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Article

From Top–Down Regulation to Bottom–Up Solutions: Reconfiguring Governance of Agricultural Nutrient Loading to Waters

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Abstract: Animal agriculture is shifting toward larger farms and regional agglomerations in many countries. In step with this development, manure nutrients have started accumulating regionally, and are leading to increasing eutrophication problems. Nevertheless, the same trend may also prompt innovations in manure treatment. For example, Valio Ltd (the largest dairy processor in Finland) is planning a network of facilities that would remove water from manure, fraction the nutrients in it, and produce biogas from the excess methane. One of the main hurdles in developing this technology is that the current regulatory framework does not support a shift from diffuse loading, which is seen in the traditional application of manure on fields, to point-source loading; the regulations may even prevent such a change. This article analyzes a governance framework that addresses this dilemma in EU–Finland, and discusses how the governance described could curtail the nutrient loading of agriculture to waters. The approach is based on adaptive governance theory. We argue that traditional top–down regulation, which emphasizes food security, contains serious shortcomings when it comes to managing agricultural nutrient loading to waters, and that the current regulatory framework does not necessarily have the adaptive capacity to facilitate new, bottom–up solutions for manure treatment. Interestingly, the strict water quality requirements of the EU Water Framework Directive (2000/60/EC) open new windows of opportunity for such solutions, and thus for improving the overall sustainability of animal agriculture.

Keywords: adaptive governance; regulation; EU law; animal agriculture; nutrient loading; eutrophication; manure treatment; water protection; food security

1. Introduction

Eutrophication resulting from excessive loads of nitrogen and phosphorus to surface waters causes nuisance and economic damage to societies around the globe. For example, outbreaks of mass algal blooms have led to outright financial losses for communities that rely on lakes or rivers as sources of drinking water. Notable blooms have taken place, for instance, in the Baltic Sea, Lake Erie in North America, and Lake Taihu in China [1–4].

The main anthropogenic source of nutrient loading is food production. Crops are produced in large, open areas prone to stochastic weather events, leading to surface runoff and the subsurface leaching of nutrients. In Finland, as in many other countries, animal agriculture is shifting toward

larger and more professional farms agglomerated in certain regions. This development is having an unintended consequence: manure nutrients have started accumulating in those regions, potentially leading to massive problems from nutrient loading [5,6].

When the eutrophication of surface waters became an environmental issue, regulatory machinery emerged to curtail nutrient loading. Current environmental laws, such as the European Union (EU) Industrial Emissions Directive (2010/75/EU), require industrial operators to obtain environmental permits for activities causing point-source pollution. The permits set limit values for nutrient loading that can be monitored with high accuracy and without excessive costs. Technical solutions and substantial investments in abatement technologies have followed apace. As a result, point-source loading has been reduced dramatically. In the Baltic Sea, the external loading of phosphorus—the main driver of blue green algae blooms—has decreased by more than 50% from its peak levels in the 1980s [7].

However, this success in reducing point-source loading has not been reflected in the water quality improvements in the Baltic at the scale desired [8]. Accordingly, any regulatory or technical innovations that would improve the utilization of manure nutrients, and thus reduce diffuse-source loading, would have considerable significance. The scale of the problem is substantial. In Finland, manure originating from production animals contains around 20,000 tons of phosphorus, which is about 75% of the phosphorus in the total biomass of the country. Currently, the field application of manure and the uptake of crops are principal mechanisms abating nutrients.

Interestingly, the same emergence of larger and regionally centred animal farms causing the nutrient problem might also provide solutions. Larger unit sizes and regional agglomeration provide economic returns to scale that may enable larger investments and energize timely innovations in collaborative networks, opening new windows of opportunity in manure treatment and its regulation [9,10]. In Finland, for example, Valio Ltd (the largest dairy processor in the country) plans to establish a network of manure treatment facilities that would produce biogas as well as fraction the nutrients in and remove the water from manure in an economically feasible way [11]. In examples from other countries, the Irish BHSL offers large-scale solutions for collecting energy and nutrients from poultry litter, while Perdue AgriRecycle operated a massive pelletizing facility on the Delmarwa Peninsula from 2001 to 2017 [12–14]. Such developments make it possible to sever the pernicious link between spatially agglomerating animal operations and regional nutrient loading. This in turn would drastically improve the overall sustainability of animal agriculture. In the long term, food security can only be based on environmentally sustainable food production [15,16].

Such a change in manure treatment would also alter its regulatory framework: a manure treatment facility is a point source of nutrients, which falls under stricter legal scrutiny than traditional field application, as it is a source of diffuse pollution. Regulation such as the EU Nitrates Directive (91/676/EEC) sets limits on field application, although the practice is largely governed through voluntary agri-environmental subsidy programs. By contrast, a manure treatment facility requires an environmental permit under the Finnish Environmental Protection Act (527/2014) and must fulfill, among other conditions, the water quality requirements of the EU Water Framework Directive (WFD 2000/60/EC). This shift in the applicable regulatory framework between diffuse and point-source operations creates a dilemma: while the environmental problems of intensive livestock production could be solved by converting diffuse into point-source loading, the current regulation does not support such a shift, and may even prevent it.

This article analyzes a governance framework that addresses the dilemma and discusses how the governance could curtail the nutrient loading of agriculture to waters. The approach is based on adaptive governance theory and seeks to reassess the relationship between the top-down regulation of and bottom-up solutions to the problem. We analyze how the EU–Finnish regulatory framework has managed agricultural nutrient loading, whether it facilitates emergent grassroots solutions to manure treatment and whether there are new windows of opportunity for such solutions. We use an investment plan by Valio Ltd as a real-world example to concretize our approach. The core question of the article is whether the EU–Finnish legal framework has the adaptive capacity necessary to

facilitate what is an emergent shift toward sustainable food production through bottom-up solutions. Methodologically, our article builds on legal analysis, the case study approach, and literature reviews on adaptive governance and agricultural manure management.

We conclude that traditional top-down regulation contains serious shortcomings when it comes to managing the complex environmental problem of agricultural nutrient loading to waters. Moreover, we argue that the current regulatory framework does not necessarily have the adaptive capacity to facilitate new, bottom-up solutions for manure treatment. Then again, the strict water quality requirements of the WFD open up new windows of opportunity for such solutions. Thus, finding the right balance between the nutrient abatement objectives and the regulation of adaptive bottom-up solutions is crucial to solving the nutrient loading problem. The regulatory framework should have the capacity to take into account the overall impact of manure treatment and agricultural nutrient loading to surface waters, groundwater, and the Baltic Sea, not only the point-source pollution that treatment facilities cause.

The section to follow presents adaptive governance, which forms the theoretical framework of the article. Section 3 proceeds to analyze traditional top-down legal regulations of farming activities, while Section 4 discusses emergent bottom-up solutions to manure treatment from a technical and legal perspective. The last section contains discussion and conclusions on the shortcomings of the current governance framework and how it could be improved.

2. Adaptive Governance as a Theoretical Framework

Common pool resources, such as water, are notoriously complicated to manage and govern sustainably. As Hardin famously illustrated, they attract short-sighted behavior that often leads to a collapse of the resource and ecosystem services it provides [17]. Moreover, the management of common pool resources is riddled with complexity and uncertainty [18,19]. For a number of years, the principal challenge for environmental governance has been to determine what kind of policy mix would best address complex environmental challenges such as the overuse of natural resources, climate change, disruption of nutrient cycles, and eutrophication [20]. Whereas Hardin's approach was to tackle the externalities problem with the privatization of common pool resources, or to regulate them with substantive laws, complex problems compounded by uncertainties often require a more potent solution. Both direct regulation and markets suffer from critical deficiencies in their failing to pay enough attention to emergent behavior and self-organization when seeking effective solutions to complex environmental problems [21–23].

Adaptive governance theories have emerged to address this shortcoming [24–26]. Adaptive governance has been defined as “a range of interactions between actors, networks, organizations, and institutions emerging in pursuit of a desired state for social-ecological systems” [27]. One typical feature of adaptive governance is that it facilitates institutional designs that encourage experimentation and learning among public managers and private operators [23,24,28]. In this regard, it bears a close family resemblance to collaborative governance and new governance theories, which embrace emergent behavior, collaboration between public and private actors, and learning as prominent features of environmental governance [23,27,29,30]. The links between adaptive governance and transformative governance are also evident [28].

Collaborative processes that bring together public and private stakeholders to solve environmental problems at the level where they emerge are typical examples of adaptive governance. In the Finnish context, an illustrative case is Iijoki's otva, which is a project with processes bringing together stakeholders to discuss new management approaches to social-ecological uncertainties and trade-offs between hydropower interests and the recovery of migratory fish stocks [31]. Such examples of adaptive governance have drawn especially strong research interest in the North American context [32].

With the inclusion of legal scholars, the research on adaptive governance has focused increasingly on studying the role of law in facilitating emergent grassroots behavior in managing social-ecological problems [32]. Top-down regulation has been remarkably effective in solving simple environmental problems, such as point-source pollution, in countries with the requisite political will and institutional

capacity [33]. Despite its impressive track record, the role of such regulation (law) in adaptive governance is mixed. On the one hand, emergent solutions to complex environmental problems require laws as a source of authority and a means to resolve disputes [34]. On the other, strict top-down laws regulating substantive solutions to environmental problems are commonly criticized for creating barriers to bottom-up experimentation and learning, although these would be crucial for reaching the desired social-ecological states [23]. Adaptivity is a characteristic of emergent grassroots developments, and cannot be imposed by regulation without risking major shortcoming in governance. Law needs adaptive capacity—that is, room for the private and public stakeholders to experiment with novel technologies and management approaches in dealing with complex problems, one being agricultural nutrient runoff. Law can do no more than facilitate adaptive governance [27].

The pursuit of a desired social-ecological state through grassroots behavior is contingent on two critical factors: whether the social system (law included) is prepared to facilitate such behavior, and whether there is a window of opportunity for such behavior. The windows come in many shapes and sizes, ranging from natural disasters to policy shifts, technological developments, and litigation [24,26,35]. The governance of nutrient pollution in EU-Finland currently has at least three such windows available to it: the first is the strict water quality requirements of the EU Water Framework Directive (legal window), the second is a societal shift to large-scale farming units (societal window), and the third is the development of centralized manure treatment technology (technological window). The core aim of the article is to determine whether the relevant social systems in general, and the law in particular, are prepared to make use of these opportunities.

The reason why emergent behavior is best equipped to navigate complex problems and seize opportunities is illustrated in Figure 1 below:

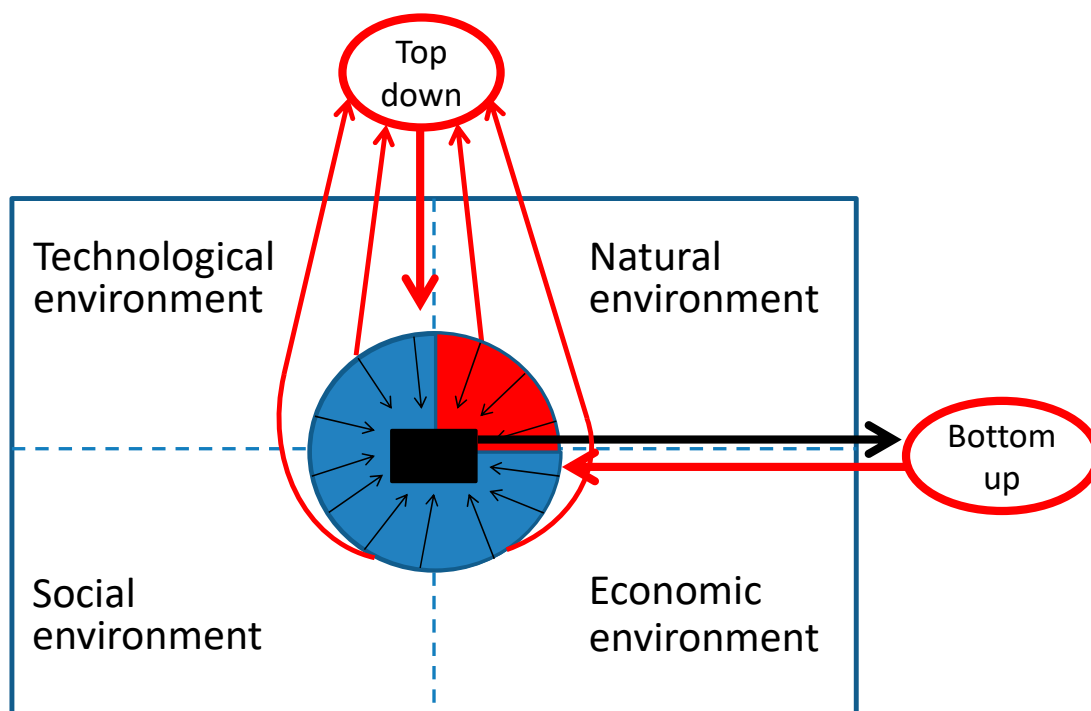


Figure 1. Top-down and bottom-up approaches. A bottom-up approach uses the regulated operator's own, continuously updated information on its interface with the operating environment. With a top-down approach, the regulator must gather the information. The faster the environment changes, and the more dimensions the operational environment has, the harder it is for the regulator to update information, and the higher the potential gains from a bottom-up approach.

An operator such as a company or a farmer (black box in the middle of the figure) is influenced by different operating environments (thin black arrows). Since information on these environments

is crucial for its economic performance, the operator always possesses the latest and best available information. In addition, the operator influences these environments through its own activities (circle around black box); the sector of the circle corresponding to the natural environment is colored red to denote the negative externalities associated with that environment.

Given the option (or mandate) to do so, an operator can identify the most innovative ways to mitigate the environmental externalities (thick black arrow in the figure) by using information on the environments. The regulator could facilitate such a bottom-up approach by enacting adaptive regulation that sets clear environmental targets, but allows operators leeway in choosing the best bottom-up means to meet those targets. However, the traditional top-down approach imposes substantive solutions, does not allow the operator such leeway, and forces the regulator to collect the information (thin red arrows) and enact detailed regulation (thick red arrow). The more complex and frequently changing the operational environment and the regulated industry are, the harder it is for the regulator to keep the information base for top-down regulation updated.

Since Dietz et al. coined the term “adaptive governance” in 2003 [24], there has been an almost exponential growth in theoretical scholarship in the field [27]. Not surprisingly, the main focus of the research is shifting toward empirical and practical examples [27]. In this article, we draw inspiration from adaptive governance theory and apply it in a context that is somewhat different to the collaborative governance examples in the literature. In the context of managing agricultural runoff, we study the role of law in supporting or hindering corporate front-runners in transformative technology. The theory does not offer a method, but a normative perspective in answering what kind of environmental governance is likely to be effective in responding to complex problems such as agricultural nutrient runoff.

3. Top-Down Governance of Agricultural Diffuse Nutrient Loading

Where environmental law in general has developed apace, the effective centralized governance of diffuse nutrient loading to waters has remained an elusive goal. This dilemma is not due to lack of effort: the past few decades have seen the EU adopt a multifaceted approach in trying to address the issue. In what follows, we focus on three of the principal top-down instruments in EU-Finland: the EU common agricultural policy (CAP), the Nitrates Directive, and the Water Framework Directive.

3.1. Economic Incentives

The EU common agricultural policy is the most cost-intensive instrument designed to check agricultural nutrient loading to waters. It is a financial tool that has witnessed a rise in environmental concerns during its existence. The CAP has three key concerns, each of which affects the shape the policy ultimately takes:

1. Trade
2. Food supply and security, and
3. The environment.

The current CAP (2014–2020) is largely characterized by flexibility and a multitude of voluntary measures [36]. While the flexibility can work toward pro-environmentalist objectives, it also makes the environmental aspects less binding and more case-specific [37]. It has even been pondered whether a greater regional or local focus might be more efficient for the purpose, promoting solutions tailored to the regions involved and paying full attention to their priorities and needs.

The most recent CAP reform was envisaged as a profound transformation toward ‘greening the CAP’ by making the instrument more environmentally friendly. However, at the end of the day, productivist discourse emphasizing farmers’ income and food security figured more significantly in the reform than, for example, the further abatement of agricultural nutrient loading [38]. Nevertheless, the CAP includes a mandatory component of environmental considerations in the direct payments, resulting in mechanisms such as crop diversification, the maintenance of permanent grassland, and ecological focus areas. “Mandatory” means that a Member State cannot opt out of implementing

the component: the funding allocated for it is 30% of each Member State's national ceiling for direct payments [39]. Most of the environmental mechanisms of the CAP are subject to the individual Member State's discretion [36].

The binding references from the CAP to the Water Framework Directive were removed in the EU parliamentary process [40]. Thus, the CAP was decoupled from the WFD, and its ambitious water quality objectives, counteracting both the CAP's environmentalism and the ability of the WFD to achieve its aims [41,42]. Bearing in mind that environmental considerations did not come up in CAP discussions until the 1990s [43], the progress of environmental concerns in the CAP has nevertheless been clear and resolute.

From the perspective of adaptive governance, the reflections on the CAP's development draw an interesting picture. The CAP has developed toward environmentalism—albeit with no clear nutrient abatement objectives—yet has also been moving toward flexibility, regionality, and tailoring policy to specific needs. All in all, the discussion surrounding the CAP emphasizes a move toward the regional or even local level as a way forward in controlling agricultural nutrient loading.

It is also worth reflecting on whether the CAP has made the most out of the window of opportunity for greening it during the most recent reform. The development of the CAP has been a constant battle between varying and also conflicting interests and their objectives, and even though environmental concerns have gained impetus, their role in the current version of the CAP is not as central as was expected [37,41]. The current CAP encompasses flexibility that favors adaptive governance, but at the same time, its environmental objectives are not clear and well-defined.

3.2. Pollution Prevention

A second key regulatory instrument addressing agricultural nutrient loading to waters is the Nitrates Directive. It dates back to the 1990s, and represents the first generation of environmental regulation designed to prevent pollution from entering the environment [43,44]. The regulatory logic in the directive is straightforward, and captures the physical and realistic aspects of the nutrient-loading dilemma.

The directive requires Member States to set the dates on which manure can be spread on fields, the aim being to balance the runoff of nutrients into nearby waters with the needs of optimal growth. The directive encourages regional tailoring of the policy by requiring Member States to designate parts of their areas as nitrate-vulnerable zones, which are subject to stricter regulations. Finland has designated the entire country as such a zone, effectively rendering moot the option of tailoring policy regionally on the basis of the intensity of animal agriculture. Member States must monitor and report the implementation of the directive and its results (Nitrates Directive, Art. 1, 2 (k) and 3–6). Thus, even though the Nitrates Directive's primary approach is not that modern, it includes some adaptive components.

The Nitrates Directive operates with process standards (manure distribution restrictions) and specification standards (regulation on nitrate-vulnerable zones). In order to employ more advanced performance standards—familiar from regulation on point-source pollution—the regulator ought to know the amount of pollution emitted from the property [44,45]. Thus, the incompatibility between agricultural nutrient loading regulation and more developed environmental performance standards is partly explained by the difficulty of establishing trajectories in the case of diffuse pollution. The issue boils down to the question of adequate information: the ability to pinpoint exact emission sources and establish trajectories is the key difference between point- and diffuse-source pollution. In the case of the latter, it is difficult to establish the robust and site-specific scientific findings required to warrant regulation [46].

The EU Industrial Emissions Directive, implemented in Finland through the Environmental Protection Act, regulates sources of point-source pollution and utilizes environmental permits to meet its targets. In order to be granted an environmental permit for an animal farm, the applicant must have enough land on which to spread the manure produced by the farm. The land may be either owned by the applicant or its use agreed upon with neighboring farms. A specific acreage is designated for each

animal type, representing the area needed for manure [47]. However, the permit does not specify the application rates per hectare; it merely guarantees that the farm has enough field acreage at its disposal. Here, the link between manure distribution and water pollution is broken: authorities establish the amount of available land, but the scrutiny is not extended to the amount of water pollution that the manure causes.

3.3. Water Quality Requirements

The CAP and the Nitrates Directive illustrate the basic challenge of regulating agricultural nutrient loading: the environmental issue is significant, but due to trajectories that are difficult to establish, legally binding regulation is difficult to justify. By contrast, the EU Water Framework Directive (WFD) is site-specific and sets clear water quality objectives for each water body. In principle, the WFD draws upon adaptive management theory and seeks to employ ecological knowledge to its fullest, accepting a holistic understanding of ecosystems and taking an integrated approach toward activities affecting them, agricultural nutrient loading included [48–50].

In the WFD, waters are categorized as water bodies and river basins. Member States are obliged to evaluate and assess the quality of water bodies. Then, the evaluations are incorporated in river basin management plans, which include classifications of environmental programs and measures adopted to achieve the environmental objectives [51]. The environmental objectives of the directive require that no water bodies may deteriorate in quality, and that they should attain good ecological status (WFD, Art. 4 (1) and Annex V).

Since the directive was adopted, there has been a running debate on whether it imposes substantive requirements on Member States in addition to procedural obligations. This issue was settled in the *Weser* ruling (C-461/13), in which the Court of Justice of the European Union (CJEU) ruled that the environmental objectives of the WFD are binding when authorizing individual undertakings [52,53]. However, since activities causing agricultural nutrient loading—for example, land cultivation—do not need authorization, they do not face administrative scrutiny, and their acceptability is never considered in the light of the environmental requirements of the WFD. Thus, while the Water Framework Directive is a prime example of regional water management in the EU, the lack of administrative oversight undermines its ambition of controlling agricultural nutrient loading.

Having analyzed the challenges of the top-down governance of agricultural diffuse nutrient loading in this section, we go on to discuss whether the structural changes in agriculture and developing manure treatment technologies might provide answers to ‘the top-down or bottom-up’ dilemma. We shift the perspective from diffuse- to point-source pollution, and analyze how the regulatory framework of EU–Finland facilitates or hinders emerging bottom-up solutions.

4. (Mal)adaptive Facilitation of Bottom-Up Solutions to Nutrient Loading

4.1. Structural Changes in Agriculture as a Source of and Solution to Manure Management Problem

Animals had multiple roles in traditional agriculture. Since inputs of food production and food itself were scarce, no resources were wasted. Pigs, for instance, transformed household waste into edible form (meat). Bovine animals provided milk and meat, but also transformed grass into nutrient-containing manure, which was used as crop fertilizer. Spatially, animals thus concentrated much-needed nutrients from forests and pasture lands onto crop fields, which were closer to farm centers.

As specialization within agriculture took hold, animal numbers per production unit increased. This development continues. Larger farms are more likely to grow than smaller ones, and smaller ones are more likely to cease production. As a result, average animal numbers per facility are on the increase [54,55].

The logic of how nutrients flow through the production system has not changed, but the increase in scale has turned spatial scarcity into potentially harmful nutrient abundance. Moreover, today, nutrients in animal feed and forage might be imported from other parts of the world. Some of the

nutrients in feed are transmitted to end products, and thus eventually to food-processing facilities and wastewater treatment plants. However, the largest share of nutrients is being found in the excrement of production animals. On the largest farms, the quantities of manure have long since exceeded the amounts economically sensible for fertilizing crops in the fields close to production facilities. As a result, nutrients accumulate in the soil and eventually leach into the surrounding environment, causing water quality problems. Throughout the developed countries, the eutrophication of surface waters is ever more closely linked to concentrated animal production [56–58].

Technically and economically, two impediments prevent the efficient utilization of manure nutrients. The first is the above-mentioned excessive quantity of manure nutrients in a given location. As it contains a great deal of water, manure is too heavy to be hauled long distances without economic losses. Excessive manure will stay within a particular radius of the source farm as a surplus [58,59]. The second impediment is the mismatch between the ratio of nitrogen and phosphorus that crops need, and the ratio in manure. Phosphorus occurs in excess in essentially all manure types and for most crops. As manure is mostly applied based on crops' nitrogen needs, phosphorus will be applied excessively, even in areas where nitrogen input and output are in balance [59–63].

Figure 2 below illustrates conceptually how the gradual increase in unit size influences nutrient surpluses:

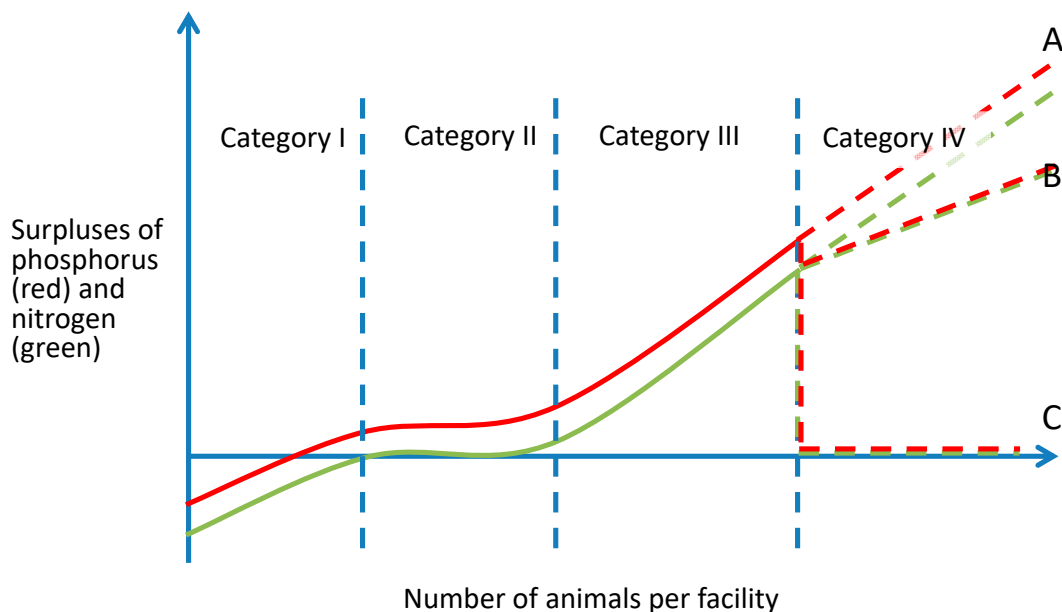


Figure 2. Influence of unit size on nutrient surpluses.

The horizontal axis denotes the number of production animals in a representative facility. Nutrient surpluses are depicted on the vertical axis, the red curve denoting phosphorus and the green curve denoting nitrogen. Nutrient surpluses change with the number of production animals. We identify the following four categories in this development:

Category I: Nutrient deficiency. There are only a few animals per farm, and the manure nutrients they generate are not sufficient to satisfy crops' agronomic needs. Manure is utilized extensively; there is even a market for (almost) untreated manure. While crop production is reduced by the lack of nutrients, soils may start accumulating phosphorus in the fields closest to the farm center. Historically, all farms operated in this category. Even today, many developing countries suffer from nutrient deficiency [64].

Category II: Stabilized production. Farming is economically sustainable, and the number of animals does not increase above that at which the quantity of manure would become excessive. Within the economically critical radius, farms are able to acquire land as they grow. That is, all manure generated at the farm center is hauled to and applied on the farm's own fields in accordance with the

nitrogen requirements of crops. Phosphorus is applied somewhat excessively because of the different phosphorus–nitrogen ratio in crops and in manure.

Category III: Manure dumping. Economic returns to scale have gradually increased the unit size. The quantity of manure generated in the regions of intensive animal agriculture is so high that, on the one hand, manure cannot be applied according to crops' needs, and on the other, excessive costs prevent the haulage of manure across different regions. Hence, nutrient surpluses of both nitrogen and phosphorus increase in step with increasing animal numbers [59,60].

Category IV: Technological breakthrough to the decoupled world. Economic returns to scale, spatial agglomeration, and vertical integration trigger technological innovations in manure management. Paths A, B, and C in Figure 2 depict alternative scenarios. Path A is the business-as-usual scenario, where surpluses continue to increase with farm size. Path B depicts a combination of separation technology that decreases the weight of manure and an innovation in feed management that decreases the phosphorus content of manure. Path C denotes full decoupling, where the weight of the manure is reduced to a level permitting long-distance hauling, and the main nutrients are fractioned. Fractioning makes it possible to apply both nutrients exactly according to crops' needs. Path C describes a situation in which manure nutrients become almost perfect substitutes for mineral fertilizers.

Development from Category I to Category III is taking place throughout the world. As there are currently no drivers in the markets that would mitigate the accumulation of manure nutrients, entering Category IV seems like the only viable option to regain sustainable animal production.

To sum up, there is an urgent need to decouple nutrient surpluses from intensifying animal agriculture—that is, to move into Category IV (C), following Path C in Figure 2. As described in the introduction, the firms operating in the industry are developing the necessary technologies for that purpose. In the following, we analyze whether water protection regulation is encouraging or hindering the implementation and further development of such technologies. Using the example of Valio Ltd's planned manure treatment facility, we illustrate the regulatory stumbling blocks in moving from Category III to full decoupling, as depicted by Path C in Category IV.

4.2. Regulatory Incentives for and Stumbling Blocks to Manure Treatment Facilities

Valio's facility, to be built in Nivala, a municipality in Northern Ostrobothnia, offers a case showing how nutrient surpluses and intensifying animal agriculture could be decoupled in many regions. The plant will treat manure collected from nearby dairy farms and produce fertilizers and biofuel from it. The facility has been designed to treat a maximum of 19,500 tons of sludge manure, and will produce 2400 tons of solid fraction (phosphorus), 3500 tons of liquid fraction (nitrogen and potassium), and 650,000 m³ of biogas per year. The solid fraction will be refined into phosphorus fertilizer fractions, and the biogas will be refined into traffic fuel [65].

The municipality granted Valio an environmental permit for the facility in spring 2018 based on the Finnish Environmental Protection Act [62], but Valio retracted its permit after a few months to make changes in the plans [65,66]. Valio has reapplied for an environmental permit, and the permitting process has begun.

The facility will cause point-source pollution in the form wastewater, air, and noise emissions [64]. From a legal perspective, the wastewater emissions pose the biggest challenge. The facility will produce a maximum of 12,000 m³ wastewater per year. Even after treatment, the wastewater will contain ammonium nitrogen (maximum 20 mg/L) and nitrogen (maximum 20 mg/L) [64].

While diffuse pollution from agricultural fields is loosely regulated (see Section 3), point-source pollution from a manure treatment facility must meet the strict legal requirements of the Water Framework Directive and other legislation in EU–Finland. In a significant development, in 2015, the Court of Justice of the European Union (CJEU) issued a ruling—the Weser (C-461/13) ruling cited above—providing an interpretation of the environmental objectives of the WFD. The court first declared that unless a derogation is granted, the Member States must refuse authorization for an individual project where it may cause a deterioration of the status of a body of surface water or where

it jeopardizes the attainment of good status. Second, it stated that there is deterioration of the status as soon as the status of at least one of the quality elements falls by one class, even if there is no fall in classification of the body of surface water as a whole.

Following the ruling, if the nutrient emissions of a manure treatment facility jeopardize the achievement of the environmental objectives of the WFD (non-deterioration and good status), the first option is to minimize the emissions. Additionally, the Finnish Environmental Protection Act requires the use of the best available technology (BAT). However, even if the facility fulfills the BAT requirements, the emissions may still jeopardize the strict environmental objectives of the WFD, in which case achieving the objectives could require technically unfeasible or disproportionately expensive wastewater treatment measures. We do not have enough knowledge as yet on Valio's planned facility to assess the feasibility of taking measures that go beyond the BAT requirements.

The second option under the directive is to offset emissions by taking compensatory measures in the receiving water body or in its drainage basin. In Valio's case, diffuse loading to the recipient water body may decrease substantially when manure is treated in the facility and not spread on the nearby fields. However, the Finnish environmental permit system does not recognize nutrient offsetting. The Environmental Protection Act aims to prevent and control pollution, not to manage the combined effects of different activities through offsetting. While diffuse pollution to the receiving water body may decrease substantially with the construction of the facility, such positive overall impacts cannot be considered in environmental permitting [67].

The third option is to apply the derogation regime of the WFD. Article 4(7) provides a possibility to derogate from the environmental objectives due to new activities, but it can be applied to nutrient pollution only in cases where the status of the receiving water body (or, in light of the Weser ruling, one of its quality elements) deteriorates from high to good. In addition, a derogation requires that the modifications to a water body are to be made for reasons of overriding public interest, and that there are no significantly better environmental options to reach the objectives of the activity [68]. Thus, the possibilities to derogate from the environmental objectives of the WFD in the case of the planned manure treatment facility are rather limited.

All in all, while the WFD opens a window of opportunity for new manure treatment technologies by requiring EU Member States to achieve good environmental status for surface waters, it also poses legal challenges. Even where the net impact of a biofacility on the quality of water bodies would be positive, the directive does not allow (unless a derogation is granted) local point-source emissions that would jeopardize the environmental objectives for a single water body. What is more, the permit system of the Finnish Environmental Protection Act, which is largely based on the EU Industrial Emissions Directive, fails to consider the combined effects of nutrient loading on a river-basin scale, for instance.

5. Discussion and Conclusions

The management of agricultural nutrient loading is changing in Finland due to new opportunities to treat manure and produce fractioned fertilizers and biofuel from it. While this article has not assessed the environmental impacts of such developments from a scientific perspective, it is clear that new technologies provide a promising opportunity to abate agricultural nutrient loading to inland, coastal, and marine waters in regions where intensive animal agriculture causes nutrient surpluses. However, the challenge is whether the regulatory framework can adapt to the change from diffuse-to point-source pollution and support emerging bottom-up solutions such as Valio Ltd's manure treatment facility.

The current top-down regulatory framework in EU-Finland has serious shortcomings when faced with the task of managing the complex environmental problem of agricultural nutrient loading to waters. The regulation on the field application of manure is loose and ill-coordinated with the environmental permit system. It places greater emphasis on food security and farmers' income than the abatement of nutrient loading. One part of the problem is that the agricultural sector consists of

numerous operators, whose combined environmental impact is clear but whose individual emissions are difficult to verify.

New opportunities to manage agricultural nutrient loading through bottom-up solutions have emerged with the structural change in agriculture, new manure treatment technologies, and the strict requirements of the EU Water Framework Directive. However, the current regulatory framework has only limited adaptive capacity, making it ineffective in facilitating these solutions. Moreover, while the WFD may open a window of opportunity for bottom-up solutions, this is likely a narrow one, given that the instrument's focus is on single water bodies. For example, if the emissions of a manure treatment facility cause the status of a water body's quality element to deteriorate—that is, the ratio of one of the quality elements falls below the level for the current class—the facility cannot be granted a permit without a derogation, even if it has positive combined effects on waters.

Finding the right balance between the nutrient abatement objectives and the regulation of adaptive bottom-up solutions is of the utmost importance in solving the nutrient-loading problem. It is a challenging task that relates to the regional scale of the problem. In addition to considering the local-scale environmental impacts of a manure treatment facility, the regulatory framework should be able to take into account the overall effects of such a facility on nutrient loading at the national and river basin levels. This improvement would require adjustments in the regulatory framework of EU–Finland.

The economic viability of manure treatment facilities depends on three aspects closely linked to the regulatory framework: operation costs, sources of raw materials, and markets for products. The operation costs depend partly on the pollution prevention requirements; pollution control must be based on the best available technology, which takes the economic costs into account. Access to raw materials could be enhanced through animal farm permits that require—or at least allow—manure to be treated instead of being spread on fields. Regulation could also advance markets for products by, for example, advancing biogas use in public transport and requiring the use of organic fertilizers in addition to chemical ones.

Finally, the new manure treatment technologies open up possibilities to combine food security with environmentally sustainable food production. While the aim is that “all people, at all times have physical, social and economic access to sufficient, safe and nutritious food” [69], there is also an urgent need to reduce the environmental impact of food production. These technologies also provide a timely reminder of the water–energy–food nexus approach [70,71]. The treatment of manure is required for protecting waters from the impacts of food production. The end product is a combination of fertilizers and biogas, the latter being used for energy. Thus, the new, bottom-up solutions can greatly advance water, energy, and food security, and effectively combat eutrophication and harmful human-induced climate change.

From a theoretical perspective, our article illustrates that adaptive governance theory has much to give also in contexts that expand on, or even deviate from, narrowly defined collaborative governance arrangements. The development of Valio's centralized manure treatment technology is a good example demonstrating how law can fail in its ecological goals by imposing ill-advised limitations on the grassroots implementation of ecologically sustainable technology.

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