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Compelling collective action: Does a shared pollution cap incentivize farmer cooperation to restore water quality?

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Abstract: Decades of voluntary efforts to reduce agricultural nonpoint source pollution have been ineffective at protecting water quality worldwide. While farmer collective action is needed to deal with the geographical extent of diffuse pollution from nutrient runoff, theoretical expectations from commons governance research predicts that farmers will not protect water quality since they have few incentives to do so. These different factors indicate that compulsory approaches are needed. However, the commons literature has tended to overlook the constructive roles that government regulation can play. Research on why farmers adopt on-farm conservation measures similarly has failed to explore farmer cooperation, instead focusing mainly on financial motivations of farmers. Yet, some adoption research indicates that social norms are essential factors shaping (non)adoption, but which are largely overlooked by existing agri-environmental policies. This study examines the important gap of how government regulations can incentivise farmer cooperation to improve water quality. I focus on a case study of the Florida Everglades, where farmers face joint liability under a phosphorus pollution cap and which has resulted in improvements in water quality over the past 20 years. Farms' drainage disrupts the oligotrophic conditions of the Florida Everglades, but water quality has steadily improved since regulations began in 1994. However, the regulations set compliance jointly for farmers, devolving responsibility to ensure sufficient adoption of conservation practices and deal with free riding. While state monitoring shows that collectively farms have improved water quality, we do not know whether participation is widespread or concentrated among a few large farms. This study provides the first analysis of farm-level water quality outcomes for this area and how judicial, legislative, and local institutions interact to encourage farmer cooperation. Results show that a large majority of farms have improved their water quality, demonstrating that collective action has been a key element in the outcome. At the same time, poor-performing farms reveal the shortcomings of joint compliance. I end by

discussing the implications of how individual and collective requirements can provide farmers with valuable information while also drawing on farmer social dynamics to encourage greater participation.

Keywords: Agri-environmental governance, conservation adoption, farmer collective action, nonpoint source pollution, social-ecological system

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1. Introduction

Water quality impairment from agricultural nonpoint source (NPS) pollution remains a pressing governance challenge worldwide (Carpenter et al. 1998; Patterson 2017). Similar to other common-pool resource (CPR) dilemmas, the challenge of preventing farms' NPS pollution from harming shared waterways is exceptionally difficult (Smith and Porter 2010). Widespread adoption of on-farm conservation measures to limit soil erosion, nutrient runoff, and drainage, often called best management practices (BMPs), are essential to restore the health of impaired waterways (Daroub et al. 2011). While this dilemma is widely understood, government-led efforts to encourage BMP adoption are mostly voluntary and have failed to generate sufficient participation to improve water quality (Barnes et al. 2013; Ribaudo 2015; Leventon et al. 2017). Alongside biodiversity loss and climate change, the spatial extent of NPS pollution means that widespread collective action is necessary to address the problem.

While widespread cooperation is lacking, achieving sufficient BMP adoption through regulations also appears to be problematic. Existing research demonstrates that farmers remain unconvinced of their farm's contribution to downstream impairment, despite mandatory BMP adoption (Macgregor and Warren 2006; Barnes et al. 2009). Requirements can fuel a sense of unfairness rather than desired management changes (Barnes et al. 2013). Farmers dislike regulations in part because of perceived inflexibility, lack of autonomy, and additional bureaucratic hassles and costs that come with prescriptive requirements (Emery and Franks 2012; Taylor and Van Grieken 2015). Even where farmers participate in collaborative governance, efforts can focus on improving public opinion or protecting agricultural interests ahead of improving water quality (Prokopy et al.

2014; de Loë et al. 2015; de Krom 2017). Cooperation is difficult to achieve because NPS pollution is a complex and contested environmental challenge that features significant ambiguity around how much individuals contribute to the overall problem, many stakeholders and competing priorities, and multiple levels of governance to coordinate (Cash et al. 2006; Patterson 2017).

The commons literature has largely overlooked the challenge of agricultural NPS pollution (Kerr 2007), despite extensive insights into how natural resource users can cooperate to avoid environmental degradation (Ostrom 1990; Dietz et al. 2003). Since farmers rarely face the consequences of downstream water quality impairment, a theoretical challenge is to understand how to generate widespread BMP adoption in the absence of local, mutually experienced feedbacks that can encourage cooperation to avoid environmental degradation (Stern 2011; Patterson 2017). In addressing large-scale environmental problems, one influential research approach has been the principle of subsidiarity in nested governance arrangements, where some rights and responsibilities are devolved to natural resource users. In contrast to centralized control, devolving some responsibilities can improve government's access to local knowledge, benefit from community-based self-monitoring and enforced trust, gain disaggregated feedback on rule performance, and reduce enforcement costs by improving legitimacy from local participation in rulemaking (Marshall 2008). However, commons research has tended to focus on subsidiarity in cases where local resource users gain livelihood benefits. This paper, in contrast, examines subsidiarity dynamics when livelihoods incentives for protecting ecosystem health are absent or weak.

To deal with agricultural NPS pollution, one potential way forward is for government regulations to incentivize collective action by employing collective, rather than individual, subsidies and penalties. There is limited but growing attention to collective agri-environmental approaches, though many studies have focused on biodiversity conservation rather than NPS pollution. Collective approaches may offer several advantages that are similar to subsidiarity: attention to social norms and reciprocity by encouraging farmer-to-farmer interaction (Marshall 2004; Burton and Paragahawewa 2011); reduced transaction costs for coordination and increased participation by devolving some responsibilities to trustworthy non-governmental intermediaries, such as agricultural cooperatives (Marshall 2008; Dedeurwaerdere et al. 2015); and improved legitimacy for BMP adoption with greater flexibility and farmer input into how to meet environmental goals (Emery and Franks 2012; Del Corso et al. 2017). This study's focus on regulations complements calls in the commons literature for greater attention to the various roles that government can play to encourage behavioral change (Koontz et al. 2004; Anthony and Campbell 2011; Mansbridge 2014).

This paper contributes to the literature by examining how state regulations relying on collective penalties and devolved implementation responsibilities can encourage farmer cooperation to improve water quality. It does so through a case study of the Florida Everglades, which stands out as an uncommon success story of greatly improved water quality (SFWMD 2017) under mandatory BMP adoption. While it appears that regulations drive water quality improvements, nested governance arrangements make farmer cooperation a critical question. The 1994 Everglades Forever Act relies on a shared phosphorus pollution cap, which is backed by court-mandated water quality standards. Farmers in the Everglades Agricultural Area (EAA), whose drainage water flows south into the Everglades, face joint liability to annually maintain their collective total phosphorus (TP) load 25% below a pre-regulatory baseline level. Over 22 years, EAA farms have averaged annual TP loads 55% below their baseline, maintaining compliance in every year (Davison et al. 2017). Water quality in the Everglades has improved as a result, with more than 90% of monitoring sites meeting restoration goals of phosphorus concentrations at or below 10 parts per billion (ppb) (SFWMD 2017).

However, no research has examined whether devolving the responsibility TP load reductions to EAA farms has led to collective action to curb potential free riding. Since there are no individual penalties as long as the group maintains compliance, the outcome could reflect the efforts of a few large players. Moreover, the shared pollution cap is overseen by the state government but overlaps with both federal court-backed water quality standards of 10 ppb and EAA agricultural drainage management shaped by hundreds of shared canals and pumps. I address two research questions to examine why water quality has improved in the Florida Everglades. First, in what ways do the nested judicial, legislative, and local drainage institutions incentivize cooperation? Second, given those nested governance arrangements, does the shared pollution cap under the Everglades Forever Act result in widespread improvements or permit substantial free riding? This paper provides the first analysis of farm-level TP loads in the EAA, despite more than 20 years of publicly available data. After identifying the relevant institutional arrangements from 65 semi-structured interviews and analyzing TP load outcomes from state records, I discuss the importance and relevance of collective regulatory incentives for addressing agricultural NPS pollution in other contexts.

2. Farmer cooperation and governance challenges for agricultural NPS pollution

2.1. Farmer challenges for improving water quality

Both voluntary and regulatory approaches face barriers in generating effective participation to reduce NPS pollution. Here, I draw on agri-environmental research that has studied primarily commodity-focused farms that use fertilizers, pesticides, irrigation, soil tillage, and tile drainage, which are similar to EAA agricultural production. Agri-environmental research has highlighted many economic and non-economic factors that influence farmer decisions on BMP adoption (Siebert et al. 2006; Blackstock et al. 2010). Some water quality BMPs do provide economic benefits for farms, such as cost savings from reduced fertilizer use (McGuire et al. 2013). Other BMPs, such as the timing of planting or the use of perennial grasses, may not increase profitability and require subsidies (Boardman et al. 2017). A growing body of research shows that social concerns are important drivers of adoption and non-adoption. In some cases, farmers are more likely to participate in watershed-scale efforts to improve NPS pollution if they expect other farmers to reciprocate BMP adoption (Lubell 2004) and if farmers see widespread reciprocity as critical to their community's "viability" (Marshall 2004, 277). Conversely, social norms can also create substantial barriers. Burton (2004) showed that farmer reputations – staked to visible signs of good farming, such as straight crop rows and high yields – can make it difficult to get farmers to adopt BMPs that do not fit existing social norms.

2.2. Government regulations and farmer cooperation

A major challenge for government regulations is that penalties or restrictions for farms may be likely to generate resentment and resistance instead of understanding and engagement (Armstrong et al. 2011; Barnes et al. 2013). Pollution designations can offer one way for governments to use monitoring data and encourage livestock and row crop farmers to participate in watershed-scale effort (Prokopy et al. 2014), as well as generate awareness and dialogue about potential management changes (McGuire et al. 2013; de Loë et al. 2015). Farmers may invoke questions of distributive fairness, if monitoring efforts do not clarify how much pollution is due to agriculture versus other sectors (Macgregor and Warren 2006). Moreover, existing governmental approaches, such as current European biodiversity policies, are problematic because they fail to encourage farmers to cooperate at regional scales to deal with necessary ecosystem extent, discourage knowledge exchanges between farmers that could also change social norms, and do not address coordination and administrative barriers (Leventon et al. 2017).

In contrast, Franks and Emery (2013) show that collective agri-environmental schemes for biodiversity conservation increased farmer-to-farmer learning, incentives for farmers to monitor each other's efforts, and greater farmer buy-in to the scheme's performance from their engagement. A few studies have shown that collective subsidies, through group bidding for agro-biodiversity conservation contracts (Narloch et al. 2017) and through a bonus payment for meeting participation thresholds to reduce pesticide use (Kuhfuss et al. 2016), can be effective in increasing participation. Farmers are too often treated as homogeneous actors, while in reality tailoring messages to deal with diverse motivations is key to BMP adoption (Blackstock et al. 2010). Devolving some agri-environmental contract responsibilities to a trusted intermediary can reduce administrative barriers and help promote local legitimacy. For example, in France, a pesticide cooperative played a critical role as a credible intermediary in negotiating with both farmers and government agencies to reduce pesticide uses and garner farmer enrollment in the program. The authors identified the transition in underlying social acceptability as a fundamental component of widespread participation and effective water quality outcomes (Del Corso et al. 2017).

2.3. Biophysical influences on farmer collective action

In addition to economic, social, and institutional incentives, the role of local biophysical contexts in shaping collective action problems has not been given sufficient attention in environmental governance research (Bodin 2017). Many of the studies discussed in this background section do not address whether local biophysical conditions play a role in shaping perceptions that cooperation is needed, regardless of the type of farming operation. However, several studies have identified biophysical-cooperation dynamics of agricultural water management. Marshall (2004) finds that a shared shallow aquifer creates a CPR dilemma for Australian farmers. Excessive irrigation raises the water table, which in turn causes soil salinization. All farmers need to reduce irrigation to minimize this shared risk to crop production. Lansing's (2007) study of highly interconnected irrigation canals in Bali finds that rice farmers flood fields at the same time to suppress pests across the system. Uncoordinated flooding would allow pests to move between fields and pose risks to all farmers. In another case, drainage infrastructure obligates row crop farmers to coordinate decisions on maintenance or appeal to state authorities to enforce changes in the common interest (Ranjan and Koontz 2018).

3. Materials and methods

3.1. Study site: regulating water management in the EAA

This case focuses on the effect of water quality restrictions governing agricultural water management in south Florida's EAA. The EAA is an administratively defined area based on extensive and interconnected canal infrastructure that provides irrigation and flood control to farms and which drains south into the Everglades. Six major canal arteries and large hydraulic pumps to control flow are

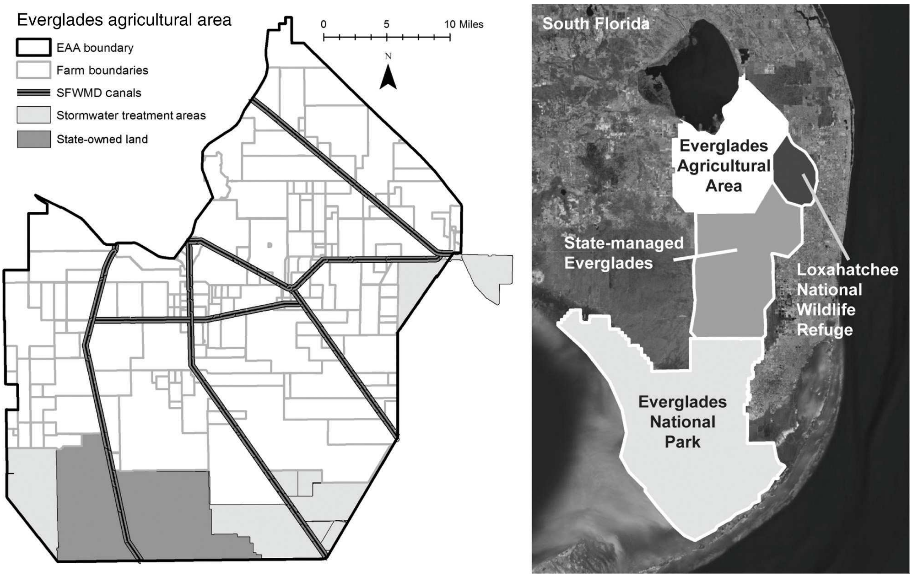

Figure 1: Everglades hydrological connections.

owned and managed by the state, under the administration of the South Florida Water Management District (SFWMD) (Figure 1). Hundreds of additional pumps are owned by farms individually, as well as jointly through landowner-managed drainage districts, which are quasi-governmental entities with self-taxation powers. The EAA is home to Florida's multibillion-dollar sugar industry. Sugarcane is the primary crop by acreage, accounting for 80%, while vegetables, sod, and rice comprise the remaining major crops (Daroub et al. 2011). There are 60 active farming operations. Two companies, Florida Crystals and U.S. Sugar, cultivate more than two-thirds of the area's farmland. A third company, the Sugar Cane Growers Cooperative (hereafter Growers Coop), is comprised of 45 member farms and manages nearly one-quarter of the EAA. The remaining land is managed by 58 other farms and businesses (hereafter Other Businesses), 11 public-sector entities, and 37 private residences (Table 1).

In the 1980s, phosphorus pollution from EAA drainage water led to species invasions in the Everglades. This led to a federal lawsuit against the state of

Table 1: EAA land management based on everglades works of the district permits issued by the SFWMD.

Number of land managers		Total acres	Percent	Mean acres
EAA basins by acreage and land management				
EAA	157*	459,465.71	100.0	2926.53
Fla. Crystals	1	183,905.68	40.0	–
US Sugar	1	145,717.41	31.7	–
Growers Coop	49**	106,205.35	23.1	2168.37
Other businesses	58	16,951.85	3.7	292.27
Municipal	11	6195.42	1.4	563.22
Residential	37	445.01	0.1	12.03
Basins with a single manager				
EAA	27	247,947.22	54.0	9183.23
Fla. Crystals	1	102,330.90	16.8	–
US Sugar	1	77,288.43	22.3	–
Growers Coop	22	64,483.46	14.0	2931.07
Other businesses	3	3844.43	0.8	1281.48
Municipal	–	–	–	–
Residential	–	–	–	–
Basins with shared management				
EAA	148	211,518.49	46.0	1347.25
Fla. Crystals	1	81,574.78	14.9	–
US Sugar	1	68,428.98	17.8	–
Growers Coop	42	41,766.89	9.1	852.39
Other businesses	56	13,107.41	2.9	225.99
Municipal	11	6195.42	1.3	563.22
Residential	37	445.01	0.1	12.03

*Because 18 farms operate in basins with both single and shared management, the number of land managers listed in single and shared categories does not equal the total number of EAA land managers.
**There are four administrative units within the Growers Coop that manage land based on permit data, which are additional to the organization's 45 member farms.

Table 2: Distribution of land managers in basins under single and shared water management.

Land management categories	Operation in single and shared management in basins			
	Total	Both	Single Only	Shared Only
Number of individual land managers in the EAA				
EAA	157	18	9	130
Fla. Crystals	1	1	–	–
US Sugar	1	1	–	–
Growers Coop	49*	15	7	27
Other businesses	58	1	2	55
Municipal	11	–	–	11
Residential	37	–	–	37

*There are four administrative units within the Growers Coop that manage land based on permit data, which are additional to the organization's 45 member farms.

Florida in 1988 for failing to uphold its water quality standards that resulted in a court-backed settlement.

The Florida legislature incorporated the major components of the settlement into the 1994 Everglades Forever Act (Rizzardi 2001; Sklar et al. 2005). The settlement established stringent, long-term water quality standards of 10 parts per billion (ppb) of phosphorus and joint compliance for EAA farms (*United States v SFWMD et al.* 1992). Joint compliance was a concession to EAA representatives. To meet the restoration target, farms would adopt BMPs to minimize fertilizer application, soil erosion, and sediment transport through canals. Farms collective TP load would need to be 25% lower than their pre-regulatory load and maintained at that level or better each year. Compliance would be measured as water flowed into several stormwater treatment areas (STAs), which would further assimilate phosphorus before exiting into the Everglades (Figure 1).

To ensure that farms adopted BMPs effectively, the SFWMD established the Everglades Works of the District permitting program for EAA farms. The SFWMD issued permits based on where one or more farms have a diesel-powered hydraulic pump, which is used to raise and lower the water table for irrigation and drainage. The permits refer to these areas as "basins." While not topographical, these areas function like river basins in that surface water flows out to SFWMD canals at a common point: the pump. Water management in the EAA is very interconnected. There are 173 basins; 44 have shared management, which accounts for 47% of the area's farmland. Only nine farms operate entirely independently (Table 2). Since Everglades Forever Act regulations went into effect in 1994, water quality in the Everglades has improved from a five-year flow-weighted mean of 24 ppb from 1979–1983 to 9 ppb from 2011–2016 (SFWMD 2017).

3.2. Data collection and analysis

First, to examine whether collective action has driven improvement in Everglades water quality, I perform a narrative analysis drawing 65 semi-structured interviews.

The narrative analysis is based on interview responses that described or referenced how federal, state, and local institutions encouraged farmer cooperation around water management. Interviews included 34 farmers, 11 state and federal officials, 10 EAA agricultural extension agents, and 10 additional key stakeholders. A census of the EAA farming operations was undertaken, while purposive sampling was used to identify government, extension, and other interview subjects. De-identified statements favoring or disfavoring collective action are included in the supplementary materials. I also reviewed legal documents pertaining to the 1991 lawsuit settlement and 1994 Everglades Forever Act, state monitoring reports, and published oral and environmental histories.

Second, to examine whether collective action incentives have subsequently resulted in widespread improvement, I analyze publicly available state monitoring and permit data. The permits require farms to submit daily monitoring data on drainage volumes and phosphorus concentrations, which are recorded by automated samplers at each pump. The SFWMD uses these data to calculate an annual per-acre TP load (called a unit area load) for each basin, which is published each year in the *South Florida Environmental Report* and includes a baseline basin TP load as well. I combined these per-acre numbers with the acreages managed by individual farms in each basin, which are listed in the permits. I then calculated projected and actual TP loads for each farm by adding together the TP loads across each basin in which they farm. I report a projected one-year TP load and a one-year average actual TP load, based on yearly *South Florida Environmental Reports* from 2001 to 2015.

While this approach does not factor trends into the analysis, such as improving or worsening loads across years, it provides a valuable snapshot of whether or not farms have contributed to reducing phosphorus pollution overall. I also verified and consolidated farms that are listed under different names in the permits but are part of the same company using Florida's Division of Corporations online database. To be clear, the SFWMD does not use these basin-level data to calculate compliance, which is measured only at STA inflow locations. These data provide comparisons between basins and how basins perform over time (Adorisio et al. 2006).

4. Compelling farmer cooperation to improve water quality

4.1. Collective action incentives from nested governance arrangements

Nested Everglades water governance creates overlapping sets of incentives that encourage farmer cooperation to adopt BMPs. These include the litigation and court-backed water quality standards that heightened farmers' attention to their water management, information sharing encouraged by group compliance, and drainage coordination obligated by shared infrastructure and interdependent flood risks. A reasonable expectation would be that court-backed enforcement and state regulations primarily drive BMP adoption. However, interview responses paint a more nuanced pictured about the forms of farmer cooperation that underpin BMP adoption. This is especially important to understand given that no farm faces individual penalties under the Everglades Forever Act as long as the group maintains compliance, which has occurred in every year of the regulations.

4.1.1. Court-backed enforcement

The lawsuit created substantial fear within the farming community that their livelihoods were at risk because it coincided with calls from environmental groups and scientists to eliminate agriculture and return the EAA to wetlands to advance restoration (Hollander 2004). In settling the lawsuit, EAA representatives negotiated to be regulated collectively rather than individually. Farmer responses show that a majority preferred group compliance to minimize regulatory intrusion and avoid in-fighting, given the substantial public criticism directed at them during the settlement negotiations (see also Yoder and Roy Chowdhury 2018). The choice to be regulated collectively represents a first form of cooperation – to deal with livelihood risks, rather than water quality. The outcome was an agreement where EAA farms would collectively reduce and maintain their TP loads 25% below a baseline of 1980s average loads. This would be achieved through on-farm BMP adoption. Individual penalties, in the form of requiring additional BMPs, would only be an option if the EAA became non-compliant first. Group compliance has been the source of criticism by environmental groups concerned that it allows phosphorus "hot spots" from free riding, where individual compliance would produce more rigorous adoption. The Florida Audubon Society, an influential environmental organization, filed an administrative court petition in 2013 arguing that BMPs needed to be tailored to farms to maximize their effectiveness. While the petition was dismissed on procedural grounds, they argued that BMPs adopted in Everglades Works of the District permits were nearly uniform and thus underperforming (*Florida Audubon Society v. Sugar Cane Growers Cooperative of Florida et al. 2014*).

While group compliance created the potential for free riding, given the absence of individual penalties, the court-backed settlement agreement also established stringent and specific long-term water quality standards of 10 ppb for phosphorus. It required 35,000 acres of farmland to be converted to STAs to perform much of the phosphorus reduction and mandated an "agricultural privilege tax" on EAA farms to pay for some of the STA construction. Over time, ongoing court rulings and negotiations have led to the expansion of STAs to 58,000 acres and another 38,000 acres of farmland converted for water storage to improve STA capacity and advance restoration (SFWMD 2013). While the potential for free riding exists, it is also clear that the loss of the area's farming base, which could continue to diminish if the EAA became non-compliant, presents important shared livelihood risks to all farmers. This form of compliance, though not achieved through individual penalties, has been enforced through an iterative process to meet Everglades restoration targets.

4.1.2. Group compliance, sharing information, and feedbacks

While the court's enforcement provides a hammer, the Everglades Forever Act's BMP regulations offer farms flexibility in deciding what BMPs they adopt. Group compliance has encouraged information sharing between farmers, regulators, and extension agents. The state legislature tasked the SFWMD with the responsibility to develop a permitting program to ensure that farmers carried out the BMP adoption agreed to in the settlement, but provided no further guidance. Senior SFWMD officials opted for a consultative approach with leaders in the farming community to solicit their views on what BMPs would be effective. Extension agents, located at the University of Florida's Everglades Research and Education Center (EREC) in the EAA, also provided advice to both groups on what practices would reduce TP loads.

A critical outcome of these consultations was that the regulations required a BMP plan that targeted (1) fertilizer application, (2) soil erosion, (3) and sediment transport through canals. Farms were required to adopt BMPs in each category, but provided flexibility to choose which BMPs they felt would work best for their farm (Daroub et al. 2011). In reviewing permits and interviewing farmers, Audubon's petition is accurate. There is relatively little variation in the types of BMPs that EAA farms adopt. Interview responses indicate that the consultative approach generated a list of socially acceptable BMPs, which lessened farmer resistance to adoption and mistrust of SFWMD regulators. Group compliance, while initially sought to maintain some autonomy from potentially prescriptive regulations, subsequently encouraged farmers to talk with one another about BMP adoption to achieve joint compliance. These interactions represent a second form of cooperation.

Communication has occurred through regular trainings hosted by EREC and the Growers Coop, with senior farm managers and executives at both Florida Crystals and U.S. Sugar participating as well. Early trainings involved extensive discussions and presentations on how to ensure BMPs were implemented effectively. Trainings for new employees continue to occur twice per year. Individual farms also need standardized procedures for BMP implementation, given the large numbers of managers and employees in most farming operations. Also in response to the lawsuit, the large companies formed the EAA Environmental Protection District, a self-taxing entity to raise funds for shared research. While funds were initially directed at research to examine (and contest) the 10 ppb threshold (see Richardson et al. 2007), it has subsequently funded EREC scientists to do research to improve BMP effectiveness (e.g. Daroub et al. 2007).

Flexible BMP implementation and information-sharing forums are effective because of extensive monitoring data and the reputational meaning EAA farmers ascribe to it (see also Yoder and Roy Chowdhury 2018). Monitoring data provides critical feedbacks on water quality outcomes within the EAA. Farmers, extension agents, and regulators commented in interviews on the importance of the monitoring data. After the first year of the regulations, state monitoring showed that the EAA had collectively reduced its TP load by 60%. This result allayed many concerns that maintaining compliance would not be feasible. At the basin level, monitoring data showed which farms were contributing the most or least to improving water quality. Responses from farmers and extension agents noted that there was pride associated with have low TP loads and concern associated with increasing phosphorus levels. The published basin data showed de-identified permit numbers on an EAA map, which meant that farmers could recognize their neighbor's performance. This also encouraged some farmers to seek out their neighbor to ask for recommendations on how to reduce their TP loads. Farmers also identified cost savings from reduced fertilizer application as one economic benefit from BMP adoption. At the same time, many farmers and extension agents commented that BMP adoption is costly. Most farmers commented that they would continue to do most of the BMPs even if there were no regulations, but that they would do some of them less frequently. This additional rigor illustrates an advantage of compulsory approaches over voluntary adoption.

4.1.3. Coordinating drainage decisions

While the court-back settlement and group compliance provide enforcement and information incentives, both governance arrangements complement pre-existing drainage coordination needs that EAA farms face over mutual flood risks. The use of shared pumps and canals interacts with the areas hydric soils to create interdependent consequences for managing the water table. The area's hydric soils affect water management through subsurface seepage, where neighboring farms can cause flooding or be flooded if they raise the water table in a canal or field above a neighbor's water table. This consequence is amplified because fields have varying soil depths, since hydric soils oxidize and subside when exposed to air. In the EAA, soil subsidence has occurred up to seven feet in some locations (Sklar et al. 2005). Where this becomes a serious challenge is that nearly half of EAA farmland is in basins with shared management – meaning there is one hydraulic pump for two or more farms, which ranges as high as 44 farms in one basin. Shared management is widespread because decades earlier many landowners decided to form drainage districts, which provide self-taxing authority to purchase pumps and dredge and maintain canals. Nine drainage districts cover 108,000 acres across 19 basins. Yet, many additional acres involve shared pumps between farms. Even the largest companies, Florida Crystals and U.S. Sugar, have 44% and 47% respectively of their farmland in basins where they share a pump with another farm.

Farms must communicate often when they irrigate or drain, since their decision will may affect their neighbors, regardless of whether they need agreement to operate a shared pump. Drainage coordination represents a third type of cooperation. Where the Everglades Forever Act intersected with these coordination challenges was through rainfall detention BMPs: the slowed velocity and reduced volume farms would discharge into SFWMD canals. During south Florida's five-month rainy season, farms can be inundated with up to eight inches of rain in a single day. To prevent crops from becoming flooded, farms would run their pumps overnight and drain the canals empty regardless of actual rainfall, disturbing the sediment in the canal beds. The rainfall detention BMP required farms to counter-intuitively increase their flood risks. In the permit, each basin would choose whether to wait for a half inch, one inch, or 1.5 inches of rain to fall before running their pumps to drain, while also not disturbing the canal bottom. Vegetable operations wanted quicker drainage and opted for half-inch rainfall detention, while sugarcane was more flood-tolerant, so many basins with only sugarcane opted for one-inch detention. The few ranches in operation opted for 1.5-inch detention or ceased pumped discharges.

Farmers were incredibly skeptical of rainfall detention initially. Moreover, it had to be incorporated into existing coordination to irrigate and drain because of shared pumps. Several respondents explained that the coordination occasionally caused some tensions and disagreement because some farms become flooded quicker than others. Self-monitoring is a key aspect of the interconnected canal infrastructure, given the need to maintain compliance and the shift in mentality. Even on farms with their own pump the number of employees involved means individual farms still need standard operating procedures around when pumping should occur. Yet, after the monitoring data demonstrated a substantial reduction in TP loads in the first year of the regulations, the tensions around the rainfall detention BMP lessened. The value of saving money from using less diesel fuel became a socially acceptable, if not preferred, rationale to justify the BMP on business grounds. Overall, farmer collective action occurs in three ways in response to water quality regulations: (1) in lobbying for group compliance to protect shared livelihoods; (2) in sharing information to improve BMP effectiveness to maintain group compliance; and (3) in coordinating and regulating drainage practices.

4.2. Farm-level phosphors outcomes

While interview responses portray three ways that farmer cooperation occurs in nested Everglades water governance, it does not demonstrate to extent to which this cooperation is evident in reduced TP loads within the EAA. Comparing projected to actual TP loads among individual farming operations reveals that most farms are improving water quality (Figure 2). Florida Crystals and U.S. Sugar have the largest reductions in TP load and account for most of the improvements in water quality. This is unsurprising since they are the largest land managers. Within the Growers Coop, 33 of 49 member farms have reduced their TP loads, while 34 of 58 Other Businesses have reduced their TP loads as well. Also notable is that Florida Crystals has a per-acre average of 0.52 pounds TP, while US Sugar and Growers Coop members average 0.91 and 1.23 pounds of TP per acre (Figure 2). Not only is the Florida Crystals the largest land manager, it has much lower per-acre averages than U.S. Sugar and many Growers Coop farms. However, there are 10 Growers Coop farms with per-acre TP loads lower than Florida Crystals.

There are 16 Growers Coop farms and 24 Other Businesses exceeding their projected TP loads, which reveals that many farms still have not contributed to

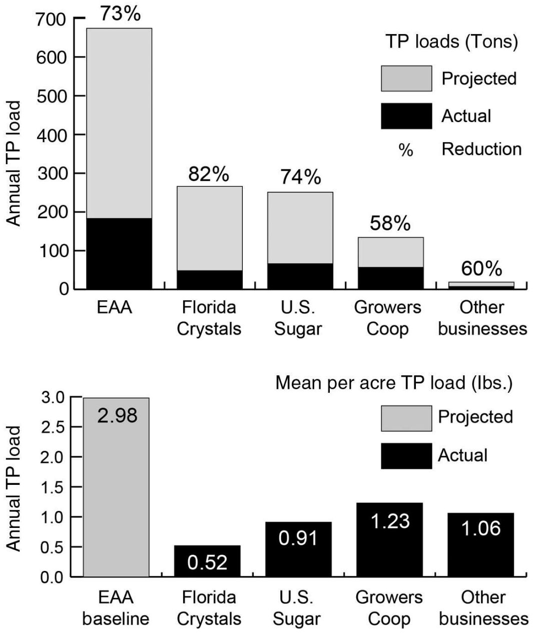

Figure 2: Annual TP load reductions within the EAA.

improving water quality. These farms generate 11% of the EAA's overall TP load and have per-acre TP loads of 1.9 pounds on average. Of those, 11 Growers Coop farms and 23 Other Businesses have more than doubled their projected loads. This demonstrates a clear shortcoming of the group compliance approach. However, the increases could be due to changes in crop choices rather than poor management, as vegetables generally has higher TP loads given their higher fertilizer requirements compared to sugarcane. The Everglades Forever Act does not regulate land use.

I also looked at TP load outcomes by basins, since shared water management is a major aspect of whether collective action is occurring or not. Basin analysis tells a similar story, where 128 of 173 basins (74%) have reduced their TP loads relative to projected amounts (Table 3). Of the 45 basins exceeding their projected loads, 33 basins also have per-acre loads above the EAA average of 0.98 pounds. Of these, five basins have per-acre loads exceeding three pounds of phosphorus, which is higher than the EAA's pre-regulatory baseline average. Within these five basins, four have only a single manager, while the fifth basin is a drainage district with several dozen farms.

The presence of basins exceeding their projected TP loads is further complicated by the 22 Growers Coop farms, as well as both Florida Crystals and US Sugar, that manage land in multiple basins where most but not all of the basins

Table 3: Number of basins decreasing and increasing TP loads.

Majority land manager	Basins under single management			Basins under shared management		
	Total	Decreased	Increased	Total	Decreased	Increased
EAA	129	99	30	44	29	15
Florida Crystals	32	27	5	21	14	7
U.S. Sugar	26	19	7	20	14	6
Growers Coop	68	50	18	28	18	10
Other businesses	3	3	–	23	16	7
Municipal	–	–	–	20	13	7
Residential	–	–	–	11	5	6

have reduced their TP loads. All but two of these farms have generated net reductions in TP loads overall. Examining drainage districts reveals patterns that are similar to individual farms and basins. Of the 19 basins under drainage districts, 12 have TP loads below projected level, while all drainage districts have per-acre loads below two pounds. Moreover, six of the drainage districts average TP loads of less than one-half pound per acre. Basin size also does not appear to be a determining factor.

4.3. Strengths and weakness of devolving BMP implementation under joint compliance

These findings on water quality within the EAA demonstrate that a majority of farms have contributed to reducing NPS pollution. This shows that devolving responsibility for implementation to farmers under the Everglades Forever Act's shared phosphorus cap has generated widespread and effective BMP adoption. These outcomes are consistent with the interview responses demonstrating that a substantial shift in BMP adoption has occurred, which is supported by evidence of changes in social acceptability tied to on-farm benefits and reputational pressures tied to monitoring data under group compliance. Farmer cooperation has played a central role in this outcome, given the importance of sharing information informally between neighbors, consultations with regulators in identifying effective and acceptable practices for the BMP plan, attending BMP trainings with EREC staff, and self-monitored rainfall detention through coordinated drainage decisions. However, it is important to note that this occurs through overlapping forms of cooperation that are not geared exclusively to improving water quality. Initial farmer cooperation focused on protecting shared livelihoods. Moreover, court-backed enforcement has reduced the area's farming base, which is a critical form of compliance that is not dependent on maintaining joint compliance under the Everglades Forever Act.

While the majority of farms demonstrate that cooperation has played a key role in shifting practices, there are 40 farms and businesses and 45 basins that have increased their TP loads. This lends credibility to Audubon's concerns about phosphorus hot spots and suggests that farmers are not optimizing BMP adoption to generate the lowest TP loads in all cases. These shortcomings are not entirely unexpected since interview responses from farmers and agricultural extension agents emphasized the costs of BMPs, despite the importance of cost savings from rainfall detention, soil testing, banding fertilizer, and laser-leveling fields. Dredging canals and removing floating aquatic vegetation would provide water quality benefits, according to extension agents, but are also more costly than beneficial to the farm business. Moreover, record-keeping and reporting are also additional costs tied to BMP adoption that several farmers noted make it more expensive to farm generally because of the labor costs involved.

At the same time, increased TP loads should be interpreted cautiously in terms of farm management. Many of these basins had relatively low baselines and their overall contribution to the EAA TP load is small. TP load increases do not necessarily or conclusively represent poor management. They could represent a shift from sugarcane to vegetable cultivation, which are not captured by the permit data. Still, some type of ratcheting mechanism or incentive would appear to be a valuable addition to group compliance, given that STA expansion has been necessary to improve their phosphorus-assimilation capacity. The five basins where TP loads continue to be greater than three pounds per acre, which is higher than the average baseline for the EAA, provides the most striking shortcoming in failing to improve water quality. Overall, both regulators and farmers faced substantial uncertainty in whether the BMP regulations would succeed. Given this uncertainty, the widespread improvement across a majority of farms and basins demonstrates an important transition to better farm management that has occurred under collective regulations.

5. The role of collective incentives in government regulations to reduce agricultural NPS pollution

Two interconnected governance challenges for agricultural NPS pollution are (1) the lack of locally shared consequences among farmers from their water management (Stern 2011) and (2) that individualized regulations can generate resistance rather than greater BMP adoption (Barnes et al. 2013). This study has demonstrated that collective regulatory incentives play a key role in tackling both of these problems simultaneously. The threat of livelihood risks, especially in the form of lost farmland, is critical to motivating farmers to opt for group compliance and heightening awareness of their water management. From a theoretical perspective, this potentially substitutes for the lack of mutually experienced feedbacks in other common-pool resource contexts, where the consequences of overuse or free riding are often salient. While the lawsuit offers a (contentious) start, the group compliance and consultative approach between farmers, extension agents, and regulators draw crucially on aspects of sharing information, social acceptability of required practices, and farmer monitoring of rainfall detention. Individualized compliance and centralized rulemaking would lack these critical incentives that underpin BMP adoption. Similarly, individualized subsidies for voluntary-only approaches also fail to encourage farmers to work together at regional scales, which limits the potential for social norms to change.

Despite the improvements in Everglades water quality, the interactions between judicial, legislative, and local water institutions governing EAA water management mean the collective regulatory approach in the Everglades may differ substantially from other situations of NPS pollution. The dominance of a single industry with a reasonably flood-tolerant crop (i.e. sugarcane), the interconnected drainage system and hydric soils that create interdependent water management needs, and judicial enforcement may be unlikely elsewhere. Despite these context-specific elements to the Everglades, two aspects stand out as relevant to other agricultural NPS contexts: (1) the importance of feedbacks in making water quality salient and (2) processes that legitimize the need for action and increase social acceptance of BMP adoption.

Greater attention to and use of monitoring data is needed to make the problem of water quality salient for farmers *at the farm scale*, which includes demonstrable evidence that BMPs can effectively reduce nutrient runoff without greatly reducing crop yields. In the EAA, the most compelling evidence was the reductions in TP loads after the first year of regulations, where crop yields were not diminished. This was more important than the recommendations of credible EREC extension agents advocating that rainfall detention would be effective. Farmers noted that the regulations forced them to pay closer attention to their management, while the basin-level monitoring provided valuable feedback on the effectiveness of the BMP implementation. These dynamics are consistent with the importance of "focusing events" that heighten awareness about water quality (Prokopy et al. 2014) and the value of monitoring data in different forms. For example, watershed efforts in Australia's Murray-Darling basin have used a water quality scorecard to track improvements (Patterson 2017).

The interplay between focusing events and feedbacks is an area that deserves further attention by researchers. At a minimum, it seems clear that focusing events, such as the threat of regulations, may be just as likely to secure farmers' attention on how to protect their interests as improving water quality, which was the case in the EAA. Awareness of NPS pollution appears to be growing among farmers, however. Recent research indicates that 80% of U.S. farmers in Iowa would support making nutrient control a criterion for subsidy eligibility in U.S. farm policy (Arbuckle 2013). Evidence that is more specific to individual farms would be useful in dealing with the heterogeneity of farmers in any given community and allow agricultural extension or agri-environmental officials to tailor their messages based on more specific circumstances (Blackstock et al. 2010). Where regulations could provide a nuanced role between untargeted voluntarism and inflexible, unfunded mandates would be to require farmers to trial one among several different BMPs, such as cover crops, with some additional insurance during the trial period to address financial concerns around potential yield losses. This could provide time for farmers to see the feasibility of these practices firsthand

and potentially allay fears or provide clarity on farm-specific barriers. If combined with collective incentives, peer-to-peer information sharing could help to improve knowledge around implementation and potentially lessen some resistance by providing an opportunity for social norms to adjust to new practices.

Lastly, increasing the legitimacy for and social acceptance of BMPs appears to be an essential component in shifting practices that current agri-environmental policies largely overlook. Potentially, the key aspect is legitimation, where new justifications are formed to make harmful practices less acceptable or needed changes more acceptable (Del Corso et al. 2017). For example, McGuire and colleagues (2013) found that farmers re-tested water quality based on their initial disbelief of a governmental pollution designation. This re-testing provided valuable credibility in justifying the need for reducing fertilizer application. Even if farmers accept the need for BMPs, adoption still needs to occur in ways that are socially acceptable. Burton and Paragahawewa (2011) argue that existing policies fail to draw on farmer reputations in a meaningful way. Inflexible prescriptions potentially undermine a key aspect of devolving implementation responsibility to farmers – the pride associated with demonstrating one's skill at farming. In the EAA, the issues of pride and peer pressure were important motivations, but which functioned alongside other socially acceptable justifications, such as saving money from reduced costs. Salience and legitimation offer potentially generalizable findings across many agricultural contexts. Future research should further explore how government policies, such as collective regulatory approaches, could better draw on and construct common priorities within the farming community by addressing salience and legitimacy together to protect water quality.

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