence probability of

82%. One farmer in Rotorua referenced concrete plans to sell nitrogen to the newly formed nitrogen market in Rotorua, and there is no current market in Vermont.

Broader economic and market drivers, such as price, market access and competition were ranked 4th as a behavioral driver in the Taupo region and 8th in both Vermont and Rotorua. The ranking, however, doesn't quite capture the variance in probability occurrence, which was 82% in Taupo, 44% in Vermont and only 9% in Rotorua. The other four social, economic and political setting drivers were ranked relatively low across the three regions in terms of behavioral influence. These include social context, industry or consultant advice, demographic shifts and carbon market.

4.5.3. Outcomes

Farmers across all three regions reported individual- and watershed-level social, economic and ecological outcomes related to behavioral changes and the policy process across the spectrum from negative to neutral to positive.

Individual Outcomes

At the individual level, Taupo farmers reported both more negative and positive economic outcomes on average than Rotorua and Vermont farmers in the sample. Negative economic outcome sub-categories at the individual level included compliance costs, farm viability, financial impacts, and impacts to farm economic flexibility. For example, one Vermont farmer referenced a negative financial impact related to requirements under the water quality policy, when they said: "*The biggest problem I have is we have to put a leachate system in. Ugh. It's an $81,000.00 project, which I don't think is even needed*," but later clarified that they wouldn't pay the full cost of the project.

Similarly, positive economic outcomes for individuals include the sub-categories of positive farm viability, positive financial impacts, positive farm economic flexibility and access to new markets. In terms of positive individual financial outcomes, one Taupo farmer said in terms of the impact of the water quality policy on their farm business: "*To me it's been a windfall. We bought land cheaper. We made some very clever smart moves, so it's opened up huge opportunities for me as a person*." A number of farmers in Vermont and Rotorua mentioned that the water quality policy has not had a significant impact in terms of costs of compliance on their farm economically, represented by the neutral economic category. Very few Taupo farmers referenced neutral economic impacts.

In terms of individual social outcomes, Vermont farmers on average reported more positive individual outcomes than Taupo and Rotorua and less negative social outcomes than Taupo and Rotorua. In terms of positive individual social outcomes, farmers reported increased knowledge and awareness, non-financial benefits such as pride, and recognition for environmental stewardship. For negative individual social outcomes, farmers mentioned distrust in regulation, non-financial costs like time, stress and mental health impacts, uncertainty in the future of their farming livelihoods and a few farmers in Rotorua mentioned feeling like they were unfairly impacted by the water quality policy at a personal level.

At the individual level, no farmers across any of the regions reported negative ecological outcomes on their farm as a result of their behavior changes or the water quality policy, however, a few farmers in Vermont and Rotorua, but not Taupo, referenced positive ecological change on their farms in terms of pasture or soil quality, and water quality.

Watershed Outcomes

Similar to individual level outcomes, farmers across all three regions reported social, economic and ecological watershed-level outcomes. As shown in Figure 4-5, there appears to be much greater variation in perceptions of watershed-level outcomes across the three regions.

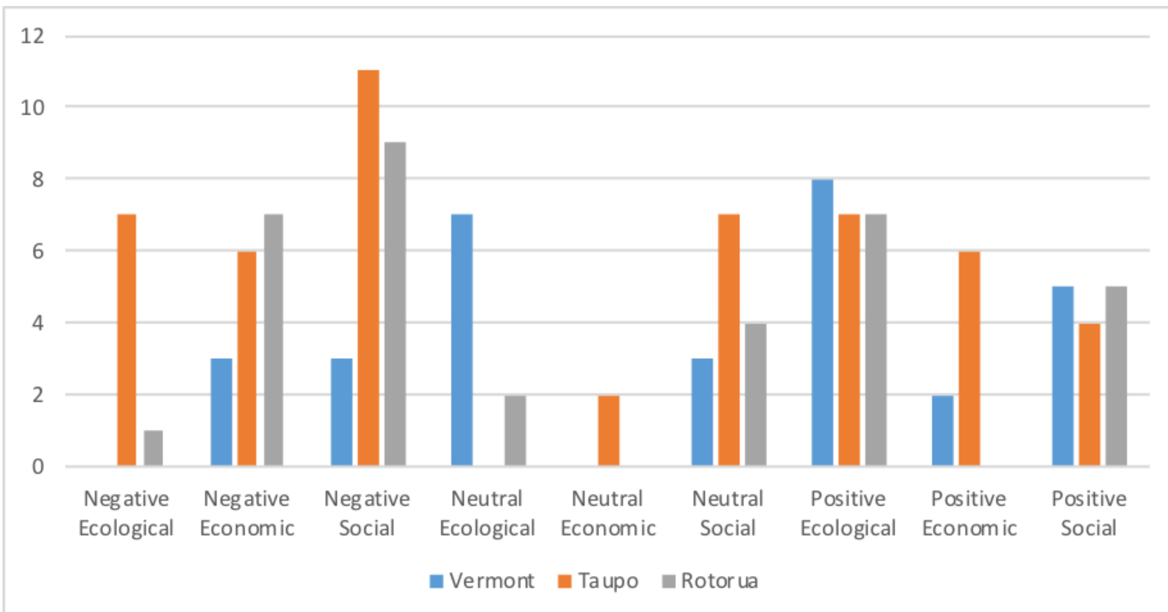

Figure 4-5. Number of watershed outcomes by region. Note for Taupo and Rotorua n = 11 and for Vermont n = 16.

Vermont Watershed Outcomes

In Vermont, relative to Taupo and Rotorua, farmers generally noted more perceptions of positive and neutral watershed level outcomes than negative. Vermont farmers mentioned increased community awareness, community well-being and fairness as positive social outcomes, and a few reported negative community well-being. One farmer described the difficulty a neighbor was facing with the new water quality policy regulations: "*And, I think it's too bad. He gets really upset about it. He's done a really good job farming all his life…So, they're basically forcing him out of business*." In terms of watershed economic impacts, only a few Vermont farmers noted negative or positive impacts. On the negative side farmers cited challenges to the agricultural community operating with low product prices and regulation, while on the positive side farmers cited financial viability with cost share assistance and flexibility in the water quality policy regulations.

Eight Vermont farmers perceived positive watershed ecological outcomes, seven perceived neutral ecological outcomes and no farmers perceived negative ecological outcomes. Most of Vermont farmers' ecological outcome perceptions related to existence or lack of farming management changes on the landscape and not on broader land use changes. Vermont farmers in the sample appeared split as to whether management changes were being made, with some farmers reflecting that don't see changes, like one Vermont farmer who said, "*I go by some of the other farms that do some of the things they do, I go, "What the heck? How do they get away with that?"* Other farmers were optimistic in their outlook for water quality from land use changes, like this Vermont farmer who said, "*I see the bigger farms – a lot of them are doing cover crops where they never did before."*

Taupo Watershed Outcomes

In the Lake Taupo watershed, similar to the individual level outcomes, farmers' perceptions were polarized, with high numbers of positive and negative outcomes. In many cases these were the same farmers. Socially, we see that every farmer mentioned at least one negative outcome of the water quality policy, either along the lines of fairness of the policy or community well-being. One Taupo farmer reflected on the policy process by remembering that the "*uncertainty emotionally and mentally [was] shocking. It demotivated farmers, a lot of farmers were depressed because they didn't see a lot of hope."* Many farmers mentioned other farmers selling their farm and leaving the catchment during the policy process. For the large number of relatively low intensity Maori farms in the catchment, farmers expressed that the policy was unfair, as one farmer reflected, "*And being a lot of Maori owned land they went overly heavy about it because it sort of hindered what they could do with their land further down the track."* Conversely, a number of farmers reported neutral and positive social outcomes, seven and four farmers respectively. Neutral watershed social perceptions included acceptance of the policy, a desire to "*just get on with it."* Positive Taupo social watershed outcomes included flexibility from nitrogen trading and the ability to sell nitrogen to the trust, which was seen as a positive outcome for Maori farms to allow them to liquidate capital without selling property. Except for freehold land purchased by Māori individuals, Māori cannot sell land.

Perceptions of watershed economic impacts in Taupo varied greatly amongst the farmer sample, with 6 farmers each reflecting on positive and negative economic impacts, with two reflecting neutral impacts. One farmer explained how the policy negatively limits their farm’s economic potential: “*Essentially, under this process we can't grow any more meat per hectare, our livestock numbers are capped at 2004 levels, and cost inexorably keep growing*.” On the positive side, one farmer reflected on farm viability in Taupo when they mentioned that “*the beauty about farming in here is that you've got a resource that comes in for 25 years. Now, I'd argue that there is nowhere in New Zealand that you’ve got a license to farm for 25 years*.”

Ecologically, perceptions of watershed outcomes in Taupo also varied greatly, with farmers again split equal between negative and positive perceptions of ecological outcomes. On the positive side, farmers perceived of the policy technically as a success, purchasing nitrogen out of the catchment, changing land use to reduce nitrogen leaching, and capping nitrogen in the watershed and in some cases farmers thought the lake was clearing up. There appeared to be some disagreement amongst farmers as to whether the policy achieved its ecological goals. One farmer said that the best thing the policy “*did [was] stop intensification of dairy farming coming close to the lake*,” while another farmer reflected that the policy didn’t do “*what they were hoping it would do which was halt dairy farming*.” Some farmers reflected negatively upon the fact that new dairy farmers were able to come into the watershed under the policy and intensify through purchasing nitrogen credits from other farmers. Additionally, many farmers reflected negatively upon the transition of much of the landscape from pastoral agricultural to pine planation, a lower nitrogen leaching land use, under the water quality policy. As one Taupo farmer reflected: “*All that now is getting developed…That should never ever be put into trees, and it is going to end up having trees. That is wrong*.”

Rotorua Watershed Outcomes

In Rotorua, farmers in the sample in general perceived more positive ecological watershed outcomes, more negative social impacts and only negative economic impacts of the water quality policy process. Economically, seven farmers reported that the policy process has resulted in a steep decline in investment in farming in the watershed and the perception that for farming "*financially, it's not doable"* to achieve future nutrient reductions required under the policy. In terms of social impact, nine farmers perceived negative social impacts at the watershed scale including impacts on community well-being and perceived fairness of the policy. According to one Rotorua Farmer, the policy process has been emotionally difficult: *"So, I think – but it's like grievance; this – this phase is the angry phase, and then acceptance might come because that's what happened…in the Taupo catchment like I say."* Rotorua farmers reported that the policy is unfair towards farms and that the urban share of the burden is being overlooked. Furthermore Rotorua farmers expressed frustration that previous actions to reduce phosphorus runoff that they have undertaken voluntarily have not been given enough credit under the new policy. A few farmers, four each, noted positive and neutral social outcomes. One farmer noted that as a result of the policy community awareness and well-being has risen: "*Well, farmers have become aware of the environmental impacts that farming has on the waterways and the lakes. So, yeah. Actually, I think that probably the biggest plus out of it is actually talking to your neighbor, and working with your neighbor, and seeing what they're doing*."

In terms of ecological outcomes, seven Rotorua farmers perceived positive ecological outcomes, with two perceptions of neutral outcomes and just one negative. One the positive side, one farmer suggested that the policy has halted land use intensification: "*I think possibly there might have been a few more farms convert to dairy, or in that time period, had [the water quality policy] not been there*." In some cases farmers reported that "*most farmers have done small changes to improve areas*" whereas others perceived that "*the land use, land use change, in the catchment, has been minor*." While a number of Rotorua farmers noted positive ecological outcomes, similar to Vermont, the outcomes were mostly around management changes, not land use change.

4.6. Discussion

4.6.1. Differential Behavior Outcomes

From the perspective of fit and functioning of the mandatory water quality policy in the three focal regions, farmers in the sample reported changing nutrient management behavior mostly in the intended direction (i.e. reduced nutrient loading). The actions of these farmers should improve water quality over time in line with the goals of the policy. The first clear take-away on behavior is that management changes are the low-hanging fruit and farmers interviewed across all three regions have made on average 2-3 types of management changes. Management changes, as defined in Table 4-3 are relatively inexpensive compared to structural and system changes, more reversible if they fail to work and do not necessarily require major time or financial investments.

The difference in structural and system changes between the regions, and in particular the dominance of structural changes in Vermont compared to the dominance of system changes in Taupo amongst our sample, may have long term implications for water quality impacts. As described above, system change are likely to be associated with a larger range of potential nutrient change because it is likely that system changes to lower intensity systems will change nutrient dynamics more significantly than structural changes. This suggests that although Vermont shows the highest reported behavior change per person in our sample, the high levels of system change reported by farmers in our sample may ultimately be associated with greater water quality improvements.

4.6.2. Water Quality Policy Interplay with SES Context

The reason for the dominance of structural versus system changes in Vermont and Taupo in our sample is likely due to the design of each of the policies, as well as the broader SES context represented by the drivers. There are major differences in how the policy appears to interplay with the SES context according to each of the regions' group mental models.

In Vermont the top three behavioral drivers are government agency assistance, the water quality policy and NGOs or other organizations. It is notable that Vermont is the only region in which the water quality policy is not reported as the main driver of behavior. In essence, Vermont farmers described an incentive-based SES context that supports farmers with financial and technical assistance to adopt new management and structural nutrient management practices with a regulatory backstop. This aligns broadly with the United States' strong financial support for farmers through subsidies and cost share programs. The design of the practice-based policy, requiring specific practices on farms, also aligns with the program structure of NRCS and other pre-existing programs to pay farmers a cost share to adopt similar practices. As a result, there are very little system change happening in Vermont, at least among those that we interviewed. Further, the heavy role of incentives in the SES context shapes the outcomes for farmers with a lack of negative social and economic impacts. Relative to Taupo and Rotorua, actor economics is ranked lower in Vermont suggesting that farmers have the financial ability to make management and structural changes with the existing financial assistance. In terms of ecological and long-term water quality outcomes, we see mixed perceptions about whether the policy is actually having an effect. Farmers interviewed were split between positive and neutral perceptions of land management changes, and there was not any discussion of big, landscape scale changes.

In Taupo, the water quality policy is reported as the main behavioral driver, coupled with farmer economics and the voluntary nitrogen market component of the policy amongst our farmer sample group mental model. The voluntary nitrogen market appears to promote system changes as opposed to structural changes and with the performance-based policy, structures do not "count" in the policy in the way they do in Vermont. Furthermore, there are not programs to assist farmers in purchasing or upgrading infrastructure due to the lack of agricultural subsidies. To adapt to the performance cap, famers in our sample sold nitrogen and used the capital to restructure their farm system. In Taupo, both actor economics and broader economics and markets are important drivers. This reflects two polarized experiences: first, many farmers are at the margin economically and do not have access to financial assistance to offset new risks and exposures and second, some farmers benefitted greatly under the new policy regime and were able to take advantage of the opportunity to further their economic situation. For many farmers in the first situation in our sample, we see that the new policy has fostered entrepreneurship and innovation in a way that was not seen in the other two regions. In Taupo, farmers are experimenting with new farm system types, such as sheep milking and new branding/marketing strategies to make up for their inability to intensify. Similarly, Taupo farmers report polarized impacts from the policy with farmers who gained significantly, farmers who struggled and very few in-between.

Finally, in Rotorua, our study captured a time of high uncertainty with a strong policy signal. Rotorua's farmers cited fewer drivers than the other two regions and fewer behavior changes. However, the water quality policy was reported as the top driver of behavior change in the region, suggesting that even though just a policy signal (i.e. not operation), the proposed rules were perceived as changing behavior. The high role of actor economics reflects that farms are pursuing changes that are low hanging fruit, while evaluating the potential economic impact of future changes. It is possible that once the policy is operational, Rotorua will look more like Taupo, with the nitrogen market playing a central role and more system changes as a result. Unlike Taupo, the regional council in Rotorua has played a role in giving cost share and technical assistance to farms to install some structures, mainly fencing and detainment berms on farms in the past ten years. However, there is not cost share available for practice adoption under the new policy. As a result, we see highly negative perceptions of social and economic outcomes in Rotorua amongst our sample. Interestingly, some farmers reported positive ecological outcomes as a result of land management changes, but again like Vermont, these were not perceived as broad landscape changes.

4.6.3. Opportunities for Water Quality Policy Fit and Interplay

Comparing across the three regions, a key takeaway is that in one way or another, farmers needed financial access or assistance to achieve structural or system changes. In Vermont, farmers used financial assistance and cost share to make changes, in Taupo farmers sold nitrogen to enable system change, and in Rotorua, without a functioning nitrogen market or extensive financial assistance options, there were much lower levels of structural and system change.

Resource system and resource unit drivers represent interesting opportunities for policy. Ecological drivers across the three regions played a role in nutrient management decisions under water quality policy. Aligning nutrient management changes with ecological functioning on farm, such as drought tolerance or reducing erosion, appears to be an important component of behavior change. Further, the role of nitrogen and phosphorus attributes, was a relatively low ranked driver across all three regions, but particularly low in Vermont. This is surprising given that farmers in Vermont reported high levels of nutrient management plan adoption, which is intended to improve efficiency in nutrient use and improve farmers understanding of nutrients in their farm system (Beegle et al., 2000). In Taupo and Rotorua, the requirement to model the farm system and staying under a nutrient cap appears to have, in at least a few cases improved farmer understanding of nutrient dynamics in a way that has changed behavior. Some

Taupo farmers reported a change in mentality on their farm system to evaluating efficiency as "*dollars profit per kilogram of nitrogen leached*."

Finally, we'd like to end with a point raised by a Taupo farmer when asked about benefits of the water quality policy:

> "*I'm nervous about the question, because a lot of research is predicated on the assumption that you can continue to improve and you can continue to reduce your environmental impact and continue to increase your production. No. The lesson from this is that you can't. We shut down 30% of the farmland in the catchment, those trees that you drove past. We spent $80 million shutting down those farms. There is nothing on the science horizon that will allow those farms to continue, and to look after the lake. So we have to get real with these conversations*" – Taupo Farmer

As this Taupo Farmer suggests, conversations around agriculture and water quality need to acknowledge the true environmental costs of agricultural production. When agricultural production is brought in line with ecological limits, as was the case in Taupo, there will most likely be a dramatic social and economic adjustment period for farm businesses. While we see relatively lower reports of social and economic impacts in Vermont, we also see less certainty in achieving the ecological goals of the policy. This is evidenced both by Vermont farmers reliance on structural changes in the region and the lack of perceived broad landscape changes. Whereas in Taupo, we see social, economic and ecological changes that have caused deep pain, as well as great opportunity and innovation. It is likely that Rotorua as reflected here was similar to the Taupo catchment

5-8 years prior. Moving forward, policy should acknowledge that win-win solutions may not always be possible. To achieve long term water quality goals, policies may require significant adjustments to farm systems that align farm production in a watershed with its ecological capacity, particularly in highly impaired systems. In these cases, policy design should focus on assisting the farming community through a dramatic adjustment period.

4.7. Conclusion

Farmer behavior change is a critical element of improving water quality and reducing agricultural NPS pollution. In this study we have looked to farmers experience and perceptions in three regions facing mandatory rules to curb agricultural NPS pollution. Water quality policy, and any policy for that matter, exists within a broader social-ecological context and the fit and interplay of a policy in that context ultimately determines the success of the policy. Farmer mental models, as used here in this study, can provide important insight into how behavior is changing across the landscape and what combinations of factors are driving it. Our results suggest that policy design interacts with the social-ecological context to produce differential patterns of behaviors and outcomes, which ultimately may mean differential improvements in water quality. Throughout the policy process, attention should be paid to the types of behaviors that are important for water quality improvements and the degree of adjustment required by farmers to achieve behavior change. Farmers will likely need support to adjust, and it is important that support is given for behaviors that will have long term water quality impacts, or else there is risk of further regulation down the line. More explicit focus on farmer behavior and experience within water quality policy can allow for improved policy design for achieving the ecological goals of the policy.

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CHAPTER 5: CONCLUSION

5.1. Synthesis of Results

In this dissertation, I have examined the interaction between water quality policy for agricultural NPS pollution and farmer behavior and decision making to improve our understanding of if and how policy will improve water quality in agricultural watersheds. After defining the problem and my approach in the first chapter, in the second chapter I use declining water quality from agricultural NPS pollution as an example case to explore ways to improve our analytical study of environmental public goods dilemmas. This chapter laid the theoretical foundation for the rest of the dissertation by calling for the need to focus greater attention on the link between institutions and behavior in environmental public goods dilemmas.

In the third chapter I built on the theoretical foundation in chapter two to explore the impact of new institutional interventions for agricultural NPS pollution (i.e. mandatory practice-based and performance-based policies) on farmer nutrient management behavior and decision making. The key insights from this chapter are that, in the sample of New Zealand farmers in 2015, there was no evidence that mandatory regimes were driving increased behavior change amongst farmers when compared to regions without mandatory policy. If the key role of these policies are to change behavior, this implies two things: 1) we need to keep monitoring behavior to see if it does change over time and 2) we may need to consider additional avenues to change behavior within policy regimes. Another key insight, however, is that we did see a potential for increased behavior change in the future in performance-based regimes and greater alignment between farmer decision making in performance-based regimes and their values and beliefs. Therefore, our results suggest that mandatory practice-based policies may not be as effective as performance-based policies in achieving long term water quality improvements.

In the fourth chapter, we analyzed grouped farmer mental models in three mandatory water quality policy regimes to evaluate the fit and interplay these policies in each context. Here we used the SES Framework as proposed in chapter two to examine farmer's reported behavior change, behavioral drivers and perceived outcomes of the policy process. We find in comparing these three regions that policy is reported as a key driver of behavior change in each of the regions, but it interacts with other SES dynamics to produce different patterns of behavior change and outcomes. In Vermont, USA the practice-based mandatory policy interacts with multiple sources of financial and technical assistance to drive management behavior changes (e.g. timing and amount of fertilizer applications) and structural behavior changes (e.g. upgrade manure pit). Whereas in Taupo, New Zealand the performance-based policy combines with a voluntary nitrogen market to drive management and system changes (e.g. transition from dairy system to cattle system). In Rotorua, New Zealand, we see that despite not having an operational policy yet, the signal of the future policy does drive behavior change. However, behavior change is not to the same extent as the other two regions, with more management changes than structural than system. Based on my analysis of these three regions, I suggest that paying attention to the types of behavior change, whether management, structural or system across a landscape has implications for water quality improvement. Additionally, we suggest that to achieve structural or system change, farmers need financial assistance or access to capital.

5.2. Broader Implications

Taking into account the theoretical and empirical analysis of chapters two, three and four, I can make some general conclusions for the study of agricultural NPS pollution. First, the social and ecological context of a policy is a critical component driving patterns of behavior change and perceived outcomes. Policy design must be tailored to its particular social and ecological context and the potential interactions between policy design and other behavioral drivers should be accounted for in order to achieve long term water quality improvements.

Second, the design of a water quality policy impacts farmers' experience of the policy and the potential for long term policy success. Incorporating the social psychological aspects of farmer decision making on nutrient management behavior enables better understanding of how we can design policy to allow farmers more flexibility and autonomy in running their farm systems. In terms of policy design and behavior change, the results from chapter three and four are somewhat contradictory. In chapter three our results suggest that policy design does not appear to drive behavior change relative to contexts without mandatory policy, but in chapter four farmers strongly perceive water quality policy to be a major driver of their changes in behavior. I will return to this discrepancy in the next section when I discuss future research directions.

Finally, acknowledging the links between agricultural NPS pollution policy and farmer behavior and decision making allows for deeper and more realistic conversations about the tradeoffs between ecological and agricultural productions goals. If we are to improve water quality and support farmers, these are the types of frank conversation that are required to achieve a fair, socially acceptable and ecologically successful policy.

5.3. Future Directions

The results of this dissertation suggest interesting avenues for future research on agricultural NPS pollution policy and environmental public goods dilemmas more broadly. As referenced in the previous section, we see different results in chapters three and four on the role of water quality policy in driving farmer behavior change. This discrepancy could be due, in part, to the different time scales at which the data were collected. The data for chapter 3 was collected in 2015, whereas the data for chapter 4 was collected in 2017-2019. Regardless, this discrepancy calls for a mixed methods approach, combining qualitative and quantitative data from the same time period in order to dig deeper into farmer decision making and behavior change across policy contexts. This might provide new insights in terms of policy design, behavior change, and survey design/qualitative approach.

Considering the study of environmental public goods dilemmas more broadly, including climate change, biodiversity loss and other types of water quality issues, this dissertation suggests that an SES framework-based study focusing on the links between policy institutions and actor decision making could provide new insights to inform sustainable resource management regimes. A related frontier is the governance of overlapping ecological issues, such as agricultural NPS pollution and climate change. The approach defined and implemented in this dissertation holds great potential for improving our understanding of how policy design for overlapping ecological issues impacts behavior, experience and policy support.

5.4. Comprehensive References

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APPENDIX 1

Table 5-1. New Zealand Regional water quality policy descriptions

Territorial Authority	Sample	Representative-ness (compared to 2012 NZ agricultural census)	Region	Policy Type	Policy Notes	Sources
Taupo District	17	3.61%	Waikato	Performance	Variation 5 to the Waikato Regional Plan (chapter 3.10 of the Waikato Regional Plan) operational as of 2011, lays out a cap and trade performance-based policy to control nitrogen leaching from agricultural land in the catchment.	Waikato Regional Council. (2012). Waikato Regional Plan (online version). Retrieved from https://www.waikatoregion.govt.nz/council/policy-and-plans/rules-and-regulation/regional-plan/waikato-regional-plan/
Thames-Coromandel District	8	1.75%	Waikato	No policy	As of 2015 there were no other mandatory water quality policies (as relating to the NPS for Freshwater) drafted, notified or operational in Waikato.	Waikato Regional Council. (2012). Waikato Regional Plan (online version). Retrieved from https://www.waikatoregion.govt.nz/council/policy-and-plans/rules-and-regulation/regional-plan/waikato-regional-plan/; Greenhalgh, S., & Murphy, L. (2017). Freshwater contaminant limit assessment of the regions. Motu Economic and Public Policy Research. Retrieved from https://motu.nz/our-work/environment-and-resources/agricultural-economics/agricultural-greenhouse-gas-emissions/freshwater-contaminant-limit-assessment-of-the-regions/
Matamata-Piako District	39	2.46%				
Hamilton District	1	1.45%				
Hauraki District	20	2.50%				
Otorohanga District	23	3.02%				
Waipa District	44	2.78%				
South Waikato District	17	2.95%				
Waikato District	63	2.41%				
Waitomo District	19	2.96%				

Rotorua District	22	2.80%	Bay of Plenty	Performance	Rule 11 of the form Regional Water and Land Plan (now RL R1 in the Regional Natural Resources Plan) is operational as of 2005 and limits property's leaching rates at their nutrient benchmark, assessed between 2001 and 2004. Rule 11 will be supplemented by Proposed Plan Change 10 of the Regional Natural Resources Plan (formerly the Regional Water and Land Plan), notified in 2016, which lays out a cap and trade performance-based policy to control nitrogen leaching from agricultural land in the catchment, including a reducing in farm-scale leaching limits by 2032.	Bay of Plenty Regional Council. (2012). Lake facts Rotorua Lakes: What is Rule 11? Retrieved from http://www.rotorualakes.co.nz/vdb/document/136; Bay of Plenty Regional Council, Rotorua Lakes Council and Te Arawa Lakes Trust. (2016). A Guide for Landowners: Lake Rotorua Nutrient Managment. Plan Change 10 to the Bay of Plenty Regional Water and Land Plan, Bay of Plenty Regional Council. (2018). Operative Bay of Plenty Regional Natural Resources Plan. Ta Mahere Rawa Taiao a-Rohe. Retrieved from https://www.boprc.govt.nz/your-council/plans-and-policies/plans/regional/regional-natural-resources-plan/
Kawerau District	1	16.67%	Bay of Plenty	No policy	As of 2015 there were no other mandatory water quality policies (as relating to the NPS for Freshwater) drafted, notified or operational in Bay of Plenty Region.	Bay of Plenty Regional Council. (2018). Operative Bay of Plenty Regional Natural Resources Plan. Ta Mahere Rawa Taiao a-Rohe. Retrieved from https://www.boprc.govt.nz/your-council/plans-and-policies/plans/regional/regional-natural-resources-plan/; Greenhalgh, S., & Murphy, L. (2017). Freshwater contaminant limit assessment of the regions. Motu Economic and Public Policy Research. Retrieved from https://motu.nz/our-work/environment-and-resources/agricultural-economics/agricultural-greenhouse-gas-emissions/freshwater-contaminant-limit-assessment-of-the-regions/
Opotiki District	8	2.08%				
Tauranga City	1	0.62%				
Western Bay of Plenty District	77	2.60%				
Whakatane Districts	29	3.43%				

Central Hawke's Bay District	48	6.02%	Hawke's Bay	Performance	Plan Change 6 to the Hawke's Bay Regional Resource Management Plan: Tukituki River Catchment put into place performance-based policy, based on a natural capital standard for landownders in the catchment. Plan change operative October 2015 with performance-based leaching standards to be met by 2020. Measurement and budgeting via OVERSEER required as of 2013.	Hawke’s Bay Regional Council. (n.d.). Plan Change 6 to Hawke’s Bay Regional Resource Management Plan: Tukituki River Catchment (No. HBRC Report No. SD 15-08 – 4767).
Hastings District	56	3.34%	Hawke's Bay	No policy	As of 2015 there were no other mandatory water quality policies (as relating to the NPS for Freshwater) drafted, notified or operational in Hawke's Bay Region.	Hawke’s Bay Regional Council. (2012). Hawke’s Bay Regional Resource Management Plan. Retrieved from https://www.hbrc.govt.nz/documents-and-forms/rrmp/; Greenhalgh, S., & Murphy, L. (2017). Freshwater contaminant limit assessment of the regions. Motu Economic and Public Policy Research. Retrieved from https://motu.nz/our-work/environment-and-resources/agricultural-economics/agricultural-greenhouse-gas-emissions/freshwater-contaminant-limit-assessment-of-the-regions/
Napier City	6	4.44%				
Waiora District	19	5.07%				
Ruapehu District	14	2.41%	Manawatu-Wanganui	Practice	Manawatu-Wanganui (Horizon's) One Plan was operative in 2014. Standards in place for priority catchments (performance), practice-based requirements for non-priority catchments. No priority catchments in Ruapehu District. One small priority catchments in Wanganui District (Kaitoke Lake) (performance). One priority catchments in Wanganui District (Northern	Horizons Regional Council. (2014). One Plan: Mo te iti - mo te rahi. The Consolidated Regional Policy Statement, Regional Plan and Regional Coastal Plan for the Manawatu-Wanganui Region (No. 2014/EXT/1338). Retrieved from http://www.horizons.govt.nz/publications-feedback/one-plan
Whanganui District	19	2.95%				
Manawatu District	57	4.33%				
Palmerston North City	13	4.61%				

					Manawatu Lake). No priority catchments in Palmerston North City.	
Rangitikei District	42	5.20%	Manawatu-Wanganui	Performance	Manawatu-Wanganui (Horizon's) One Plan was operative in 2014. Standards in place for priority catchments (performance), practice-based requirments for non-priority catchments. Standards in place for priority catchments (performance). Three priority catchments in Rangitikei District (Southern Whanganui Lakes, Northern Manawatu Lakes, coastal rangitikei).Three priority catchments in Horowhenua District (Lake Horowhenua, Lake Papaitonga, Waikawa). Eight priority catchments in Tararua District (Upper Manawatu, Weber-Tamaki, Upper Tamaki, Upper Kumeti, Tamaki-Hopelands, Hopelands-Tiraumea, Mangatainoka, Upper Gorge).	Horizons Regional Council. (2014). One Plan: Mo te iti - mo te rahi. The Consolidated Regional Policy Statement, Regional Plan and Regional Coastal Plan for the Manawatu-Wanganui Region (No. 2014/EXT/1338). Retrieved from http://www.horizons.govt.nz/publications-feedback/one-plan
Horowhenua District	16	2.79%				
Tararua District	45	3.86%				
Clutha District	59	4.86%	Otago	Performance	Plan change 6a Otago Water Plan; threshold for nutrient leaching come into effect in April 2020. Effects-based approach (performance) that allows landowners to determine methods for managing nutrients and other contaminants as long as they meet the threshold in the Plan's Schedule 16 (in 2020). Rules are operative as of May 2014, but leaching thresholds don't come into effect until 2020.	Otago Regional Council. (2018). Regional Plan: Water. Retrieved from https://www.orc.govt.nz/plans-policies-reports/regional-plans-and-polices/water; Otago Regional Council. (2016). Regional Plan: Water for Otago. Retrieved from https://www.orc.govt.nz/media/1207/regional-plan-water.pdf
Duneden City	20	2.71%				
Queenstown Lakes District	5	2.14%				
Central Otago District	37	4.80%				
Buller District	20	7.94%	West Coast	No policy	As of 2015 there were no mandatory water quality policies (as relating to the NPS for	The West Coast Regional Council. (2014). West Coast Regional Land and Water Plan. Retrieved from
Westland District	13	4.25%				

					Freshwater) drafted, notified or operational in West Coast Region, aside from the Lake Bunner Catchment in Grey District.	https://www.wcrc.govt.nz/Documents/Resource%20Management%20Plans/Operative%20Land%20and%20Water%20Plan%20May%202014.pdf
Grey District	5	2.78%	West Coast	Practice	Chapter 9 in the West Coast Land and Water Plan designates special management practice-based rules for the Lake Brunner/Kotuku-Whakaoho catchment. The practices include stock exclusion, low rates of agricultural effluent application to land, resource consents for stock crossing in water ways, and other restrictions on agricultural land use activities. The West Coast Land and Water Plan was operative as of 2014.	Stuart, B. (n.d.). Review of the Lake Brunner Project 2015. NZ Landcare Trust. Retrieved from http://www.landcare.org.nz/files/file/1824/Review%20of%20Lake%20Brunner%20Project%202015_2.pdf; The West Coast Regional Council. (2014). West Coast Regional Land and Water Plan. Retrieved from https://www.wcrc.govt.nz/Documents/Resource%20Management%20Plans/Operative%20Land%20and%20Water%20Plan%20May%202014.pdf
Waimakariri District	40	2.46%	Canterbury	Performance	The Canterbury Land and Water Regional Plan (LWRP), operative 2016, region-wide rules apply to all areas, unless otherwise specified through plan changes (e.g. Selwyn, Ashburton, and Hurunui Districts have different policy in some areas). Under the LWRP regions are divided up into nutrient allocation zones, including red for those that are more vulnerable to nutrient pollution, orange which are at risk and blue and green which are not currently at risk. In each of these nutrient allocation zones, farms are regulated based on a "baseline" nutrient leaching rate assessed	Environment Canterbury. (2019). Canterbury Land and Water Regional Plan. Retrieved from https://www.ecan.govt.nz/your-region/plans-strategies-and-bylaws/canterbury-land-and-water-regional-plan/
Timaru District	37	3.77%				
Mackenzie District	11	4.12%				
Waitaki District	39	4.51%				
Kaikoura District	4	2.90%				
Christchurch City	15	1.95%				
Waimate District	18	3.30%				

					during the years 2009-2013. Different leaching rates are permitted in each of the zones, but an increase above the N baseline is not permitted. This operates as a performance-based farm-scale cap. Some properties, based on location and nutrient leaching baseline are required to write a Farm Environment Plan and propose management practices to avoid or minimize nutrient loss. All farms are expected to be at Good Management Practice standard.	
Hurunui District	48	4.83%	Canterbury	Practice	Hurunui and Waiau River Regional Plan, operative 2013, requires farms to become part of a Collective or group with an environmental management strategy or apply for a resource consent on their own that designates practices in place to ensure regional water quality standards are met.	Environment Canterbury. (2019). Canterbury Land and Water Regional Plan. Retrieved from https://www.ecan.govt.nz/your-region/plans-strategies-and-bylaws/canterbury-land-and-water-regional-plan/ Environment Canterbury. (2019). Canterbury Water: What's Your Zone? Retrieved from https://www.canterburywater.farm/zones
Selwyn District	62	3.24%	Canterbury	Performance	Selwyn Waihora catchments, LWRP Plan Change 1, operative in June 2016, is similar to the LWRP rule structure. Under Plan Change 1, farming is a controlled activity if the property is location in certain high nutrient risk locations, or if the property is leaching nitrogen above its baseline leaching rate. Controlled farms are required to produce a Farm Environment Plan, propose Good Management Practices and could involve nutrient reductions.	Environment Canterbury. (2019). Canterbury Land and Water Regional Plan. Retrieved from https://www.ecan.govt.nz/your-region/plans-strategies-and-bylaws/canterbury-land-and-water-regional-plan/Environment Canterbury. (2019). Canterbury Water: What's Your Zone? Retrieved from https://www.canterburywater.farm/zones

Ashburton District	46	3.18%	Canterbury	Performance	Hinds catchment, Canterbury LWRP Plan Change 2, operative in 2018, performance-based policy that requires a reduction in leaching rates for those farm operations with leaching rates above 20kgN per ha per year to reduce by percentages relative to baseline. Schedule 24a in the LWRP (Good Management Practices) required of all farms as well.	Environment Canterbury. (2019). Canterbury Land and Water Regional Plan. Retrieved from https://www.ecan.govt.nz/your-region/plans-strategies-and-bylaws/canterbury-land-and-water-regional-plan/ Environment Canterbury. (2019). Canterbury Water: What's Your Zone? Retrieved from https://www.canterburywater.farm/zones
New Plymouth District	31	2.54%	Taranaki	Practice	Taranaki Regional Council's Draft Freshwater and Land Management Plan was released in April 2015 is practice-based. It requires fencing and planting on intensively farmed properties (over 20 ha) on ring plain and coastal terraces by 2020.	Taranaki Regional Council. (2015). Draft Freshwater and Land Management Plan for Taranaki (No. Document number 1496392). Retrieved from https://www.trc.govt.nz/assets/Documents/Plans-policies/SoilWaterPlanReview/DraftPlan-April2015W.pdf
Stratford District	21	3.89%				
South Taranaki District	39	2.57%				
Far North District	61	3.21%	Northland	No policy	As of 2015 there were no mandatory water quality policies (as relating to the NPS for Freshwater) drafted, notified or operational in Northland Region.	Greenhalgh, S., & Murphy, L. (2017). Freshwater contaminant limit assessment of the regions. Motu Economic and Public Policy Research. Retrieved from https://motu.nz/our-work/environment-and-resources/agricultural-economics/agricultural-greenhouse-gas-emissions/freshwater-contaminant-limit-assessment-of-the-regions/
Kaipara District	38	3.27%				
Whangarei District	66	4.10%				

Gisborne District	39	3.16%	Gisborne	Practice	Proposed Freshwater Plan, Gisborne Regional Freshwater Plan took effect when the plan was notified on October 10, 2015. Policy encourages the adoption of good management practices and in cases where freshwater objectives are not met, requires the implementation of Good Management Practices.	Gisborne District Council. (2017). Gisborne Regional Freshwater Plan. Retrieved from https://www.gdc.govt.nz/freshwater-plan-proposed/
Kapiti Coast District	17	6.75%	Wellington	No policy	As of 2015 there were no mandatory water quality policies (as relating to the NPS for Freshwater) drafted, notified or operational in Wellington Region.	Greenhalgh, S., & Murphy, L. (2017). Freshwater contaminant limit assessment of the regions. Motu Economic and Public Policy Research. Retrieved from https://motu.nz/our-work/environment-and-resources/agricultural-economics/agricultural-greenhouse-gas-emissions/freshwater-contaminant-limit-assessment-of-the-regions/
Porirua City	2	2.78%				
Upper Hutt City	7	5.98%				
Hutt City	0	0.00%				
Wellington City	5	8.77%				
Masterton District	27	4.13%				
Carterton District	14	3.99%				
South Wairarapa District	13	2.91%				
Marlborough District	51	3.00%	Marlborough	No policy	As of 2015 there were no mandatory water quality policies (as relating to the NPS for Freshwater) drafted, notified or operational in Marborough District.	Greenhalgh, S., & Murphy, L. (2017). Freshwater contaminant limit assessment of the regions. Motu Economic and Public Policy Research. Retrieved from https://motu.nz/our-work/environment-and-resources/agricultural-economics/agricultural-greenhouse-gas-emissions/freshwater-contaminant-limit-assessment-of-the-regions/

Nelson City	6	6.45%	Nelson	No policy	As of 2015 there were no mandatory water quality policies (as relating to the NPS for Freshwater) drafted, notified or operational in Nelson City.	Greenhalgh, S., & Murphy, L. (2017). Freshwater contaminant limit assessment of the regions. Motu Economic and Public Policy Research. Retrieved from https://motu.nz/our-work/environment-and-resources/agricultural-economics/agricultural-greenhouse-gas-emissions/freshwater-contaminant-limit-assessment-of-the-regions/
Tasman District	65	4.09%	Tasman	No policy	As of 2015 there were no mandatory water quality policies (as relating to the NPS for Freshwater) drafted, notified or operational in Tasman District.	Greenhalgh, S., & Murphy, L. (2017). Freshwater contaminant limit assessment of the regions. Motu Economic and Public Policy Research. Retrieved from https://motu.nz/our-work/environment-and-resources/agricultural-economics/agricultural-greenhouse-gas-emissions/freshwater-contaminant-limit-assessment-of-the-regions/
Gore District	21	3.66%	Southland	No policy	As of 2015 there were no mandatory water quality policies (as relating to the NPS for Freshwater) drafted, notified or operational in Southland Region.	Greenhalgh, S., & Murphy, L. (2017). Freshwater contaminant limit assessment of the regions. Motu Economic and Public Policy Research. Retrieved from https://motu.nz/our-work/environment-and-resources/agricultural-economics/agricultural-greenhouse-gas-emissions/freshwater-contaminant-limit-assessment-of-the-regions/
Southland District/Stewart Island	94	3.27%				
Invercargill City	6	2.35%				

Auckland City	91	2.61%	Auckland	No policy	As of 2015 there were no mandatory water quality policies (as relating to the NPS for Freshwater) drafted, notified or operational in Auckland Region.	Greenhalgh, S., & Murphy, L. (2017). Freshwater contaminant limit assessment of the regions. Motu Economic and Public Policy Research. Retrieved from https://motu.nz/our-work/environment-and-resources/agricultural-economics/agricultural-greenhouse-gas-emissions/freshwater-contaminant-limit-assessment-of-the-regions/

Table 5-2. Theory of Planned Behavior related survey questions (plus moral norm related question – environmental stewardship)

Construct	Scale	Type	Question type on survey	Aggregation type	Questions
perceived behavioral control	0-3	Ordinal (run as categorical)	List of 10 yes/no questions of which respondent could check up to 3 factors. Perceived behavioral control includes 6 of the 10 questions, the other 4 did not related to perceived behavioral control.	Simple count variable of sum the total number of checked factors out of the 6. More factors (max 3) is considered high perceived behavioral control (score of 3).	What factors led you to implement a nutrient management plan on your farm? [Tick up to 3] 1) I saw nutrient management plans successfully demonstrated on similar farms 2) Trialing a nutrient management plan on my farm was simple 3) Nutrient management plans are reversible if I change my mind 4) I had the necessary skills/knowledge to do this 5) I had good sources of advice about how to do this 6) I had the financial resources necessary to do this
perceived behavioral control_no	0-3	Ordinal (run as categorical)	Binary list of 10 questions of which respondent could check up to 3 factors. Perceived behavioral control_no includes 6 of the 10 questions, the other 4 did not related to perceived behavioral control.	Simple count variable of sum the total number of checked factors out of the 6. More factors (max 3) is considered low perceived behavioral control (note – this is the reverse of perceived behavioral control above).	What are the main reasons you have not implemented a nutrient management plan on your farm? [Tick up to 3] 1) I haven't seen nutrient management plans successfully demonstrated on similar farms 2) Trialing a nutrient management plan on my farm is not simple 3) Nutrient management plans are not reversible if I change my mind 4) I don't have the necessary skills/knowledge to do this 5) I don't have good sources of advice about how to do this 6) I don't have the financial resources necessary to do this

Subjective norms	0-30	Continuous	3 questions, each consist of 10 point Likert scale from "Strongly disagree to strongly agree"	Score for each question was added to produce aggregate norms score	To what extent do you agree with each of the following statements? 1) My family expects me to manage my farm in an environmentally friendly way. 2) The farming community expects me to manage my farm in an environmentally friendly way. 3) The New Zealand public expects me to manage my farm in an environmentally friendly way.
Attitude	3-9	Continuous	3 questions, each consist of 3 point scale from "Lower/worse" to "Higher/better"	Score for each question was added to produce aggregate norms score	To the best of your knowledge, how has/would implementing a nutrient management plan affect(ed) your farm? 1) Financial performance 2) Environmental performance 3) Farming lifestyle
Stewardship	0/1	Binary	List of 10 yes/no questions of which respondent could check up to 3 factors. Stewardship is one of the binaries.	Binary	What factors led you to implement a nutrient management plan on your farm? [Tick up to 3] ▪ Environmental stewardship
Stewardship_no	0/1	Binary	List of 10 yes/no questions of which respondent could check up to 3 factors. Stewardship_no is one of the binaries.	Binary	What are the main reasons you have not implemented a nutrient management plan on your farm? [Tick up to 3] ▪ Few environmental benefits

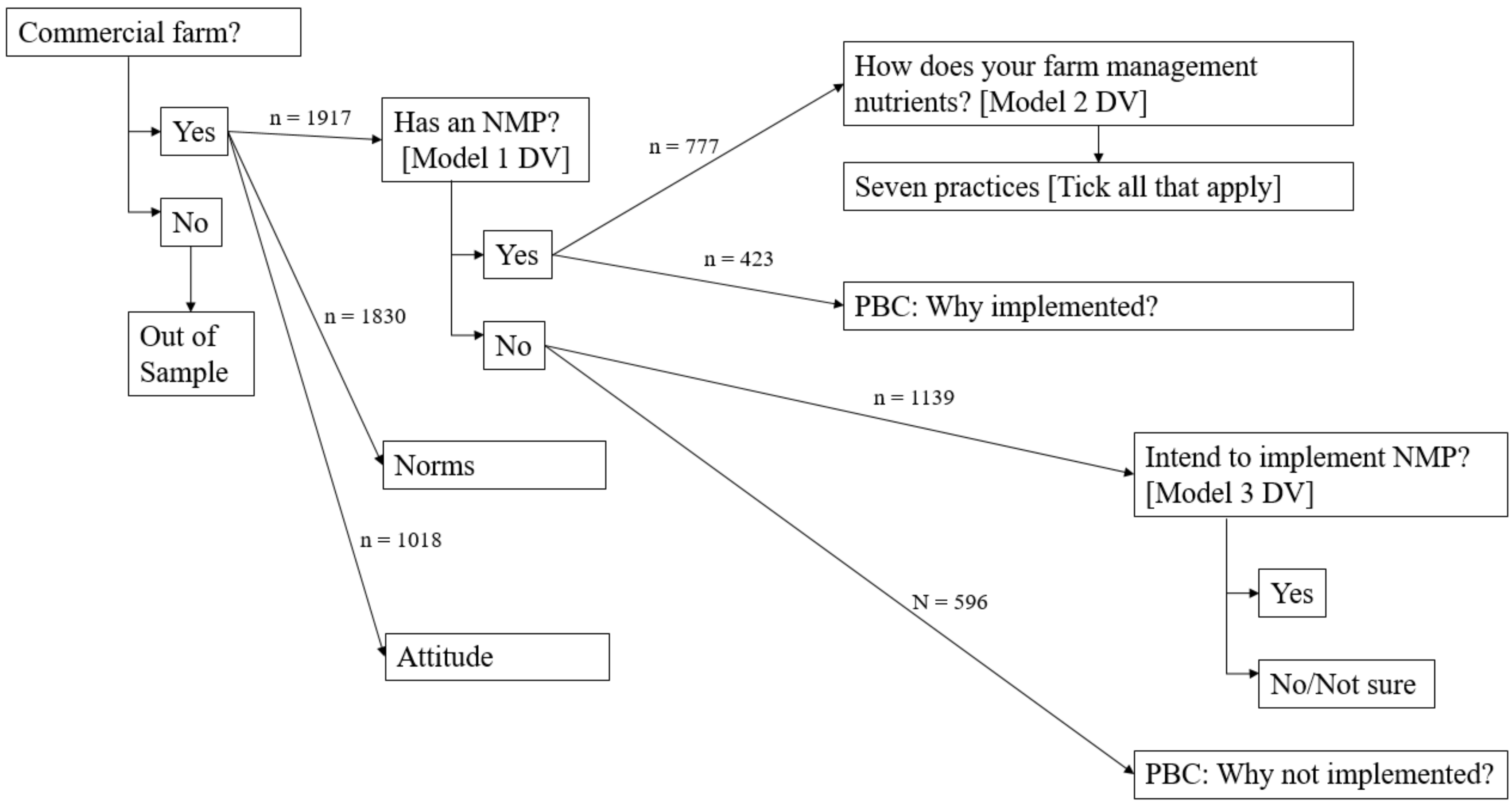

Figure 5-1. Logic of survey structure, featuring sample size (N=) associated with each question

Table 5-3. Farmer sample descriptive statistics broken down by policy type

	No policy (n = 1048)		Practice (n = 286)		Performance (n = 583)	
Continuous variables	mean	sd	mean	sd	mean	sd
farm size (thousand hectares)	0.23	0.43	0.34	0.65	0.65	2.1
age	56.94	11.52	57.52	11.38	55.14	11.74
attitude (n = 1018)	6.57	1.33	6.35	1.17	6.17	1.28
norms (n = 1830)	21.34	4.78	21.13	4.4	21.38	5
nmp_adopt_extent (n = 773)	2.64	1.35	2.41	1.16	2.77	1.41
Categorical variables	count	%	count	%	count	%
NMP (yes)	448	42.75	112	39.16	217	37.22
NMP intention to adopt (yes, n = 1139)	102	17	25	14.37	118	32.33
profitable (yes)	489	46.66	134	46.85	312	53.52
farm type						
farm type: other	279	26.62	47	16.43	131	22.47
farm type: dairy	265	25.29	70	24.48	90	15.44
farm type: sheep & beef	445	42.46	155	54.2	320	54.89
farm type: grazing support	59	5.63	14	4.9	42	7.2
education						
education: secondary school or less	367	35.02	112	39.16	221	37.91
education: certificate/diploma	296	28.24	79	27.62	169	28.99
education: bachelor's degree	202	19.27	53	18.53	112	19.21
education: advanced degree	168	16.03	42	14.69	77	13.21
education: other	15	1.43	0	0	4	0.69
N (nmp extent adoption model only)	*242*	*57.21*	*59*	*13.95*	*122*	*28.84*
0. perceived behavioral control	68	28.1	21	35.59	39	31.97
1. perceived behavioral control	90	37.19	22	37.29	51	41.8
2. perceived behavioral control	68	28.1	11	18.64	27	22.13
3. perceived behavioral control	16	6.61	5	8.47	5	4.1
stewardship (yes)	122	50.41	26	44.07	72	59.02
n (nmp intention model only)	*303*	*50.84*	*85*	*14.26*	*208*	*34.90*
0. perceived behavioral control_no	126	41.58	33	38.82	80	38.46
1. perceived behavioral control_no	107	35.31	32	37.65	68	32.69
2. perceived behavioral control_no	52	17.16	13	15.29	43	20.67
3. perceived behavioral control_no	18	5.94	7	8.24	17	8.17

stewardship_no (yes)	56	19.31	11	13.41	29	14.87

Table 5-4. NMP adoption model

Predictor	Odds Ratio (SE)
policy type (base = no policy)	
practice	0.91
	(0.16)
performance	1.03
	(0.14)
farm size	1.01
	(0.04)
farm type (base = other farm type)	
dairy	9.03***
	(1.58)
sheep and beef	0.50***
	(0.07)
grazing support	0.52**
	(0.13)
age	0.99
	(0.00)
profitable	1.35**
	(0.15)
education (base = secondary school or less)	
education: certificate/diploma	0.86
	(0.12)
education: bachelor's	0.92
	(0.14)
education: advanced degree	0.91
	(0.15)
education: other	0.51
	(0.32)
constant (not odds ratio)	-0.24
	(0.33)
District constant (not odds ratio)	0.02
	(0.03)
N	1917
chi2	350.7
p	0.00

Standard errors in parentheses
Note: * p<0.05 ** p<0.01 *** p<0.001

Table 5-5. Extent of NMP adoption models

Predictor	Full model Beta (SE)	No policy group Beta (SE)	Practice Group Beta (SE)	Performance Group Beta (SE)
policy type (base = no policy)				
practice	-0.19 (0.11)			
performance	0.06 (0.07)			
perceived behavioral control (base = score of 0)				
1.perceived behavioral control	0.11 (0.08)	0.18 (0.11)	0.02 (0.29)	0.05 (0.14)
2.perceived behavioral control	0.21* (0.09)	0.16 (0.12)	0.19 (0.30)	0.33* (0.16)
3.perceived behavioral control	0.31* (0.15)	0.44* (0.18)	-0.55 (0.57)	0.42 (0.35)
attitude	0.00 (0.03)	0.04 (0.04)	0.04 (0.11)	-0.06 (0.05)
norms	0.01 (0.01)	0.01 (0.01)	0.02 (0.03)	0.01 (0.02)
stewardship	0.21** (0.07)	0.22* (0.09)	0.10 (0.23)	0.26 (0.14)
farm size	0.06* (0.03)	0.17* (0.08)	0.04 (0.19)	0.05 (0.03)
farm type (base = other farm type)				
dairy	0.48*** (0.08)	0.47*** (0.10)	0.68* (0.31)	0.28 (0.17)
sheep and beef	0.14 (0.09)	0.218 (0.13)	0.11 (0.39)	-0.08 (0.17)
grazing support	0.24 (0.17)	0.42 (0.24)	0.29 (0.51)	-0.19 (0.29)
age	-0.00 (0.00)	-0.00 (0.00)	0.01 (0.01)	-0.00 (0.01)
profitability	0.06 (0.06)	0.04 (0.09)	-0.04 (0.24)	0.11 (0.12)
education (base = secondary school or less)				
education: certificate/diploma	-0.02 (0.08)	-0.12 (0.12)	0.11 (0.30)	0.08 (0.14)
education: bachelor's	-0.05 (0.09)	-0.13 (0.12)	0.21 (0.31)	-0.03 (0.16)
education: advanced degree	0.05 (0.09)	0.07 (0.11)	0.20 (0.31)	-0.25 (0.23)

education: other	-0.32 (0.36)	-0.15 (0.37)		-15.79 (1875.80)
constant	0.37 (0.31)	0.13 (0.41)	-0.89 (1.18)	0.92 (0.55)
TA constant	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
N	401	230	52	119
chi2	78.68	52.24	11.24	27.08
p	0.00	0.00	0.735	0.04

Standard errors in parentheses
Note: * p<0.05 ** p<0.01 *** p<0.001

Table 5-6. Intention to adopt NMP models

	Full model	No policy group	Practice Group	Performance Group
Predictor	Odds Ratio (SE)	Odds Ratio (SE)	Odds Ratio (SE)	Odds Ratio (SE)
policy type (base = no policy)				
practice	0.91			
	(0.37)			
performance	3.96***			
	(1.07)			
perceived behavioral control_no (base = score of 0)				
1.perceived behavioral control_no	1.53	1.12	4.80	1.84
	(0.44)	(0.56)	(6.45)	(0.75)
2.perceived behavioral control_no	1.37	1.00	0.25	1.74
	(0.45)	(0.59)	(0.42)	(0.82)
3.perceived behavioral control_no	1.25	0.92	0.30	1.35
	(0.62)	(0.87)	(0.68)	(0.92)
attitude	1.56***	1.98**	2.02	1.35*
	(0.16)	(0.41)	(0.89)	(0.20)
norms	1.08**	1.14*	1.06	1.06
	(0.03)	(0.06)	(0.15)	(0.04)
stewardship_no	0.98	1.09	0.34	0.78
	(0.33)	(0.60)	(0.50)	(0.41)
farm size	1.00	2.37	114.50**	1.00
	(0.06)	(1.71)	(196.90)	(0.06)
farm type (base = other farm type)				
dairy	2.89	3.62	0.22	4.20

	(1.85)	(3.63)	(0.45)	(5.47)
sheep and beef	2.21**	5.23*	0.01*	1.76
	(0.66)	(3.36)	(0.02)	(0.72)
grazing support	3.04*	2.16	0.20	4.40*
	(1.42)	(2.14)	(0.50)	(2.88)
age	0.97**	0.97	0.90*	0.98
	(0.01)	(0.02)	(0.04)	(0.01)
profitability	1.31	1.22	1.20	1.47
	(0.31)	(0.52)	(1.24)	(0.51)
education (base = secondary school or less)				
education: certificate/diploma	1.71	2.12	0.19	1.59
	(0.52)	(1.25)	(0.27)	(0.65)
education: bachelor's	2.19*	3.02	0.65	2.14
	(0.77)	(1.89)	(0.93)	(1.16)
education: advanced degree	1.25	0.53	0.22	2.03
	(0.50)	(0.50)	(0.42)	(1.08)
education: other	3.10			8.41
	(3.67)			(12.75)
constant (not odds ratio)	-5.70***	-9.23***	-0.21	-3.89*
	(1.21)	(2.62)	(3.68)	(1.67)
District constant (not odds ratio)	0.03	0.27	0.00	0.00
	(0.15)	(0.53)	(0.00)	(0.00)
N	536	271	76	186
chi2	70.27	31.87	11.90	17.51
p	0.00	0.01	0.69	0.35

Standard errors in parentheses

Note: * p<0.05 ** p<0.01 *** p<0.001

APPENDIX 2

Table 5-7. Interview protocol question for farmers

Interview protocol questions
How long have you or your family been farming in the watershed?
Could you tell me a bit about your farm system?
Can you run me through what a week on your farm looks like?
In the last 5-10 years, have you made any changes to your farm system or the management of your farm business? What was the driver for these changes?
What are the costs of these changes? Benefits?
Are you planning to make any changes to your farm system in the next 2 years?
Can you tell me a little about your experience with the water quality policy process?
Has the capping of nutrients changed the face of the watershed?
How fair do you think the policy is/was?
Would you have done anything different to manage water quality in the lake?

Table 5-8. Full codebook with descriptions and representative quotes

Nodes	Description	Example Quote
drivers		
Actor		
A_economics	funding, debt, efficiency, other sources of income, dependence on farm	*"I think, ultimately, its profitability. The most decisions we've made are on profitability. And so, the smaller, environmental changes – well, there's benefits as well. So, applying nutrients on lower rates more often, if we don't waste the nutrients, it makes more sense. So, most of those changes, we hope, eventually, help profitability as well."*
A_ethic	stewardship or land ethic, love of learning, aesthetic, price of being a "good farmer"	*"And we did a lot of those things because we were under a lot of pressure. But that's not the whole story. We are an environmental organization. So, it's sort of part of our mission to be good. So, it wasn't like we didn't want to do them. It's what we're supposed to do."*
A_flexibility	convenience, steady supply, lifestyle, flexibility in running the farm system	*"Yeah it was about giving us more flexibility in our system, and to help try and drought proof, yeah to - for the lake issue was, it was about being capped, effectively capped. That is a way of still being able to improve and maximize. But it also gave us another block of land that is*

		separate if we ever wanted to sell something or anything like that."
A_leadership or entrepreneur	Actor themselves represented leadership and entrepreneurial spirit to drive change, or actor received advice or followed path of leader or entrepreneur. For personal, the actor should mention something about trying something new, being on the cutting edge, taking a risk, taking leadership or being an entrepreneur. For receiving advice, the actor should mention a figure or figures that influenced their change.	*"Two and a half years ago we made the decision that we were sick of dealing with dairy farmers, and that we were really really keen to support [a new business initiative led by local farmers]. So we went and saw them to see what they needed and how it would work."*
A_lifestyle	this includes ease of management	*"So really I make the decision based on what I want to do, what I think is going to be more profitable, what suits the way I farm as well and my lifestyle."*
A_past experience	past experience with policy/state/regional government	*"So the decision had been made by then that they were going to benchmark and that we knew. So I knew how the farming system was going to work [because of experience with the policy process and previously owning land in the catchment]. I probably knew it better than anybody, I'd say. So that's why I was more comfortable in getting back in."*

A_social attributes	family life, succession	*"Well, I had a son and daughter both milking cows for someone else and then would come home and crutch lambs. So, I was left in the muck and getting no time off because there's only one main unit. And so, we thought if we could buy the dairy unit, we'd employ more staff and hopefully be able to get on the roster and get some time off."* *"No incentive and stuff, but the other thing with the lake is it's the taonga for the Maori. So it's their treasure. They were very keen to protect it anyway, and they'd made decisions around the lake to protect it way before Environment Waikato started."*
A_technology	availability of specific technology	*"We've modeled land use change [to make a farm diversification plan]."*
Governance		
G_gov assistance	technical or financial assistance from a government agency	*"The guy I've been working with through NRCS, he keeps me pretty informed. I'm pretty good friends with him, so he keeps me quite informed on everything and we go over stuff. I had a couple spots that I had to change things but other than that we've been pretty – we pretty much knew what was going on."*
G_ngos or other	Interactions with non-governmental entities, these include organic, extension, watershed programs, land trusts, housing and conservation board, industry group requirements or best practices, and research organizations/universities	*"As far as the rules for organic are so strict that these new laws on the water quality and watershed, we've already been having to follow since we went organic. The stream setbacks and all that are already in there for organic."*
G_other gov policies	Central, regional or local government policies that impact nutrient management, such as conservation policies	*"Well, we were up for resource consent, so it was – as far as the effluent upgrade, it helped us get a longer resource consent, and it kept us compliant."*
G_farmer group	participation in a group representing farmer interests	*"I probably got a little bit involved in [the farmer group] as to see how [the policy] was going to work more for my own selfish reasons because most of the farms around here are managed by farm managers, and I thought well if it's going to turn to shit I'd really want to be the first one*

		to get out but if I could see some opportunities I wanted to stay"
G_water quality policy	cap, state, regional policy	*"And the interesting thing was that when they brought the new rules into the catchment, the big businesses that owned those farms, sold the farms in the catchment straight away."* *"Some fields flood. Some of my land, I'm on the early spreading ban. Do with the new [water quality policy]. I got to hit them in the midsummer, so we're changing the way we got to do things, a little bit. We'll see in a few years. Hopefully, it'll benefit."*
Resource_system		
RS_ecological	erosion, runoff, endowment, improve ecosystem, nutrients, drought, flooding	*"I bought a manure truck, so I had to do it myself, now... Well, doing it myself, I'll do it more times per year, less each time, and try to minimalize runoff and get on when the land needs it. When the land can use it."*
RS_farm production	animal needs, increase/decrease, quality of product, pasture integrity	*"Originally the country that went into pines was the lower producing areas, but the nitrogen is sort of considered to be across the whole farm. So by taking out the lower producing areas it meant we could farm the better areas a little bit more intensively which gave us options, but then they sold more nitrogen and now we don't have a lot of options."*
Resource_units		
RU_n p attributes	attributes of N & P and the movement of these nutrients in the landscape and farm system	*"I'm doing it as a cover crop and I'm gonna crop it. I'm gonna do it as a forage so we're gonna chop it. We're gonna try it because the soil will pull up a lot of phosphorus out of the soil. Really, every time you plow and see the field, you're releasing that phosphorus that's bound because phosphorus doesn't move in the soil. "*
Social economic and political settings		

S_industry or consultant		*"So, we actually did a feasibility study. We got consultants to do a feasibility study, put the whole thing together, talked to the accountant, and then went to the bank and the regional council on the condition that – the last condition for doing it for buying the farm was that the pond was that we got the consent for the whole thing."*
S_ c market	Carbon Market as a driver	*"[Did you get carbon credits on that?] On the pines that they planted yes... So when [the farm] sold the nitrogen, Mighty River Power generate energy out of the lake. They've got the dams in the river. So they put a deal that they wanted carbon so they tied the two together."*
S_demographic shifts	For example, people going out of farming without a successor	*"I was renting these places – I had my milkers – and, I was renting places for my heifers. And, I had my heifers over at this farm, over here. This [neighbor 1] – that I told you he only milked 35 cows – he had sold his cows; he had retired from farming. And, I had my heifers way over at [neighbor 2's], at a different farm. And, [neighbor 2] came to me, and said, "Do you want to rent my pastures?" And so, I rented them, and it was a lot of fence, because it was a hexagon, so it was a big area."*
S_economics and markets	competition, profit, efficiency, prices broader than the watershed dynamic, carbon credit opportunities	*"The main reason why we came back in and bought here was location. Secondly, different land use in the future. And thirdly, land prices. Land prices had dropped by thirty or forty percent, so it made it economic to get back in again."*
S_n market	Nitrogen market as a driver	*"We planted about 40 hectares of pine trees, production pines, but no, the size didn't change at all. And that was partly because we'd sold some nitrate credits, once we got our cap sorted out, we had plenty so we sold it down."*
S_social context	Neighbor complaints	*"I tell my friend, I said "Farming is a hostile environment right now. It's hostile." I mean, the environment that we're in is hostile. Not only do we have pressure from regulators, we have regulations, we have pressure from intolerance from the community."*

outcomes		
Individual Outcomes		
IO_negative economic		
IO_Neg_compliance	compliance costs related to policy	*"But it's just got to the point where I might actually have to get a little bit more involved with it, because they just sent me a monitoring bill that was huge and I've just wrote a letter to them and said that I'm not going to pay that because that's 153 percent increase on last year's bill."*
IO_Neg_farm viability	Reduction in ability for farm to remain solvent and profitable, survive as a business	*"Well, just for the very reason – if you can't grow your business then you can't survive. So, we had to shift. So, we decided we would reduce our operation in the catchment, and increase our operation outside of the catchment."*
IO_Neg_financial	Reduction in profit, payoff, funding, reduced earnings, compliance, property value, new revenue streams including new products, new markets, diversification	*"Well, there are direct financial costs and there are also social costs, I think. The direct cost to you is these physical costs like building detainment berms and putting effluent ponds and buying upgraded irrigators and things like that."*
IO_Neg_flexibility	Loss of flexibility in farm management	*"And before the rules, you could do whatever you wanted to do. Now, you can probably make changes as long as you stay within the rules. So, I suppose, yes. We started cropping in the summer to develop those pellets to improve the quality of grass. And that's not going to happen. So, that hasn't changed in a way. Although, I don't know think we expected to do it for long anyway, did we? It's just an option that we don't have anymore."*
IO_negative social		
IO_Neg_distrust in regulation	Frustration or distrust with regulation or agency implementing the regulation, or in the monitoring (Overseer)	*"Oh, I just don't contact [the Regional Council]. Because I don't have enough respect or trust in them to be able to do that."*

IO_Neg_fairness	Perceived that situation is unfair in individual position	*"We planted trees on steep land to stop erosion. And we did flood control work. And I can show you that on the photos that I've got. And those things all worked really well, but the annoying thing is that now that doesn't count towards what we're doing. So, what we've done is, we've harvested the trees, and we haven't replanted. Because we need to have more grass to try and keep our cow numbers up. It's stupid. It's stupid that they're not recognizing environmental benefits that were done in the '90s and the '80s."*
IO_Neg_non-financial costs	time, depression, involvement with community	*"It was tough, man it was tough. Because we were all farming. We used to joke and say man this would be great if this was your day job. Because A) you are on a salary, B) You are really interested, C) you haven't got any skin in the game, and it's just really interesting stuff. But we were all trying to hold down, I had two little babies, trying to hold down farms, and businesses, and represent people and communicate and try and forge our way through this process, it was incredibly hard."*
IO_Neg_uncertainty in future	Uncertainty in the future of the farm system and what will be possible	*"Well, we won't have a business. Because they're looking for a 30 percent reduction. So, instead of having 230 cows, we'll have 160 cows. That just won't work. Just like if you're salary got cut by a third, it would certainly change your perspective as well."*
IO_neutral economic		
IO_Neu_compliance	Compliance with policy is a negligible cost	*"So, you know I mean the RAPs I mean definitely yes we've had to make some adaptations to our management here and all, but they haven't really impacted us detrimentally. It hasn't been a big burden or impact on us as a farm."*
IO_positive ecological		
IO_Pos_environmental quality	specific resource not specified	*"No. No benefits. Apart from environmental benefits, that's about it. Certainly no financial benefits."*
IO_Pos_soil quality	improvements in individual's soil and pasture quality	*"And all that where the brook is, it's not mud now, its grass. And going over the years, it's not just grass, it's nice grass – nice, and lush grass; and, I only pasture it, maybe, three or four times a year."*

IO_Pos_water quality	improvements in water quality at the farm-scale level, or due to farm-scale level behaviors	*"So, I think we must – so, if water quality is improving in [the] Bay… Something is happening. Some of these practices are – and I don't know whether that has to do with it or not. I just think we've done so much – that it's useful. It's proven that it works."*
IO_positive economic		*"Yeah, so that's what I'm trying to say. If I'd kept running a similar number of stock my nitrogen output would have dropped but the policy changes allowed me to improve the farm's productivity without breaching my nitrogen cap."*
IO_Pos_farm viability	improvements in ability for farm to remain solvent and profitable, survive as a business	*"Well, the NMP plan is a chance to save money, there, because we know for over fertilizing. With the first one we did, the comprehensive one, we found out that we were putting almost double manure on the grassland than we should've been. You can put too much. It's all there is to it. You put too much. That's a good thing to save money, if you can."*
IO_Pos_financial	Improvement in profit, payoff, funding, increased earnings, compliance, property value, new revenue streams including new products, new markets, diversification	*"Yeah there were benefits. For people like me that had very, very high NDAs, to have sold a few off the top. Like I sold down to a reasonable level and that would have been good if we hadn't lost the extra 1300. So there were benefits in yeah any very, very high NDA farms - could get part of their capital out. It was like selling part of your farm, but actually not losing the farm."*
IO_Pos_flexibility	Improvement in flexibility in farm management	*"Pretty much, like we sold down the cattle and replaced those cows with trading stock and they were winter grazers, so it didn't really alter the figure too much, it just gave us more management flexibility."*
IO_Pos_new markets	Accessing new markets, marketing, pricing, supply chain changes	*"We're certainly producing the product, but we haven't had a decent product to sell, which has been the biggest issue. We've tried cheese and yoghurts. We have been exporting frozen milk to our cheese maker in Aussie for the last few years. But the last 18 months we've taken on a [new] partner and they're powdering it and take it to China. That's been a pretty amazing leap forward, and it's given us a solid market with reasonable returns."*

IO_positive social		
IO_Pos_awareness	improved understanding of farm system, nutrient dynamics	*"So those sort of things, yeah, you're very aware of - we talk a whole new language now in terms of nitrogen discharge allowance, NDAs and things like that. Yeah and we're conscious of those things. We live in a different world here now."*
IO_Pos_non-financial benefits	new opportunities, involvement with community, sense of pride in work, reduces burden of work	*"Oh, I sleep easier at night. Yeah, to keep compliant with the old pond, I did some stuff that I wasn't very proud of. But he had to do it to stay compliant really. Yeah, so now all that's gone now. Easier management and all that sort of stuff is, yeah."*
IO_Pos_enviro recognition	Received recognition for environmental stewardship/sustainability of farm system	*"Then we won the [environmental award], now is the moment when the dollars profit per KG of nitrogen came together. We've been testing, the [farm system] thing is just a big experiment. We've measured ourselves against other farmers through the [award]."*
watershed outcomes		
WO_negative ecological		
WO_Neg_environmental quality	specific resource not specified	*"Well, we're back again to the nitrogen, phosphorus/biodiversity. Because if you look at what the Regional Council's job is, it's not only nutrients, its biodiversity. It's protecting native bush. Its pests. There are a lot of things. But it's only actually PC 10 hasn't taken into consideration any of those other things that actually the Regional Council is in charge of implementing, or controlling."*
WO_Neg_land use patterns		*"That was all taken out of farm land and they were farming conservatively anyway. They were having no effect on the lake over there at all because they all had sheep. But that's all in trees now."*
WO_Neg_water quality		*"So this trading of nitrogen also creates another problem of what they call hotspots. Some people don't want to know about it but of course it makes a difference. Put it this way; if I put this tea towel on the bench and I get two glasses of water, one I just sprinkle lightly everywhere, it hardly sinks through, the other one I just pour it right here, you're going to find a big puddle here that's going to run over*

		here. In effect this nitrogen cap thing has done exactly that."
WO_negative economic		
WO_Neg_farming viability	Reduction in ability for farming in the watershed to remain solvent and profitable, survive as a business/industry	*"That's just what happens. The – yeah, they're a lot of farms that are – it's kind of a perfect storm situation too, where I think the number of farms is like 750 farms left in the state... Somebody said the other day that they read from the agency that they could see 150 to 200 more farms go out this year. A lot of that's like – milk price, and then regulations at the same time."*
WO_Neg_financial watershed	profit, payoff, funding, reduced earnings, compliance, property value, new revenue streams including new products, new markets, diversification	*"Farmers have made a real stand in this catchment to say, 'We can do this, what's required by 2022, whatever the percentage top is. But what's required after 2032 is not doable. Financially, it's not doable.'"*
WO_negative social		
WO_Neg_well-being	community involvement, depression, community members leaving	*"So, I think – but it's like grievance; this – this phase is the angry phase, and then acceptance might come because that's what happened for us in the Taupo catchment like I say."*
WO_Neg_fairness	perceived fairness of the policy process/policy outcomes	*"When grandparenting was on the table, who was going to miss out? [Maori land], big time. And as owners of the lakebed, and individually owners of the farms, a lot of farms especially down in the Western area, 55% of the landholding, they had a really big series of interests to try and weigh up. And they had voluntarily retired a whole heap of their own land... And so when grandparenting came out, these guys were severely penalized. There is no recognition of those environmental benefits from having already given. So you can*

		understand why they are pretty pissed off."
WO_neutral ecological		
WO_Neu_lack of changes	Not sure whether there is a positive or negative impact on water quality or other environmental indicators at the watershed scale	*"The land use, land use change, in the catchment, has been minor."*
WO_neutral economic		
WO_Neu_economic impact	Perception that policy has had neutral economic impacts	*"But actually, well, I've personally found it pretty easy, it hasn't been too bad at all. Most of the farms down here are large Maori owned blocks, and when I talk to the other managers, they've pretty much found the same thing. There's a couple on lower benchmarks that sort of get a little bit - the farms were probably not as developed, so that's probably limited how much they can develop their farms. But in general, I don't think it has affected things too much."*
WO_neutral social		
WO_Neu_acceptance		*"But, you know, it's something that I've been involved with for 30 years of farming and so it's been a major cost to farms definitely, which everybody seems to have just – just get on with it."*
WO_Neu_well-being		*"Socially, some people who are really unhappy have gone. Which is good they've sold, probably still not happy but they were able to exit. Some of the angst around that was that the trust stood on the market and paid what private valuations, but some of those people still say that wasn't enough."*

WO_Neu_fairness	Policy is both fair and unfair	*"Everybody's got to do their share. Are they picking on us? No, I don't think so. Some people think they are, but I think everyone's gotta do their part. I think there's certainly been room for improvement; I think it runs you know. I only see something no one's – nothing's gonna change."*
WO_positive ecological		
WO_Pos_land use patterns		*"I think there would be a lot more dairy farms [without the policy], particularly on Maori lands down the bottom of the lake, which is just beautiful land. There would have been more development, yep. So, it met its purpose. I think the lake is improving too."*
WO_Pos_management changes		*"I see the bigger farms – a lot of them are doing cover crops where they never did before."*
WO_Pos_water quality		*"So – so, yeah, so, – but we want the lake to get – to get better as well and we – we – we think we're seeing that so there's a – we – we do think there is a balance in things, but – but then the financial imperative sort of seasonal; these are making some good decisions anyway, unfortunately."*
WO_positive economic		
WO_Pos_farming viability		*"And that is one of the best thing that has actually happened in this catchment, is that we have, we can trade effectively. So it doesn't lock someone in forever and gives people flexibility and things like that. A lot of people wouldn't actually realize that or use that or whatever, but that is huge flexibility. You've got to have that flexibility if you want to go ahead."*

WO_Pos_financial	profit, payoff, funding, reduced earnings, compliance, property value, new revenue streams including new products, new markets, diversification	*"So for the Maori incorporations the benefits were huge. They could take capital out of land but they can't sell it. So Maori land can't be sold. So if it was me, I owned this land and I couldn't sell it and someone was going to give me a whole lot of money for that land and I owned it, I'd have planted the whole thing in trees...So it allowed them to release capital out of their land holdings, retain their land because they can't sell it and then they've taken that money out and my incorporation have treated it as capital."*
WO_positive social		
WO_Pos_awareness	awareness of water quality, farm dynamics and environmental footprint	*"Well, farmers have become aware of the environmental impacts that farming has on the waterways and the lakes."*
WO_Pos_well-being	community involvement, depression, community members leaving	*"So, yeah. Actually, I think that probably the biggest plus out of it is actually talking to your neighbor, and working with your neighbor, and seeing what they're doing."*
WO_Pos_fairness	perceived fairness of the policy process/policy outcomes	*"Yes, I do, absolutely. I think we have a workable proposition, a workable nitrogen constraint."*
Recent nutrient management behavior		
Management change		
M_change breed	Change in animal stock, part of the physical stock of the farm, not something that can be changed on a day to day management basis.	*"Basically, change the breed really. As I say, they were very high maintenance. We had dry seasons and the following year they didn't perform very well. So we got a hardier, bit more robust sheep on board, but they don't produce quite as much, but they cost - the cost of running them has dropped as well, so - and that was to fit with putting milking on it, sort of changed the dynamics of the farm, so just that fit with the whole system."*
M_reduced fertilizer	changes in the application of fertilizer timing and/or amount, including manure	*"Just, I suppose, I have changed from putting the fertilizer on in the autumn to putting it on in the spring. Or late spring, probably, more than early spring. Due to, probably, a bigger loss would occur in the autumn."*

M_grazing off	Began or changed grazing off of livestock, or wintering off, including dairy support	*"What we've done instead of winter cropping and wintering on the farm, we've taken more animals off the farm during the winter. It also helped that the grasses that were growing now provide feed over a wider part of the season. But it's both continual productivity improvements that has come to help in the situation."*
M_increased fertilizer	increase in the application of fertilizer	*"And then, in the last few years, we've found that we haven't really had enough manure on the closer fields, and it costs a lot more to get it to the further fields, so the last few years, we've been putting more commercial fertilizer on the further fields, and sometimes no manure, and putting more of that manure on the grass ground during the summer and definitely putting more – or, enough – on the corn ground that's close by."*
M_increased stocking rate		*"Yeah, chicken as well, so it's kind of a quick background. I guess I'd say also we've grown the flock a little bit –"*
M_pursue knowledge	Actively pursue knowledge to better understand nutrient dynamics (engage in research)	*"We've actively pursued knowledge by engaging in research trials."*
M_manure spreading	Changes in the application of manure timing, amount or pattern, also changes in location of manure stacking	*"I bought a manure truck, so I had to do it myself, now. I'm gonna do – rather than hiring somebody to come in and mainly want the pit empty, so just put it on as heavy as they can put it on because they're only coming in once or twice a year. Well, doing it myself, I'll do it more times per year, less each time, and try to minimalize runoff and get on when the land needs it. When the land can use it. That way, absorption is better and I'd like to hit it as soon after cropping and pray for doing it the day before a rain, that way it gets incorporated in."*
M_notill	Switch to no-till	*"Then, as for fields, the last few years we've been – we've been kind of experimenting with no till for about 20 years, and probably six or seven years ago we went halfway no till and four years we got to 100 percent no till –"*

M_nutrient management plan	Began or revised a nutrient management plan or overseer plan	*"That was my first effort at writing my NMP, yeah. We had a different contractor doing it for us initially the first year or two. Even back then, we were already at $4,500.00, $5,000.00 then and we didn't have the land base that we have now."*
M_reduce feed inputs	Changes in purchased feed or other inputs (non-fertilizer)	*"Yeah we also bring in palm kernel at this stage. Yeah we have cut down - well we're trying to do at the moment because it is not worth losing money on using it. "*
M_seeding or cropping	Began, changed or stopped seeding varieties or cropping patterns	*"Yeah, yeah. We're gonna seed more, now. We always like our corn but we used to plant 300 acres and now we're down to 180."*
M_soil sampling	Began or changed soil sampling	*"Talking with USDA, I'm trying to reseed to improve my pastures and so I'll be doing some soil testing. I didn't do that when I went to the [nutrient management class], but I will now just so that I better understand."*
M_stocking rate	Changed number of animal units	*"No, there's no reduction in – well, actually it did come with a reduction in stocking rate as well. I think I've mentioned that we reduced from about 3.4 down to 2.9."*
Structural change		
St_barn	Change or construct barns	*"Then we're actually building a barn to bring these animals home because that contract grade is – they're doing a nice job raising them, but that's – we can more than pay for a barn."*
St_biodigester		*"[Q: When did you guys put in the biodigester?] 2008... Yup. It was something we decided to do."*
St_ buffers	Change or construct buffers or setbacks on rivers, streams or ditches	*"right, yeah, and some ditches and with buffers I think was the last project we did a while back was maybe 30 feet and then they came and planted trees and they help even compensate us a small amount for the land that we lost because our fields did go right down to those areas."*

St_detainment bunds	Change or build detainment berms to control flow of water, slow flow of water and runoff of nutrients	*"Obviously where we pug ground up is another issue, we are always conscious of that, but we've also put in a lot of detainment berms, if you can imagine this farm is elevated it's got quite a big catchment and all the water eventually is coming down into the lake. It's going to get there one way or the other. These detainment berms, so far we have done about seven with the regional Council to reduce or to mitigate the flow of water that comes through, especially when we have these big downpours."*
St_equipment	Purchase or change farming equipment	*"We have adopted the best management practice advice in terms of effluent and disposal. We put in a new storage system. A rubber-lined storage system. It – to have best practice for effluent and disposal. We brought new land application irrigators to meet the application requirement."*
St_fencing	Change or construct fences	*"We had to fence up the swamps because there are some wetlands on the backside of a couple of our fields that we had to fence out. Water quality. Like I said, it all makes sense. It makes you more money in the long run. Cows aren't gonna make milk standing in the mud."*
St_leachate system		*"The biggest problem I have is we have to put a leachate system in. Ugh. It's an $81,000.00 project, which I don't think is even needed because our bunker are – well, they're 100 feet from the brook and they're 50 feet from the road."*
St_manure pit or pad	Change or construct manure pit	*"By getting manure on the land – we put in a manure pit – by getting the manure on the land, we went – our tonnage of feed multiplied by four times in two years, per acre. It's huge. That's all money in your pocket because you're not purchasing that extra feed."*
St_milking parlor	change or construct milking parlor	*"We've been going about eight or nine years. Eight years, yeah. It didn't actually take that long, built a shed, a purpose built milking shed and pretty much within 12 months we were producing milk."*

St_stand-off pad	Change or construct stand-off pad	*"We still have no – on our own, we put in a cement pad to feed the cows on. We're still dealing with – we kind of get a nice bedded pack built that's dry, and then we get six inches of snow on top of it –"*
St_tree planting	Plant trees to restore banks or native bush (not pine plantation - that is a system change)	*"Apart from fencing off gullies and planting them in natives, rather than productions trees, that's about it."*
St_water flow control structures	add or change culvert, put in drains to divert water	*"Some of our diversion water goes through a culvert underneath this pushway. I didn't wanna pour concrete there, so what I did is I added onto the culvert on both sides and just built it up, so now the dirt is much higher than our concrete pushway, and when she came back, she said that was fine."*
System change		
Sy_purchase or lease land	Purchase new land for agriculture within the policy region	*"Well, we just barely purchased some more land. We're up to 280 acres. We rent another 100 acres of crop land."*
Sy_put land in production		*"Then there was a white pine stand that we wanted to cut and reclaim for pasture and we wanted to clear all that junk wood, and then we wanted to drastically thin out the hemlock out of the sugar bush..."Yep, he gave me approval." I said "Can we start?" "Yeah, go ahead. Get started." We start. Clear cut 20 acres here, and clear cut a bunch here, and do a bunch of work, and we only did, probably 25 percent of what we wanted to do –"*
Sy_sale or lease of land	Sale of agricultural land	*"So we decided after a lot of soul-searching that we would sell."*
Sy_switch to higher intensity	Transition to or from dairy, sheep, beef, vegetable, other, pine plantation, dairy support. Note that many farms can be multiple different farm systems at once, and may take up additional system types, for example a dairy may retire some land and plant a pine plantation. Switch from breeding operation to purchasing stock included as well, or reverse, switch from purchasing to breeding	*"Well, one would be put the sheep milking unit on...So basically, we've put that on and it has changed the dynamics a little bit. And then we've sort of intensified that area, the sheep milking area, quite a bit. Mainly with the sheep, but it hasn't changed our nutrient output a hell of a lot, I don't think."*

Sy_switch to lower intensity	Transition to or from dairy, sheep, beef, vegetable, other, pine plantation, dairy support. Note that many farms can be multiple different farm systems at once, and may take up additional system types, for example a dairy may retire some land and plant a pine plantation. Switch from breeding operation to purchasing stock included as well, or reverse, switch from purchasing to breeding	*"Really, since we went grass fed – this is recent – we've had to – we're still trying to figure out how this is changing our – last summer was the first summer we were 100 percent grass fed."*

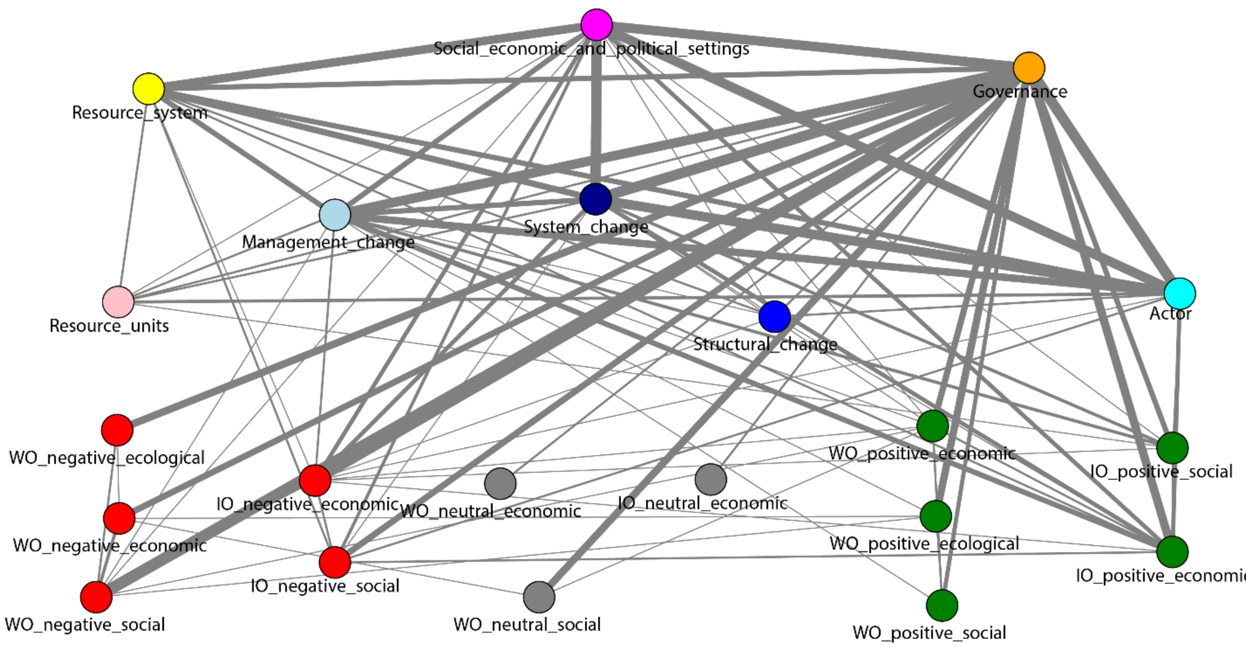

Figure 5-2. Network graph representing group mental model of Taupo farmers' watershed social-ecological system. The arrangement of nodes mimics the structure of the SES Framework in Figure 4-1 above. Color of node represents the category of node: driver nodes are orange (governance), magenta (social, economic and political settings), yellow (resource system), cyan (actor), and pink (resource system); behavior nodes are light blue (management), blue (structural) and navy (system); watershed (WO) and individual (IO) outcomes nodes are red (negative), grey (neutral) and green (positive).

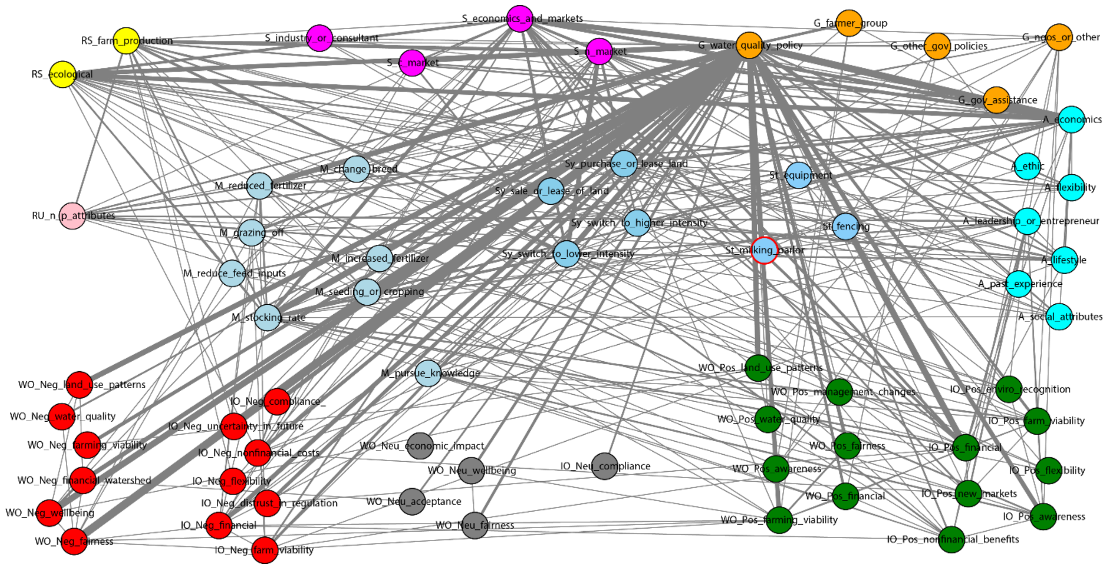

Figure 5-3. Taupo SES sub-category group mental model network.

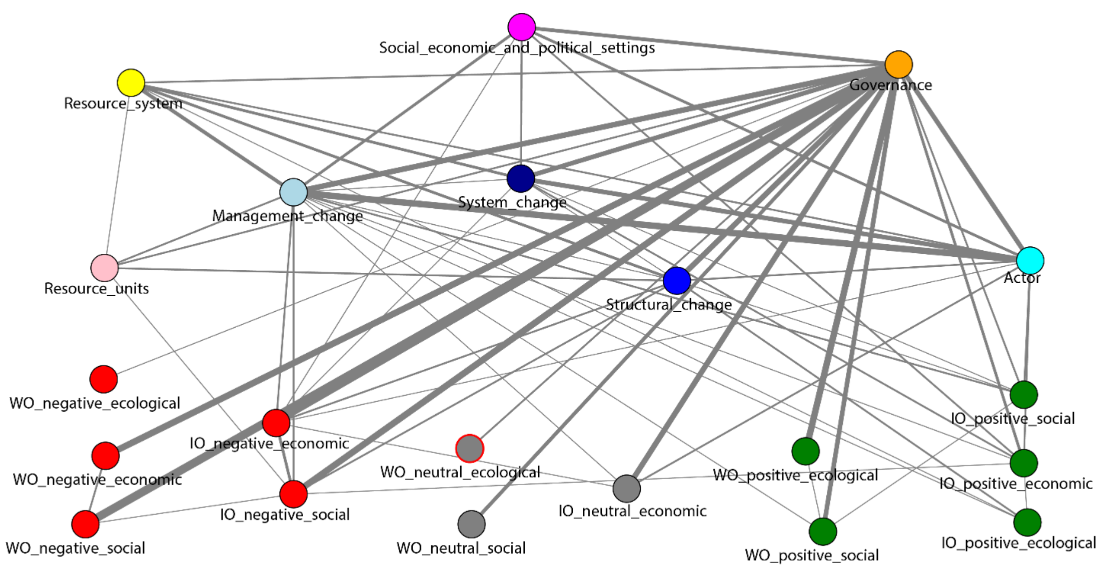

Figure 5-4. Rotorua SES Category group mental model network

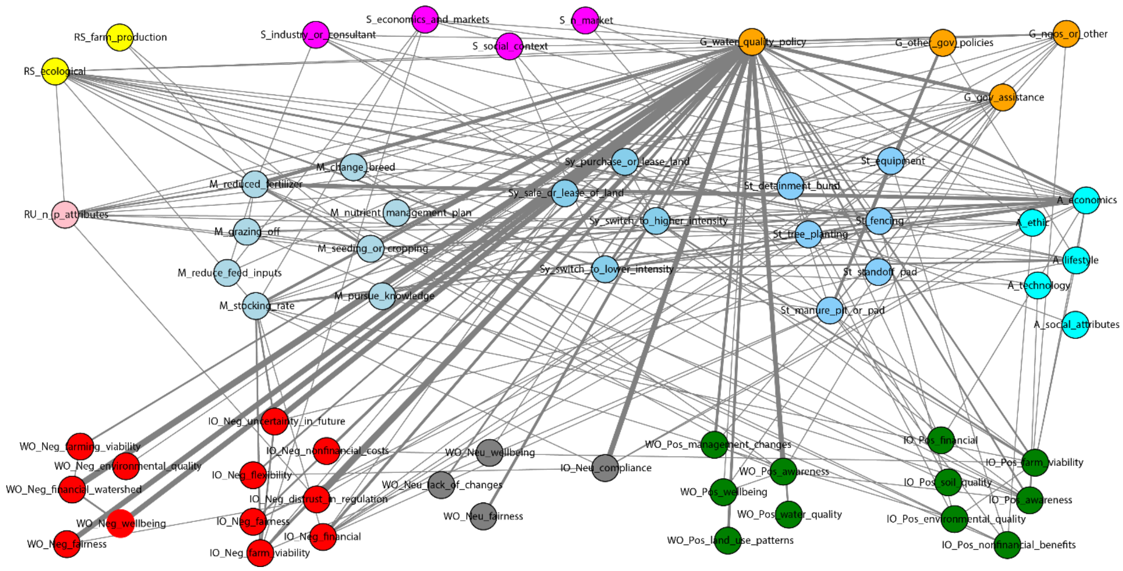

Figure 5-5. Rotorua SES sub-category group mental model network

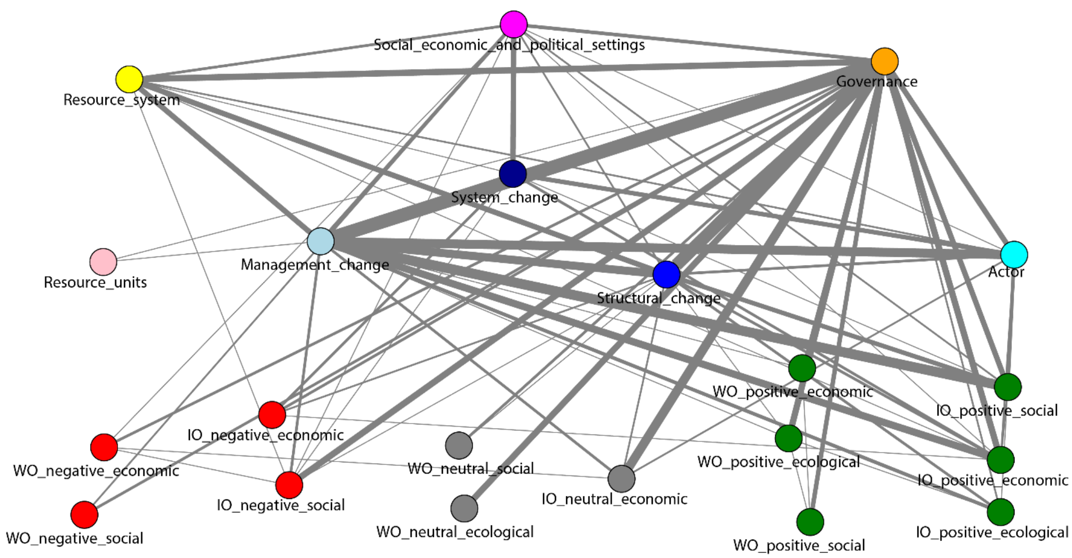

Figure 5-6. Vermont SES Category group mental model network

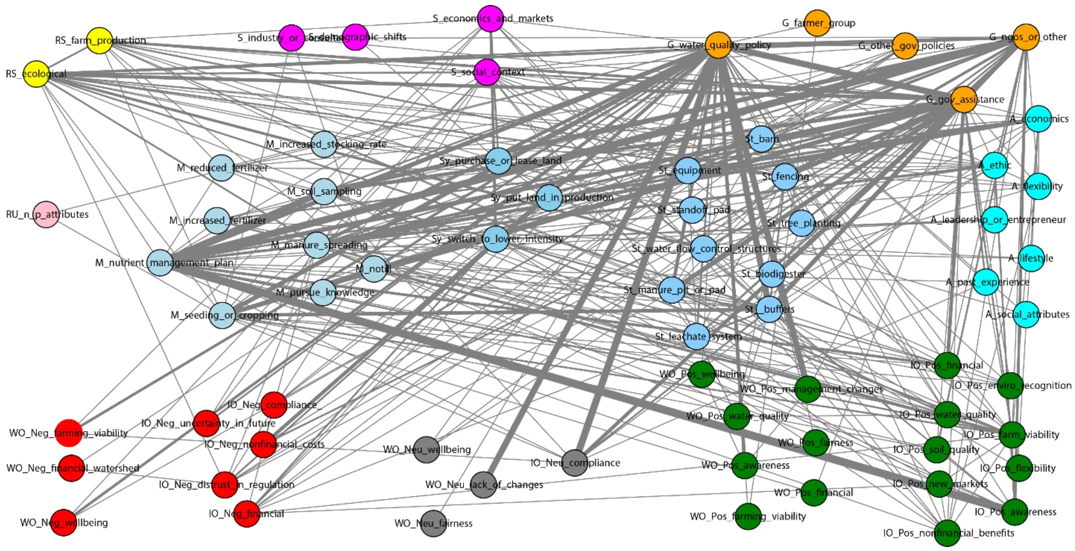

Figure 5-7. Vermont SES sub-category group mental model network.

Table 5-9. Driver node statistics by region in Driver-behavior sub-network. Rank reflects the descending rank of strength (high to low). The data driving these ranks is from the Driver-behavior sub-network so ranks do not reflect influence on outcomes.

	Taupo (n = 11)				Vermont (n = 16)				Rotorua (n = 11)			
Sub-category node	rank	strength	degree	occurrence probability	rank	strength	degree	occurrence probability	rank	strength	degree	occurrence probability
A_economics	2	49	23	91%	5	21	13	50%	2	25	16	64%
A_ethic	14	2	2	9%	6	17	15	38%	8	5	5	18%
A_flexibility	10	9	7	18%	9	8	8	13%	-	-	-	-
A_leadership_or _entrepreneur	7	17	12	27%	10	4	3	13%	-	-	-	-
A_lifestyle	8	16	11	27%	11	3	3	6%	6	9	8	36%
A_past_experience	12	5	5	9%	10	4	3	13%	-	-	-	-
A_social_attributes	10	9	8	27%	12	2	2	6%	11	1	1	9%
A_technology	-	-	-	-	-	-	-	-	10	2	2	9%
G_farmer_group	12	5	3	27%	13	1	1	6%	-	-	-	-
G_gov_assistance	10	9	7	18%	1	74	25	88%	4	14	9	45%
G_ngos_or_other	11	7	7	9%	3	48	22	75%	6	9	8	36%
G_other_gov_policies	13	4	3	27%	10	4	4	13%	7	8	5	27%
G_water_quality_policy	1	88	28	100%	2	58	26	94%	1	42	25	100%
RS_ecological	5	31	18	45%	4	31	18	44%	3	17	15	55%
RS_farm_production	6	23	14	64%	6	17	13	31%	10	2	2	9%
RU_n_p_attributes	8	16	11	27%	12	2	2	6%	5	11	10	27%
S_c_market	9	11	7	18%	-	-	-	-	-	-	-	-
S_demographic_shifts	-	-	-	-	13	1	1	6%	-	-	-	-
S_economics_and _markets	4	40	18	82%	8	9	6	44%	8	5	5	9%
S_industry_or _consultant	13	4	4	9%	10	4	4	6%	8	5	5	18%
S_n_market	3	42	18	82%	-	-	-	-	10	2	2	9%
S_social_context	-	-	-	-	7	15	13	19%	9	3	3	9%

Note: The one letter prefix of the driver sub-category node name represents the overall driver category that the node belongs to: A = Actor, G = Governance, RS = Resource System, RU = Resource Units, S = Social, economic and political setting.

Table 5-10. Drivers ranked by strength across each region. Note that data driving these ranks is from the Driver-behavior sub-network so ranks do not reflect influence on outcomes. The one letter prefix of the driver sub-category node name represents the overall driver category that the node belongs to.

Rank	Taupo	Vermont	Rotorua
1	G_water_quality_policy	G_gov_assistance	G_water_quality_policy
2	A_economics	G_water_quality_policy	A_economics
3	S_n_market	G_ngos_or_other	RS_ecological
4	S_economics_and_markets	RS_ecological	G_gov_assistance
5	RS_ecological	A_economics	RU_n_p_attributes
6	RS_farm_production	A_ethic	A_lifestyle
		RS_farm_production	G_ngos_or_other
7	A_leadership_or_entrepreneur	S_social_context	G_other_gov_policies
8	A_lifestyle	S_economics_and_markets	A_ethic
	RU_n_p_attributes		S_economics_and_markets
			S_industry_or_consultant
9	S_c_market	A_flexibility	S_social_context
10	A_flexibility	A_leadership_or_entrepreneur	A_technology
	A_social_attributes	A_past_experience	RS_farm_production
	G_gov_assistance	G_other_gov_policies	S_n_market
		S_industry_or_consultant	
11	G_ngos_or_other	A_lifestyle	A_social_attributes
12	A_past_experience	A_social_attributes	
	G_farmer_group	RU_n_p_attributes	
13	G_other_gov_policies	G_farmer_group	
	S_industry_or_consultant	S_demographic_shifts	
14	A_ethic		

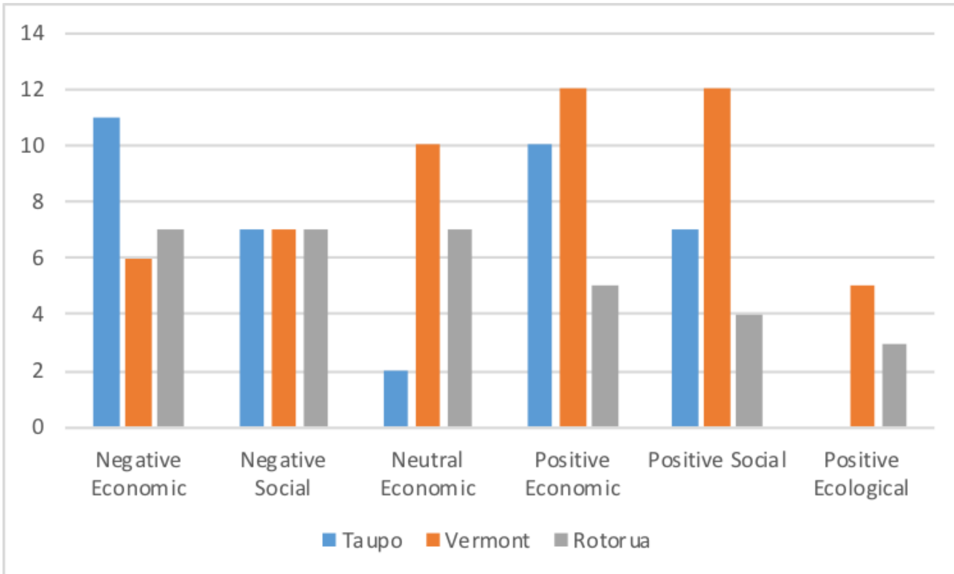

Figure 5-8. Number of individual outcomes by region. Note for Taupo and Rotorua n = 11 and for Vermont n = 16.