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System Merits or Failures? Policies for Transition to Sustainable P and N Systems in The Netherlands and Finland

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Abstract: Nitrogen (N) and phosphorus (P) cycles are absolutely vital in maintaining sustainable food systems. Human activities disturb the natural balance of these cycles by creating enormous additional nutrient fluxes, causing eutrophication of waterways and pollution in land systems. To tackle this problem, sustainable nutrient management is required. This paper addresses sustainable nutrient management in two countries: The Netherlands and Finland. We adopt a critical perspective on resource politics, especially towards opportunistic policy strategies for the pollutant management of N and P. Two research questions are considered. First, what are the key systemic and policy failures that occurred in the N and P systems in the Netherlands and Finland between 1970 and 2015? And second, which lessons can be drawn when addressing the policy responses in the two countries to cope with these failures? The cases are analyzed within Weber and Rohracher's framework that addresses "failures" preventing sustainable transitions. The results show that a number of failures occurred, besides market failures (over-exploitation of the commons, externalization of costs): lack of directionality, policy coordination, institutions, capabilities, infrastructure, demand articulation, and reflexivity. Policy responses in both countries resulted in ponderous policy frameworks that were adequate to tackle nutrient problems from the industrial sector and municipalities. However, both countries provided only a moderate response in terms of system-wide integrated policy frameworks to cope with sectoral-transcending issues. The agricultural use of N and P, in contrast to detergents, has not been subjected to strong regulatory measures.

Keywords: sustainable transition; nitrogen; phosphorus; environmental policy; policy failure

1. Introduction

Meeting the growing demand for food without further undermining the integrity of the Earth's environmental systems is an issue that requires serious attention [1,2], as agricultural systems are major forces of global environmental degradation [3]. It is considered possible to meet the food security and sustainability challenges, but only if considerable changes are implemented in nutrient and water management [4].

In this paper, we address the sustainability transition of nutrient management in food systems. Nitrogen (N) and phosphorus (P) have received less attention in the sustainability transition literature, even though they are of the greatest importance to sustainable food systems. Human activities disturb the natural balance of N and P cycles by creating enormous additional nutrient fluxes, which accumulate in the wrong places, causing eutrophication of waterways and pollution in land systems; additionally, N adds to the number of greenhouse gases in the atmosphere [5].

Inert N in the atmosphere is converted into a reactive form through the Haber-Bosch reaction and biological fixation. The Haber-Bosch process, in particular, has been responsible for an enormous surplus of reactive N in the atmosphere: each year 121 million tonnes of atmospheric N are converted to reactive streams for human use. This appears to far exceed the critical boundary, regardless of the uncertainty surrounding any precise estimate [6,7].

P is mined from limited edaphic deposits. This process is problematic because it consumes a great deal of fossil energy; moreover, P is a finite resource. It is comparable to fossil energy in the sense that one cannot mine all the economically exploitable resources [8]. P scarcity may have serious implications, like market failures or even warfare, which might endanger future food security. If global food security is to be guaranteed, P boundaries must not be exceeded [9,10].

Most environmental problems are fundamentally social and policy-related, concerned with managing consumption and production systems. Most likely, this also holds for problems that have to do with N and P. The management and use of N and P, however, have received surprisingly little attention by political scientists. Conversely, studies of N and P material flows have hardly paid any attention to the role of actors (although a method exists that combines the two [11]).

This article explores policy making in relation to the sustainability management of N and P chains. Nutrient management implies the management of nutrients to achieve both agronomic and environmental targets. To be effective, economic and environmental goals must be coherent, flexible, and controllable [12]. In this article the transition towards sustainable nutrient management is analyzed comparing two countries, the Netherlands and Finland.

Two research questions are addressed. What are the key systemic and policy failures that occurred in the N and P management systems in The Netherlands and Finland between 1970 and 2015? And which lessons can be drawn when addressing the policy responses in the two countries to cope with these failures? The article seeks to assess whether there are major differences or similarities between the countries. It critically analyzes the development of the relevant policies and institutional frameworks, addressing whether "systemic" and "policy failures" (concerning N and P loading problems) have been solved to the extent that the problems decrease in intensity. The concept of "system failure framework" [13] is used to analyze the appropriateness of policies and institutional frameworks to foster sustainable transition in regard to P and N systems. Ever since Arrow [14] acknowledged that even perfect competition does not lead to an efficient allocation of resources, market failures, and later, structural system failures approaches [15] have been used as concepts to analyze innovation systems and policy justification to foster innovation [16]. However, since sustainability transitions are inherently normative, it is important to identify not only failures to innovate but also failures of the system itself [13].

The article is structured as follows. Section 2 addresses the theoretical notion of "failures" that prevent sustainability transitions from occurring. Special attention in this section is paid to the "failures framework" described by Weber and Rohracher [13] as an integration of the multilevel perspective (MLP; [17]) with technical innovation systems (TIS; [18]). Section 3 addresses research design and methodology, which is a comparative case study research design of least-similar cases. Section 4 presents the Dutch case study, the Finnish one, and the results of the comparative analysis. In Section 5 (Discussion), the results are positioned in the academic debate on sustainable transitions failures (including an assessment of the Weber and Rohracher framework as a suitable analytical tool with which to analyze system and policy failures in sustainable transitions). The paper ends with a concluding section.

2. Theory: Systemic Failures Preventing Sustainable Transitions

In their exposition of the conceptual work of Woolthuis *et al*. [15], Weber and Rohracher [13] developed an analytical framework to describe structural-functional system failures in sustainable innovation systems. They contributed to the work on system failure framework insights from MLP by adding the macro-level failures that address public policies designed to foster sustainable transformative change. This amendment captures systems as a whole, and involves an analysis of whether actions at the micro level sufficiently address the system transformation [19]. This is in line with the innovation systems academic tradition, in which the notion of "failures" has been used more commonly as a source when theorizing on how TIS mechanisms work. (Note that Johnsson and Jacobsson [18] did the same in their key publication on technological innovation systems.) In taking the notion of "failures" as the main ground for analysis, Weber and Rohracher [13] conceptually connect with disciplinary approaches in political science and policy studies that focus on societal, environmental, and particularly complex problems as the unit of analysis (e.g., "wicked problems", a descriptor coined by Rittel and Weber in 1973 [20]). As long ago as the 1970s, scholars in these fields have been developing and elaborating theories on agenda-setting, policy making and implementation, often on the basis of "wicked", complex, or ill-structured problems (e.g., [20–22]). This can be perceived as creating institutional frameworks to cope with or mitigate problems—*i.e.*, "failures"—embedded in (societal and ecological) systems. Recently, "failures" have also been receiving more attention by scholars in system understanding [23], work that endorses some of the arguments made by Weber and Rohracher.

Table 1 presents an overview of Weber and Rohracher's failures framework [13]. "Failures" should be perceived as problems [24] or systemic bottlenecks, rather than failures in terms of not being able to achieve the preset policy goals, because the policy goals as such can give rise to "failure". Having said this, we have reason to believe that system failures can breed new insights and provide new instruments to look at nutrient systems policies; the systems considered in this articles have not transformed into more sustainable ones.

Table 1. Overview of the failures framework (Weber and Rochracher, 2012 [13]).

Failure	Failure Mechanism/Operationalization
Market failures	
Information asymmetries	Uncertainty and short-term horizon strategies of private investors lead to undersupply of R & D funding
Knowledge spill-over	The "collective good" character of knowledge leads to underinvestment in basic research
Overexploitation of the commons	Public resources are over-used in the absence of institutions restricting their exploitation
Externalization costs	Externalization of environmental and social costs leads to innovations damaging these agents
Structural system failures	
Infrastructure failure	Hard institutional failure: Lack of physical or financial infrastructure due to large-scale, long time horizon, and too poor a return on investment for private investors Soft institutional failure: Lack of knowledge and science infrastructure
Institutional failure Hard Soft	Hard institutional failure: absence, excesses or shortcomings of formal institutions Soft institutional failure: social norms, values, culture, entrepreneurial spirit, trust, *etc.* can hinder innovation

Table 1. *Cont.*

Failure	Failure Mechanism/Operationalization
Interaction failure	Strong interaction failure: strong interaction leading to lock-in into established trajectories, lack of new ideas, inward-looking behavior, lack of weak ties, and dependence of dominant actors Weak interaction failure: limited interaction and knowledge exchange inhibiting exploitation of available knowledge and interactive learning
Capabilities	Lack of appropriate competencies and resources to adapt to changing circumstances and switch to alternative trajectory
Transformative functioning failures	
Directionality	Lack of shared long-term vision, insufficient instruments to guide and consolidate the direction of change, lack of targeted funding, inability of collective coordination
Policy coordination	Lack of multi-level policy coordination across different levels and between different sectors, lack of horizontal and vertical coordination, no temporal coherence, no coherence between public policies and private institutions
Demand articulation	Insufficient spaces for anticipating and learning about user needs and user uptake of innovations, absence of orienting and stimulating signals from public demand, lack of demand-articulating competence
Reflexivity	Insufficient systems ability to monitor, anticipate, and involve actors in self-governance, lack of distributed reflexive arrangements, lack of space for experimentation and learning, no adaptive policy portfolios for diversity of options dealing with uncertainty

3. Methods

A comparative case study research design was used to analyze commonalities and differences in systemic and policy failures preventing transformative change towards sustainable nutrient systems in Finland and The Netherlands, using the conceptual framework developed by Weber and Rohracher [13].

3.1. Case Selection

The empirical study comprises two case studies: The Netherlands and Finland. The two countries were selected on the basis of two criteria in which they vary considerably. The first criterion was variation in key domestic indicators of nutrient use, indicating the nutrient use intensity in the respective national economies (an overview of country-specific indicators is presented in Table 2). The second criterion is the establishment of sustainable nutrient policy frameworks, indicating public responses to the intensity of nutrient problems. Moreover, The Netherlands, being amongst the most industrialized agricultural producers and exporters in the world, has had to cope with N and P loading problems for a relatively long time (since the late 1970s). In comparison to The Netherlands, Finland has more a more extensive type of production, but due to the long coastline of the sensitive Baltic Sea and hundreds of thousands of lakes, it has had serious environmental concerns about nutrient overloading.

In The Netherlands, the problem has been framed as a manure problem, due to intensive "landless" livestock production based mainly on imported fodder [25] policies that have focused on controlling manure management, whereas in Finland it has emerged rather as a problem related to over-fertilization, due to the spatial separation of animal and crop production followed by policies addressing fertilization rates. Hence, whereas in The Netherlands 73% of nutrient inputs originate from organic sources and only 27% from mineral fertilizers, in Finland the ratio is almost equal between organic and mineral fertilizers; mineral fertilizers being nevertheless higher [26]. Due to the tangibility and scale of the problem, The Netherlands has been a pioneer in setting strict manure regulations and experimenting with managerial, market, and innovation-based approaches, while Finland has so far had no consolidated top-down system transformation projects. Thus, there is a sharp contrast in background conditions between the countries, as well as expected differences in the design of the sustainable institutional framework for nutrients that has been established.

Despite these sharp differences, we expect to find commonalities in the types of failures that prevent sustainable transformative change, which influence the design of sustainable nutrient policy frameworks. This would allow us to further elaborate Weber and Rohracher's failures framework [13]. In sum, for case selection, a "least similar" selection method was used [27].

Table 2. Key national nutrient indicators in The Netherlands and Finland.

Some Indicators in 2012	Unit	The Netherlands	Finland
GNP	Euro/person in 2012	42,193	35,928 [28]
Land area	km^2	41,543	304,331 [29]
Freshwater area	km^2		33,815 [29]
Population		16,788,973	5,426,674 [28]
Population density	Persons/km^2	404.8	18
Indicators of agricultural production			
• Milk production	Million Liter	11.675	2330.10
• Beef meat	Million kg	373.53	83.07
• Pork meat	Million kg	1331.73	186.13
• Poultry meat	Million kg	942	113.37
• Eggs	Million kg	NA	6705 [30]
Arable land	kg/ha of arable land [29]		
• cereals	%	11	50
• grassland	%	53	29
Nutrient use in mineral fertilizers			
• N	kg/ha of arable land	210	60
• P	kg/ha	20	8
Nutrient loadings into water from agricultural soil			
• N	ktonne/year	50 (2013)	30 (2014)
• P	ktonne/year	4 (2013)	1.8 (2014) [31]
Nutrient regulation: Agriculture			
• N		Total N depending on soil and crop type (150–385 kg N/ha) [32]	N from mineral fertilizer depending on soil and crop type (60–120 kgN/ha) and manure N (10–30 t/ha)
• P		Total P depending on soil P (24–50 kg P/ha/a) [33]	P from mineral fertilizers depending on soil and crop type (4–34 kg/ha) and P from manure (0–40 kg/ha)
Dominant sewage sludge disposal (2010) [34]		Incineration (100%); agricultural use (0%)	Landscaping, road construction (≈40%); agricultural use (3%)

3.2. Comparative Analysis of Failures that Prevent Sustainable Transformative Change

First or all, case histories for The Netherlands and Finland were established. Data used to construct the case study histories were drawn from secondary sources, such as academic publications (journal articles, book chapters, PhD theses), professional reports (notably by national agricultural research institutes), and government publications (such as white papers). The Dutch researchers did this for the Dutch case and the Finnish researchers for the Finnish one. After the historical case narratives for the two countries (see Sections 4 and 5) had been drafted, a comparative analysis was conducted spanning the 1970–2015 period. This involved manual coding of both case histories for the occurrence of particular "failures" according to the Weber and Rohracher classification [10], in particular, the key concepts of "failures" to prevent transformative change towards sustainable nutrient management. These types of failures were then analyzed and compared between the two countries (considering commonalities and differences). In addition, overviews of the key national nutrient policy schemes were made for the 1970–2015 period. The coding process involved two steps to safeguard quality: first, the Dutch researchers coded the case narratives and analyzed them for failures; secondly, the Finnish researchers repeated this procedure. Analysis following the coding process was done via qualitative interpretation of texts.

4. Results

4.1. Case Study: The Netherlands

The Netherlands is a very densely populated Western European country with an economically significant agricultural sector. The country is renowned for its large-scale, intensive livestock farming. It has a large dairy sector covering over 60% of agricultural land, and also produces large quantities of beef, pork, and poultry. To provide feedstock, many nutrients are imported (directly and indirectly via feedstock) and used domestically, leading to an enormous nutrient volume, notably of animal manure. Although the Netherlands is said to control point source pollution well, surface water pollution from trans-boundary sources and diffuse pollution from agricultural sources are still major problems [35,36]. The agri-food sector contributes most to domestic nutrient accumulation, of both N and P in all economic sectors. It is the import of feed products and ore for fertilizers in combination with the accumulation of nutrients in the soil that forms the main cause of the problem. Most P is imported as ore, animal feed, and food products. The majority of nutrients are exported again as livestock products, since Dutch agriculture is strongly export oriented, with Germany as the main export market. Although import and export flows are among the highest in the world (for 2012 import: 344 Mln kg N; 16 Mln kg P; export: 253 Mln kg N; 11 Mln kg P; accumulation: 91 Mln kg N; 5 Mln kg P), large quantities of nutrients accumulate in the Dutch soil due to the surplus of animal manure and excreta [37].

4.1.1. Nutrient Governance and Policies

Nutrient management in The Netherlands is mostly practiced in two sectoral domains: agriculture and water. In administrative terms, the agricultural sector falls under the responsibility of the Ministry of Economic Affairs, Agriculture and Innovation. The water sector falls under the responsibility of State Water Affairs ("Rijkswaterstaat"), which is part of the Ministry of Infrastructure and the Environment. Responsibility for environmental affairs in The Netherlands lies with the Ministry of Infrastructure and the Environment. Fostering multi-sectoral and interdepartmental cooperation has taken years to become established, as substantial institutional barriers related to departmental and sectoral competences and interests had to be overcome. Currently, national policies to reduce nutrient losses are generally implementations of common EU directives, and include many regulations. The goals, objectives, targets, and measures of these EU directives (Nitrate Directive, NECD-NH_3 Directive, and Water Framework Directive) are, however, clearly linked [38].

4.1.2. Nutrient Management in the Agriculture Sector

The nutrient debate in agriculture has a long tradition in Dutch politics, going back to the early 1960s when intensive livestock farmers were subjected to severe regulatory restrictions. Many of these regulations were dropped in the late 1960s, however. Environmental issues and nutrient management were not considered of any importance on political and policy agendas. P overloads were, in fact, only ascribed to detergents. The oversupply of manure was seen as a problem that could be solved by improved transport logistics; manure treatment was not even considered as a serious alternative [28]. Moreover, the agricultural sector—as the dominant sectoral regime—was strongly organized and accepted only agricultural stakeholders and experts. Critical environmental NGOs and the environment ministry (Vomil) were not considered serious partners. The agricultural regime acted, so to speak, as an "Iron Triangle", with little space for "regime outsiders", other visions, and beliefs [39]. (The notion of "Iron Triangle" involves a small, stable set of government and non-government actors who collaborate to control fairly narrow government programs and policies which are in the direct economic interest of each party to the alliance (in the Dutch case the agriculture sector and the Ministry of Agriculture, but excluding environmental NGOs and the Ministry of the Environment); in Iron Triangles the participants have a high degree of mutual commitment to each other, but are rather reserved towards (the entry) of "outsiders". Iron Triangles differ from "issue networks", in which larger sets of actors are involved with a quite variable degree of mutual commitment [40,41]).

In 1974, the Ministry of Agriculture published a White Paper on intensive livestock farming, and introduced new policies: manure storage banks and levies on feedstock (with revolving funds). The policy, however, was not very effective as the nutrient problem had become obvious in the late 1970s, manifested in the large-scale eutrophication of surface waters (clearly visible to the public) and threatening water quality. In 1984 a National committee ("Latijnhouwers") was established to investigate the issue. Although the urgency of the problem was manifest, the (intensive) livestock volume (in particular pigs) continued to grow (by no less than 20% between 1984 and 1986 [39]).

In 1983, the so-called "Super Levy"—implying that dairy farmers were to pay a levy for every liter of milk that was produced surpassing a particular quota—was implemented to cope with the manure problem. In addition, by 1984 the minister of Agriculture (Braks) enacted a temporary Act urging agricultural stakeholders to (finally) address the manure problem. The establishment of new pig and poultry farms and enlargement of existing ones was officially prohibited in some manure-intensive regions. Between 1985 and 1987 the (national) Steering committee on "manure problems" was tasked with designing new regulations, which would lead to an intensification of limitative manure regulations via the implementation of a complex set of new regulations [39]. In 1987, the first manure law was enacted to regulate the production of animal manure from livestock farming in The Netherlands. This law was a real milestone in Dutch agriculture. Besides the manure law, the Soil Protection Act (1986) was also enacted. In addition, compensatory provisions by regional (Provincial) governments were created to gain the support of the livestock holders, which would give some leeway in smoothing the implementation of the Act (by weakening the expected resistance from the agricultural sector). Implementation of the "Super Levy" (and its supporting policies) resulted in a stark decrease in livestock numbers (particularly bullocks). Additionally, the nutrient content (notably P) of (concentrate) feedstock decreased. Moreover, the use of N fertilizers in agriculture decreased considerably between 1986 and 1990 (a decrease of 37.4% in use; a decrease of 61.9% in surplus) [37].

In 1991, the EC enacted the Nitrate Directive, urging member state governments to take more action to foster sustainable nitrate management. In trying to protect the livestock sector, the Dutch agricultural sector lobbyists tried to negotiate less-strict regulations on N discharge. The attempt failed, however, and it would be 1995 before N was finally regulated (limiting both the use of manure and fertilizers) [35]. By 1995 the Dutch prime minister negotiated with different stakeholders, which resulted in stringent tasks for livestock farmers, "to attain a manure disposal target or lower the production volume (the latter would mean economic decline of the sector)" [39]. In fact, EU directives on N and water quality provided the necessary framework for the intensification of Dutch manure regulations. Production rights in the form of tradeable quotas and manure production rights, combined with soil emission norms and standards, dominated several rounds in the revision of Dutch manure regulation.

Until 1999 the use of N fertilizers barely declined, however, because manure policy still emphasized only cutting the use of P. In 1998 an innovative manure registration system, MINAS, was introduced to compel farmers to register the amount of nutrients they purchased and used, and how much and where they were disposed of (in fertilizer, feedstock, and manure [42]). Emissions more than the pre-set standards (called the "loss" standards) were subject to taxation, giving livestock holders an incentive to cut the use of intensive N fertilizers and feedstock concentrates [37]. By October 2003, however, the European Court of Justice ruled that The Netherlands was not complying sufficiently with the 1992 Nitrate Directive, in that the country was failing to meet the European Nitrate Directive implementation by not transforming it into national policy. In other words, the MINAS system's implementation was falling short of expectations. This led to intensification of manure policy, and the development of a new policy, using a system of usage standards for N and P, replacing the MINAS system.

Although MINAS was abandoned in 2005, the accounting system based on targets and flexible economic instruments continued to have many advocates in favor of its use, as it was considered to deliver the highest potential, at least in theory [28]. After 2006, a so-called "new manure policy" resulted in the recovery and re-use of P from waste disposal, digestion of animal manure (e.g., to produce biogas), efficient use of (concentrated) feedstock resources, improving utilization of nutrients, and improving export rates of animal manure [37]. The regulatory process culminated in 2011 in the development of a new Manure Act, putting a manure cap on all individual Dutch (livestock) farms, combined with the compulsory management of all farm manure. This Act was designed along three lines. First, a new system would be created to balance manure production and discharge at both macro- and micro-levels. Second, the amount of nutrients in manure was to be decreased by setting standards for feedstock. Third, quality products from animal manure (at the same level of artificial fertilizer qualities) were to be recognized as such in the future (animal manure products replacing artificial fertilizers). Figures 1 and 2 present time series of N and P surplus on agricultural ground in The Netherlands for the period of 1980–2013.

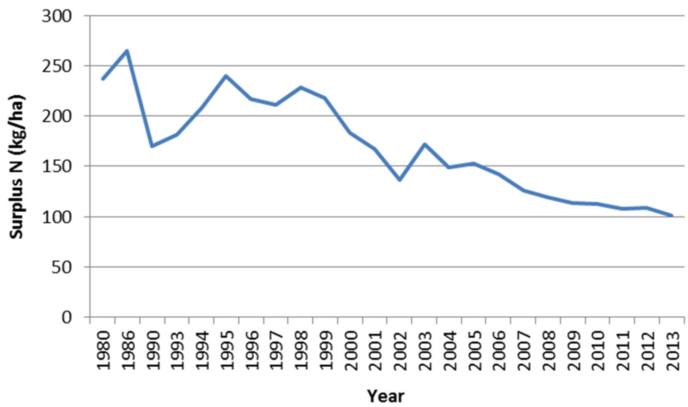

Figure 1. N in agricultural ground in The Netherlands 1980–2013 [31].

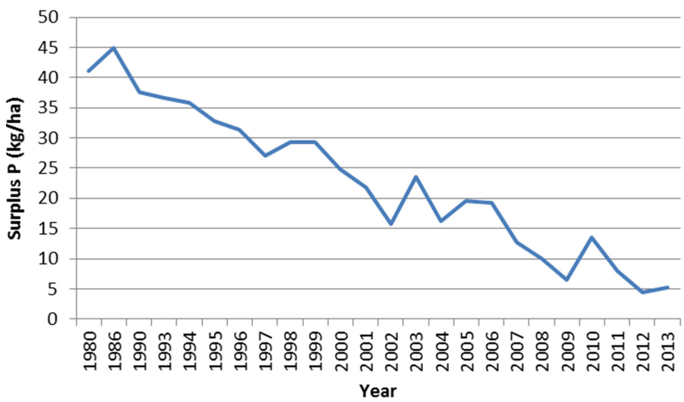

Figure 2. P in agricultural ground in The Netherlands 1980–2013 [31].

Besides the Nitrate Directive, another common EU Directive was enacted to reduce losses of nutrients. The National Emission Ceilings (NEC) Directive (enacted by the EU in 2000 and adopted by The Netherlands in 2001) aimed to decrease the negative effects of acidification, eutrophication, and ground-level ozone pollution. For all EU Member States, periodic ceilings were set for a limited set of substances. In relation to nutrient emissions from the agricultural sector, the NEC Directive was important because it set out to decrease the impact of ammonia (NH_3). Its implementation in Dutch policy was laid down in regulations (*i.e.*, the Ammonia and Livestock Act and several regulatory decrees) and included rules on the low-emission use of manure [43].

In Western Europe, Dutch manure policy is still considered very stringent; much more so than comparable Western European countries, such as Belgium and Denmark [44]. Disposal of animal manure is still considered very expensive for livestock holders (particularly those who own too small a land area to use it as fertilizer and are hence bound to sell it—or get rid of it in another legal way—and pay for transportation). It is even said to endanger their competitive position. By 2014 manure policy—following EU Directives—was primarily based on the premises of animal (production) rights and milk quota (restricting the size of livestock herds/flocks). This had the disadvantage that the wrong incentives were provided: no incentive was put in place for livestock holders to produce manure only once a responsible manure outlet had been found. In addition, the system was criticized (by central government) for impeding entrepreneurship and limiting options for the livestock sector to anticipate market developments [45]. By 2015, however, the EU dropped its policies on milk quota and animal rights, which was expected to increase problems with the intensity of nutrient use [44]. This prediction turned out to be correct, and the size of the national dairy herd grew rapidly (by 100,000 since termination of the quota); as a consequence, the national P cap was not met. By failing to meet this challenge, the agri-food sector failed to come up with a solution of its own (by not responding adequately to an invitation from the Secretary of State). As a consequence, a P "production cap" for livestock farmers (dairy) was introduced (in line with EU policy), leading to widespread panic among livestock farmers who had just enlarged their herd (and invested in farming capital assets, like innovative barns) following the termination of animal rights and milk quota. However, given the urgency of the P problem, even the farmers' organization, LTO, confirmed that "something had to be done" [46,47].

4.1.3. Nutrient Management in the Water, Industrial, and Municipal Sectors

Following pollution problems with surface waters in The Netherlands in the 25 years after WWII, the Surface Water Pollution Act was enacted in 1970. Besides pollutants considered (directly) dangerous to water quality—like heavy metals—nutrients were also regulated and codified. The Act used a permit system to achieve water quality standards with maximum pollutant concentration caps. Water quality objectives were prescribed for functional decentralized governments—known as "water boards"—in terms of reduction levels for pollutants. Following the eutrophication problems in the 1970s and (early) 1980s, N and P were considered the main surface water pollutants within the scope of the Surface Water Pollution Act. The urgency of the nutrient problems in the 1980s also led to more attention and an increased budget for innovative water treatment technology. The latter was also supported by a progressive environmental permit system urging firms to purify water and waste streams ever more stringently. By 2000, the water boards had become increasingly successful at removing N and phosphate from sewage, some of them being able to remove as much as 75% of P and more than 70% of N [35]. During the 1990s, the EU prepared the Water Framework Directive, which targeted water quality and conservation of related (aquatic) ecosystems, which was enacted in 2000 (EC/2000/60), and implemented in The Netherlands in April 2005 (by amendments in the Water Management Act and the Environment Management Act [48]). Implementation of the Water Framework Directive meant that nutrient concentrations were not to exceed certain levels, established to ensure the conservation of ecosystems, and basically required reductions in both N and P [38].

By 2012, the release of nutrients since 1986 had decreased dramatically, with 73% less N and 90% less P. Improvement of agricultural business plants and modification of production processes led to a nutrient emission decrease of 87% for N and 95% for P. In the household sector, the decrease of nutrient emissions resulted mainly from modifications to water sewage treatment installations (leading to better N and P removal rates), while the introduction of laundry detergents free of P contributed to a significant decrease in the presence of nutrients in surface waters, contributing to cutting N emissions by 67% and P emissions by 90% in 2012 [49].

4.1.4. Impact of Sustainable Nutrient Management Policies

According to the Dutch Agricultural Economic Institute, manure policy, in particular the national implementation of the Nitrate Directive, contributed positively and significantly to the improvement of water quality between 1990 and 2003. However, its contribution was considered to be rather limited thereafter [44]. The general conclusion on the manure policy and nutrient concentrations in water is that policies had had a positive effect in decreasing nutrient surpluses and had improved groundwater quality. The latter, however, was mainly due to measures related to the implementation of the Water Framework Directive. Implementation of the NEC Directive effectively reduced ammonia emissions [38].

Despite these relative successes, a more intense policy was needed to attain pre-set emission targets [50]. Although different policy strategies were followed to solve or mitigate the nutrient problem, nutrient concentrations were still considered a problem by the Dutch Environmental Assessment Agency and the Agricultural Economic Institute. From 2006 until 2010, total N and phosphate in manure increased by 15.1 and 6.6 ktonnes/year (3.2% and 3.9%), respectively, due to both increasing numbers of livestock and increasing excretions per animal. During this period, the implementation of animal production rights (*i.e.*, maximum number of livestock permitted) was at a maximum. P production (175.8 ktonnes) was higher than the ceiling (1.75%), and approximately 70% of agricultural landholdings had high phosphate levels in 2010 [36]. Evaluation of the Manure Act showed that water quality standards for N and P concentrations were not met in half of the measurement sites (and in 75% of surface water measurement sites [50]), and critical loads of N were still exceeded in the majority of Dutch ecosystems [38]. Moreover, with the current policies in place, the general protection goals of three EU Directives were not expected to be met (ibid.).

4.1.5. Innovative Trends in Sustainable Nutrient Management

Besides setting strict standards and implementing economic incentives and tax levies, The Netherlands also experimented with policies to spur innovations in nutrient management. Although many experiments have been conducted since the 1980s (including the important and effective policy innovation of the "Super Levy"), three lines of policy innovations are addressed in this paper: (1) TransForum, a Transition Management program in the agricultural sector; (2) the Nutrient Platform, a value-chain-wide network of actors advocating sustainable nutrient use; and (3) the Biobased Economy, an innovative philosophy advocating re-use of nutrients for industrial purposes.

TransForum was launched in 2004, a program of research, learning' and experimentation with sustainable transformation innovations in the agricultural sector (adopting the Transition Management approach, which was at the time adopted by central government to spur innovations on environmental issues [51–53]). The program was initiated by the Dutch government in collaboration with universities and was funded from a national natural gas revenues fund. The core idea was to learn and spur innovation via the Triple Helix approach (note that a transdisciplinary approach, which includes all stakeholders who jointly construct material flow analysis, can be viewed as a way to overcome problems related to incomplete information on flows, which in turn is important in relation to policy making, i.e. setting specific norms or standards, or quantified policy goals) (between parties representing science, industry, civil society and government): a combination of practice-oriented experimentation with new knowledge development and application, with a strong business emphasis.

An important practice-oriented experimental project in TransForum was the pilot testing of combined, integrated farming concepts. The TransForum project "reinvented" and refreshed this traditional mode of production by developing the concept of a "mixed farm" for a group of specialized farms at the regional scale. The livestock holders who were members of these groups were then expected to re-use each other's waste streams. This concept turned out to work quite efficiently and contribute rather effectively to nutrient utilization. Although the program provided a lot of new knowledge, it remains unclear whether, and if so, how this new knowledge is being or will be used. Moreover, few, if any, innovations have actually been taken into practice [54].

As of 2012, the transition to a sustainable nutrients economy is being facilitated by the so-called *Nutrient Platform*. This Platform originated from an initiative taken by seven organizations, drawn mainly from the Dutch water and waste sectors, dating back to 2008. Stakeholders from many sectors became involved: water authorities, water works, waste conversion, waste collection, sludge conversion, fertilizer producers, research institutes, nutrient management, bio-based economy advocates, ministries, and livestock holders. According to its spokesman, the Nutrient Platform applies transition management to chain-wide issues related to nutrients, especially P. It supports a cross-sectoral network of stakeholders, consisting of partners throughout the value chain involved with water treatment, waste collection, agriculture, fertilizer production, and energy production. Moreover, several government bodies and research institutes became involved. The Nutrient Platform's core tasks were to manage networks across the comprehensive multi-sectoral set of stakeholders, raise awareness about the urgency of (investments in) sustainable nutrient management, and place the issue on policy agendas in national and European decision-making arenas. By applying this strategy, the Platform strived to solve problems that have to do with economic, policy-related, and legal barriers. In 2011, the Nutrient Platform succeeded in bringing stakeholders together and having them sign a multilateral agreement: The P Value Chain Agreement [55]. This multilateral policy instrument fitted in well with the Dutch corporatist tradition of making negotiated agreements and setting voluntary (non-binding) multilateral targets involving a sectoral domain's principal stakeholders.

An important industrial issue related to nutrient recovery was the evolution of the Bio-based Economy (BBE). BBE represents a transition towards a bio-based chemical industry, with closed production chains combined with a significant reduction of CO_2 in energy supply and consumption [56]. The incorporation of BBE into the national policy agenda (2011) spurred the establishment of many research projects and pilots. In BBE, agriculture is envisioned as becoming ever more closely integrated into the overall economic system [56–58]. It is far from clear, however, what the implication of BBE will be for the nutrient problems caused by agriculture.

4.2. Case Study of Finland

Natural resources in Finland are relatively abundant and the population density is low compared to The Netherlands. Furthermore, the agricultural sector's role in the national economy is marginal, but it has had a historically significant role in local food security, and practically—until joining the EU in 1995, Finland protected the domestic market from foreign competition, having a high degree of self-sufficiency in its food supply. Agriculture is less intensive than in the Netherlands. However, Finland has an extensive coastline on the Baltic Sea, which is particularly sensitive to excess nutrient run-off and Finland is by far a net importer of N and P (total imports in 2002–2005 of N and P in food, feed and fertilizers: 198,000 t/a of N and 20,000 t/a of P; total exports: 13,000 t/a of N and 2000 t/a of P; surplus 185,000 t/a of N and 18,000 t/a of P [59]. Fertilizers are regarded as imports into the system regardless of their origin, since atmospheric N and rock P are not biologically available until they are processed into fertilizers (Ibid.). Finland has the only phosphate ore mine in Western Europe; it is owned by Norwegian Yara and produces 800,000 tonnes of phosphate, 500,000 tonnes of fertilizers, 300,000 tonnes of sulfuric acid, and 150,000 tonnes of nitric acid [60]).

4.2.1. Nutrient Governance and Policies

In Finland nutrient management largely falls under two sectoral domains: the agricultural and environmental sectors. These fall under the responsibility of the Ministry of Agriculture and Forestry (MAF) and the Ministry of Environment (ME), respectively. However, regional environmental authorities, which issue environmental permits for industries (such as wastewater treatment plants or pig producers) are subject to the Ministry of Trade and Employment (MTE). Agriculture is the main sector responsible for nutrient loadings in Finland, in 2014 accounting for 59% of P loading and 47% of N loading [61]. In comparison, point sources account for 15% and 24%, respectively, of which municipalities emitted 6% and 17%, respectively [61,62].

Environmental awareness emerged in the social and political spheres around the 1960s, when the first water conservation law was enacted [63]. Water conservation has always been an issue that is taken seriously in Finland, due to the large numbers of sensitive freshwater lakes and an extensive coastline on the Baltic Sea. Eutrophication and water pollution have historically raised the primary public environmental concerns. In response to these issues, the first municipal water treatment plants were built as early as 1910 (in Helsinki and Lahti), but it was not until the 1970s that the treatment technology leaped forward and actually improved water quality [64]. Improvement was mainly due to the stricter water management policies that were applied in a techno-economic manner to industries and municipalities [65]. The agricultural sector (as a source of pollution) had no place on the national policy agenda until the 1980s (in contrast to the Netherlands). This was largely due to the fact that the Ministry of Environment was established only in 1983. Before then, it was only agricultural interest groups that set the agri-environmental policy agenda [66]. It was only at the beginning of the 1990s that a producers' interest group (MTK) accepted the fact that the agricultural sector was a key polluter. Following this development, efforts were made to develop a coordinated agri-environmental governance framework (ibid.). This involved setting ambitious nutrient reduction targets, including lowering P emissions in agriculture by 50%.

4.2.2. Nutrient Management in the Industrial and Municipal Sectors

Nutrient loadings from municipalities and industries, especially the paper and pulp industry, have decreased since the 1970s, in large part due to successful techno-economic approach that spurred innovation in this polluting sector. Tightening pollution regulation drove major companies in the paper and pulp industry to develop better water treatment technology in attempt to achieve cost savings [67]. P reduction technology has been especially successful, as reduction rates have improved constantly ever since (from 25% to 95%), while nitrogen removal improved from 21% in 1971 to 56% in 2010 (technologically and economically much more difficult) [64,68].

Since the 1970s, nutrient management in municipalities and industries has been regulated and is currently managed by nutrient emission caps set by environmental permits granted to industries and sewage sludge treatment facilities. The polluter-pays principle (PPP) has been effective in steering towards ambitious environmental objectives (more than in agriculture). However, despite high recovery rates at treatment facilities, municipalities produce 150,000 dry tonnes of sewage sludge annually. Thus far, only 3% of this quantity is utilized in agriculture [69]. It is likely, though, that new EU-wide legislation (beginning in 2016) forbidding landfilling of biodegradable waste, will reinforce the recycling and energy use of biodegradable waste streams. New amendments to the waste legislation forbid the disposal of biodegradable waste to landfill [70].

4.2.3. Nutrient Management in the Agriculture Sector

Fertilizer use in agriculture has increased exponentially since the 1960s, peaking in the late 1980s and decreasing thereafter [64]. Before the 1960s, nutrient inputs mainly derived from manure. However, due to an expansion of mineral fertilizer use, production began to specialize regionally, and mineral fertilizer inputs outgrew nutrient inputs from manure. It took years of negotiation between the environmental sector and the agricultural sector until environmental issues were adopted on the agenda of the agricultural sector in the early 1990s [66,71]. At that time, some mitigation measures were applied, such as fertilizer taxation (in the period 1976–1994), which became mandatory during the 1980s and 1990s [72]. The fertilizer tax was initially designed to control overproduction, but in 1992 it was expanded to target nutrient pollution [73]. However, these policy instruments were abolished when Finland joined the EU. Figure 3 presents graphs on N and P surplus in Finland (kg/ha on agricultural land).

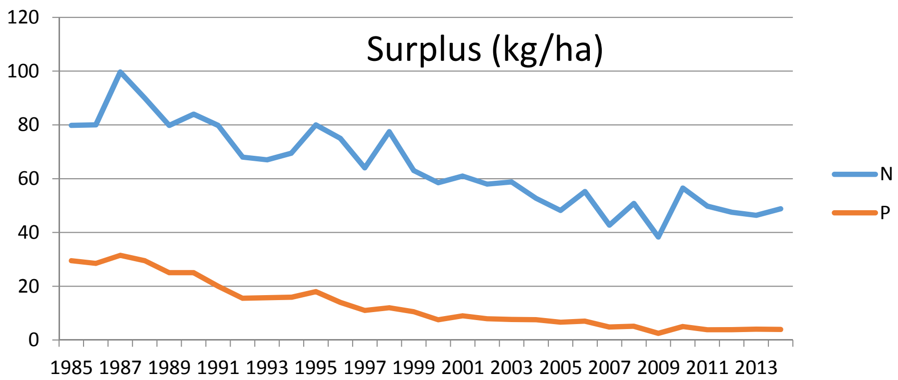

Figure 3. N and P surplus in agricultural soil (Finland) [74].

Joining the EU in 1995 can be considered the beginning of agri-environmental policy in Finland, for the Ministry of Environment and environmental interest groups finally became legitimate stakeholders in agri-environmental policy-making. Finland deployed a very broad and costly form of agri-environmental program (AES) (as per 1995), which compensated farmers for their loss of income due to the opening of the domestic market, and for the uptake of environmental measures [71]. Initially, fertilizer caps were set so high that they did not have much additional environmental effect. Furthermore, reducing the use of mineral fertilizers made (far) more economic sense than other options [66,71]. Since 1995 the terms of the agri-environmental subsidy have become more stringent. In a more recent program (covering the 2007–2013 period), over 90% of farmers and over 90% of arable land had become subject to this scheme: 70% applied to cropping farms and 30% to livestock farms [66]. The subsidy scheme can be considered as an influential steering mechanism in nutrient management. The agri-environmental subsidy scheme was mainly financed from the national budget, accounting for two-thirds of a total 345 million euros (in 2010). One third of this sum was covered by the EU.

The subsidy scheme was divided into a general protection scheme and a more specific one. The former was more lenient (in terms of permitted fertilizing rates), but also more extensive as it accounted for 85% of the farmers. The latter was more stringent; it only accounted for the other 15%. One aspect of the general protection scheme sets a baseline for mineral fertilizer use for all crops, and includes some other measures, such as a longer buffer zone than is required by Water legislation. Environmental regulations, in particular the EU Nitrate Directive (enforced in 2000) also set caps on manure dispersion, but constraints on land availability push farmers to apply as much manure as possible to a given land area, usually in greater amounts than would be essential for crop nutrition [75]. The general protection scheme was based on the voluntary agreement of individual farmers. The subsidy scheme offered a compensation based on the estimated costs of carrying out environmental measures, not on the actualized gains. Most of the basic-level measures, particularly in the first two programs, were fairly lenient and were actually quite rational, economically speaking. However, in 2012 the program was considered as "ineffective" (in actual steering capacity) and inefficient in an official policy evaluation [71,76]. In order to increase efficiency, the scheme was said to be better tailored to individual farming and regional conditions, with varying levels of support.

However, this was not possible due to EU rules regarding AE payments [72]. Moreover, it should not be forgotten that the agri-environmental subsidy comprised a significant proportion of farmers´ income.

The agri-environmental subsidy scheme had a dual effect. According to the farmers [66], the subsidy program has directly influenced agricultural practices, and has contributed to reducing negative environmental impacts. Its main achievement is considered to be lowering the nutrient balances (and in turn the amount of nutrients applied per hectare). However, according to the National Audit officials, the agri-environmental subsidy scheme has been ineffective in terms of steering and costs [71], and particularly ineffective in those regions with the severest environmental impact, such as the South-West coastal area [76].

4.2.4. Impact of Sustainable Nutrient Management Policies

Nutrient removal technology has effectively reduced P and N loadings (although N-containing gaseous losses have not been reduced as effectively) to water systems from industries and municipalities. However, the residual sludge is mostly used in green landscaping and is not returned to agricultural land to replace new, inert nutrient sources. The untapped potential to increase nutrient recycling is constrained by hazardous substances having little source separation in the current waste management system, some recovery technologies, social perceptions, and undeveloped markets. Nevertheless, the biggest challenge concerns the agri-food sector. Although the AES program has become more stringent, coercive policies to reduce nutrient loadings are limited to the EU Nitrate Directive. Current policies are based on voluntariness and economic compensation, and they have achieved a broad level of commitment: over 90% of farmers and farmland. The problems with policies are that they are still inadequate to incentivize change at a sufficient level and pace. First, the requirements are not sufficient for the majority of farmers (used as a very necessary additional income), and little change is incentivized and in only poorly targeted ways. Second, there is a lag time in the impact due to: (i) the nutrient reserve (especially P) accumulated in field soils; and (ii) to the internal loading in the water systems, which has become more important. Nutrient balances have decreased, and the application of N fertilizer is now perceived to be at the lowest level possible, whereas the application of P fertilizer could still be more precise regionally [72], particularly as P accumulates in soils. The most severe challenges are posed by regional segregation of cereal and livestock production, which makes recycling of nutrients by transporting them from surplus areas to areas with nutrient shortages more difficult, and the conversion of crop land to obtain a sufficient area to apply manure, and to replace small field plots. The trend of intensifying livestock production implies even larger amounts of manure concentration, with insufficient areas of surrounding land.

4.2.5. Innovative Trends in Sustainable Nutrient Management

Since the 1970s, sustainable nutrient management has been a key challenge in efforts to restore and conserve the Baltic Sea. The issue was set in a transnational environmental agenda and has also contributed to policy making. In 2010, the Finnish central government set the official goal of making Finland a model state for nutrient recycling. Consequently, it designed a comprehensive roadmap, which considers action in the entire agri-food chain, not only primary producers [69]. Whereas the development of an agri-environmental policy framework emphasized more general rural development and the maintenance of ecosystem services in rural and natural areas [77–80], "green growth" industrial advocates have identified the future potential of a (distributed; small-scale decentralized solutions) BBE (but only recently, since 2014) [81,82], which is based on the national Natural Resource Strategy for Finland, set by central government. As in The Netherlands, BBE is expected to provide economic benefits, to ensure future competitiveness and to stop degrading the environment in Finland. BBE strives to close material and energy cycles, in particular closing nutrient cycles. As a signal, the Ministry of Environment, Ministry of Agriculture and Forestry, and Ministry of Trade and the Economy have announced the setting up of a national project with the aim of inducing nutrient recycling in the near future [83].

4.3. Results of the Comparative Analysis

Table 3 presents the main commonalities and differences between the cases of The Netherlands and Finland.

Table 3. Results of the comparative analysis.

Key Commonalities	Key Differences
• P surplus successfully decreased in both countries. N surplus, however, decreased much less (in relative terms) and showed a more fluctuating pattern. • Source pollution (by industry and municipalities) has steadily, and drastically, decreased due to environmental regulations and (efficient) sewage sludge treatment technology.	• The problem framings of nutrient issues differ: in The Netherlands it has traditionally been about manure management and the livestock sector, whereas in Finland it has traditionally been about excessive fertilization.
• The agricultural sector's relative share of nutrient emissions is the greatest problem. • Agency: in both countries the agricultural sector has wielded great power in setting policy agendas, and initially strongly resisted acknowledging the problem.	• Agency in agri-environmental policy: in Finland nutrient problems were defined explicitly by two sectors: the agricultural and environmental sectors, whereas in The Netherlands this was mostly set in the agricultural sector.
• Fertilizer use in agriculture increased significantly from the 1960s onwards, but has decreased significantly since the later 1980s and 1990s.	• In the agricultural sector, the Dutch policy approach to sustainable nutrient management is more regulatory and innovation-based (the "Super Levy" and the MINAS registration system) than in Finland. Finland tends to rely on voluntary economic incentives, notably limitative subsidy schemes in agriculture.
• Livestock holders do not prioritize nutrient management, and are only influenced via regulation.	• In The Netherlands, multiple transition oriented programs have been running since the 1990s. In Finland this has appeared only recently.
• Infrastructural conditions to support optimal storage and exchange of manure are sub-optimal, in Finland due to long distances and regionally specialized cropping versus livestock keeping, and in The Netherlands due to the limited field area, and expensive transport costs.	• In Finland, municipalities have an important role in nutrient removal from sewage waters. In The Netherlands this task is administered by specialized, decentralized government bodies ("water boards").
• In agriculture, there are two dominant discourses: (i) large scale intensive farming; (ii) small-scale ecological farming.	
	• In The Netherlands, schemes have been established to encourage the exchange of nutrients between regions with excess supply and regions with a shortage of nutrients.
• Nutrient management initiatives stem from environmental NGOs, and when advocated on policy arenas met resistance from agricultural regime actors, which lasted for years.	• A sector-wide voluntary agreement has been concluded in The Netherlands between key stakeholders from economic sectors. In Finland, voluntary agreements have only been concluded at a systemic basis, and only locally.

Table 3. *Cont.*

Key Commonalities	Key Differences
• EU Directives provided additional, necessary support in delivering legitimate policy frameworks. On the other hand, the role of the EU is less supportive when one addresses the termination of milk quota and animal rights, which intensifies nutrient problems.	
• In both countries, BBE is advocated by central government as an integrated technical solution to nutrient problems, thus ignoring the option to a more systemic, structural change through breaking the regional specialization of cropping and animal husbandry.	

4.4. Drivers of Successful Nutrient Management

In retrospect, both countries have been effective in tackling point-source pollution at the end of the pipe. Environmental permit systems, together with water quality regulations and policy to spur innovation in water and waste stream purification systems, have proved to be effective in lowering nutrient emissions in industry and by municipalities. For nutrient management in the agricultural sector (in particular, regarding lowering N), however, it is more difficult to identify the drivers of change. Therefore, we focus on the periods in which substantial decreases in nutrient surpluses (of N, in particular) occurred. For The Netherlands these were the periods 1986–1990, 1998–2002, and 2004–2007. For Finland these were the periods of 1987–1990 and 1995–2005. Table 4 presents the key policy instruments and incentives that were implemented in the respective periods, and can roughly be ascribed to lowering nutrient emissions.

Table 4. Key policy instruments and incentives responsible for lowering nutrient emissions (with year of implementation).

Year	Country	Key Policy Instruments and Incentives
1986–1990	The Netherlands	Interim Act on Manure Management (1984). Manure Act (1987). Soil protection Act (1986). Levy system (production) "Super levy" (1983). Compensatory provisions by provincial governments.
1998–2002	The Netherlands	EU Nitrate Directive (1992) and EU Water Framework Directive (2000): intensification of Dutch manure regulations (1995). MINAS (manure registration system which emphasized "loss" standards and which was accompanied by manure transfer agreements; 1998).
2004–2007	The Netherlands	EU Nitrate Directive, EU Water Framework Directive and EU-NEC Directive (via implementation in national regulations). "New manure policy" (replacing the MINAS system, with usage standards for N and P; 2004). Production rights in the form of tradable quotas and manure production rights. TransForum, innovation and sustainable transition program.
1987–1990	Finland	Fertilizer taxation (in the period 1976–1994) Fallow regulations
1995–2005	Finland	EU Nitrate Directive (1992) implementation in national regulations (from 2000). Agri-environmental (AE) subsidy programs (1995).

Table 4 reveals that "successful" instrumentation for lowering nutrient emissions basically involved combinations of regulation and the use of registration and accounting systems based on targets and flexible economic instruments (like subsidy schemes and taxation). Regulations were used in multiple parts of nutrient systems: e.g., to regulate use of nutrients (as fertilizers) and to regulate disposal of nutrients (in the form of manure emitted to water or soil). Nutrient regulations were found in different domains: manure policy, water (quality) policy, and soil conservation policy. Taxation (levies) was used to influence production rights (e.g., dairy) and the disposal and transportation of manure. Progressive regulation (periodically tightening norms) was used to spur innovation in nutrient recovery and water purification technology (as well as programs specifically targeting agricultural innovations, like TransForum). When implemented, however, regulations met considerable resistance from farmers. Compensatory provisions (often offered by regional governments) were used to smooth the implementation of the more rigorous regulations by national government. Moreover, by enacting and enforcing the nitrate and water quality directives, the EU had an important role in nutrient management in both The Netherlands and Finland (also in warning these member states and forcing them to intensify national policy). Without its involvement, nutrient management by the two countries would probably have been considerably worse.

The sets of "successful" policy instruments and incentives that jointly spurred the lowering of nutrient emissions, however, do not reveal how nutrient management worked in practice. Therefore one needs to have a more nuanced view of what happened when these instruments were implemented, what problems they encountered during this process, and how they relate to Weber and Rohracher's systemic and institutional failures.

4.5. Key Failures Revealed

The sustainable nutrients cases of The Netherlands and Finland present different types of failures, both in terms of not having a "sustainable nutrient economy" ("In contrast to "nutrient management", which is often used exclusively in agriculture and water sanitation contexts, the nutrient economy involves the entire value chain of nutrients, from their biophysical form to fertilizers, to plants and animals, to food consumed, and finally to the waste and excreta disposed of by humans and then treated in sanitation plants. In addition, the term "economy" as used here refers to all the instrumental elements (e.g., policy and market institutions) that govern nutrient flows between the different parts of the value chain. In other words, for the purposes of this paper, the nutrient economy is a system of connected activities between which nitrogen and phosphorus flow to support food production and consumption." [84]) (e.g., with no more "losses" of nutrients), and having established institutional frameworks that appear to have "interwoven" inertia, falling short of recognizing the systemic, multi-sectoral, and multi-level character of the sustainable nutrients issue. Besides the obvious market failures (over-exploitation of the commons, externalization of costs), we observed failures in: directionality, policy coordination, institutions, capabilities, infrastructure, demand articulation, and reflexivity. We address these failures per item (see also Table 5).

Table 5. Results of the analysis using the "failures" framework.

Type of Failure	Implication in the Dutch and Finnish Case Studies
Directionality failure	• There appears to be no single goal on the policy agenda concerning sustainable nutrient management. Instead, there are several goals (on P, on N, on manure as such) scattered among multiple policy sub-domains and sectoral domains. • The agricultural sector, on the one hand, and industry and municipalities on the other, are viewed as the main sectors for which policy goals have been formulated. • The waste and water sector appear only loosely related to existing key policies (e.g., as a source for monitoring emissions and purification of waste streams). • Only recently in Finland and The Netherlands, have initiatives been taken to form an overarching, integrated, multi-sectoral policy agenda to address a sustainable nutrient transition.

Table 5. *Cont.*

Type of Failure	Implication in the Dutch and Finnish Case Studies
Policy coordination failure	• The long and intensive negotiations between the agricultural sector's advocates and those of the environmental movements in the 1970s and 1980s show that inter-sectoral collaboration cannot be taken for granted. Up to the present day, the discourse coalitions of agriculture (in favor of scaling and large-sized "mega farms"), and the environment (opposed to scaling and "mega farms") cannot easily be reconciled, let alone coordinated by agencies. • The sectors involved—water, waste, agricultural, industry, households—still appear to be closely organized and institutionalized within their own respective domains (these sectoral institutional inertias resemble institutional failures). • Attempts to encourage collaboration between actors from different sectors on a non-prioritized issue like sustainable nutrients encounter considerable resistance. • The lack of policy coordination, or rather the absence of a coordinated sustainable nutrients policy framework, could be a sign indicating a networking/(inter-sectoral) interaction failure.
Institutional failure	• Sector-specific institutional inertia (in particular in the agricultural sector) has an impeding impact on any cross-sectoral negotiations and policy-making. • After years of limitative regulations, in 2015, the EU lifted the caps on animal rights and milk quota, which immediately had a dramatic impact on manure production, and hence N emissions. • The problem with the Dutch agri-food sector sector exceeding the manure cap in 2015 is a clear sign that the sector is not capable of governing the issue itself (hence government interventions were again required).
Capabilities failure	• In the Dutch case, it was shown that central government bargained for less drastic national policy targets when negotiating with the EU for implementation of the nutrients directive. Not (entirely) surprisingly, a few years later the country was criticized for non-compliance with EU regulations, and was forced by the EU to abandon its domestic policy approach. • Although compliance with N and P emission caps has improved in both countries, policy goals were not met, and EU norms were even exceeded. Given the policies and enforcement capacities in place, this raises questions. • Non-compliance with manure regulations by livestock holders (notably pig farmers) is still a major issue, as sample-wise enforcement actions show.
Infrastructural failure	• Related in a sense to the capabilities failure, there are problems concerning a lack of appropriate infrastructure to store, distribute, and dispose of nutrient-intensive organic streams, especially in agriculture. • Whereas the industry, household, and water sectors succeeded in both countries in constructing and operating appropriate infrastructures, this does not hold for the agricultural sector. • Although policy responses to the severe manure problems in both countries in the 1980s spurred innovation and upscaling of infrastructure supporting manure collection (e.g., the MINAS system in The Netherlands, and later on the manure distribution optimization programs in both countries), infrastructural conditions are still sub-optimal.
Demand articulation failure	• Historical sustainable nutrient programs and policies tend to emphasize the supply side of the nutrient system (e.g., targeting livestock holders and industries with a plethora of policies). • There appears to be a lack of attention to the consumer side of the market. Both countries made little effort, for instance, to market low-nutrient products. Potentially, such an effort could go hand-in-hand with an ecological farm products marketing approach. This might be related to the proportion of people consuming ecological food products and beverages in both countries, which is rather small compared to other countries. • Large-scale retail food companies tend to have neglected sustainable nutrient management.

Table 5. *Cont.*

Type of Failure	Implication in the Dutch and Finnish Case Studies
Reflexivity failure	• Due to its complex, multi-sectoral nature, the sustainable nutrients issue appears poorly recognized and poorly monitored, particularly by those setting political and policy agendas. Vested sectoral interests and perceptions are hard to replace, and only a handful of "frontrunners" within sectors are involved, stressing issues that appear related to sustainable nutrient management. • If one is to take the nutrients issue seriously one has to acknowledge its multi-sectoral drivers and interconnectedness. It appears that reflection on the issue has only started now that P is becoming increasingly scarce and expensive and N becomes more of a serious problem to (intensive) livestock holders and water boards. • There is no such thing as an (integrated) sustainable nutrients innovation program, as innovation projects are all carried out within their own respective sectors. • Aside from the successful (water and sludge purification) innovation in the industrial sector, there is little evidence of upscaling successful low-nutrient best practices (e.g., innovative farm barns with conveyor belts to capture "fresh", methane-rich manure).

4.5.1. Directionality Failure

There appears to be no single goal on the policy agenda concerning sustainable nutrient management. Instead, there are several goals (for P, N, and manure as such) scattered among multiple policy sub-domains and sectoral domains. In both countries, the agricultural sector on the one hand, and industry and municipalities on the other hand, are viewed as the main domains for which policy goals have been framed. However, they address only one part of the nutrient value chain. In the policy frameworks, the waste and water sector appear only loosely related to existing key policies (e.g., mostly as a source for monitoring emissions). Moreover, in Finland and The Netherlands, initiatives have only recently been taken to form an overarching integrated, multi-sectoral policy agenda to address a sustainable nutrient transition, using a circular economy approach.

4.5.2. Policy Coordination Failure

Related to the directionality failure in terms of systemic parts of a system (economic sectors), is the lack of policy coordination between the different sectors. The long and intensive negotiations between the agricultural sector's advocates and those of environmental movements in the 1970s and 1980s show that inter-sectoral collaboration cannot be taken for granted. Up to the present day, the discourse coalitions of agriculture (in favor of scaling and large-sized "mega farms"), and the environment (opposed to scaling and "mega farms") cannot easily be reconciled, let alone coordinated by agencies. Moreover, currently, the sectors involved—water, waste, agricultural, industry, households—still appear to be closely organized and institutionalized within their own respective domains (these types of sectoral institutional inertia resemble institutional failures). This is, for instance, apparent in the poor Dutch implementation of the Water Framework Directive which hardly contains any measures to reduce nutrient loads from agricultural soils (as 65% of P input in surface water stems from agricultural sources) [38]. Attempts to encourage collaboration between actors from different sectors on a non-prioritized issue like sustainable nutrients encounter considerable resistance. In a sense, the lack of policy coordination, or rather the absence of a coordinated sustainable nutrients policy framework could be a sign indicating a networking/(inter-sectoral) interaction failure. The lack of cross-sectoral collaboration is problematic, as cross-sectoral collaboration has been identified as necessary for better nutrient management [85].

4.5.3. Institutional Failure

Throughout the period analyzed here, there are disincentives in sectoral policy frameworks that are highly relevant to sustainable nutrient management. For instance, after years of limiting regulations, in 2015, the EU lifted the caps on animal rights and the milk quota, which immediately had a dramatic impact on manure production, and hence N emissions. Moreover, sector-specific institutional inertia (in particular in the agricultural sector) have had an impeding impact on any cross-sectoral negotiations and policy-making. The problem with the Dutch agri-food sector exceeding the manure cap is a clear sign that the sector is not capable of governing the issue by itself (hence government interventions were again required). Another problem relates to prior failures to meet the policy goals, which have also led to increasing bureaucracy, which in turn damps down entrepreneurial experimenting and innovation in the agri-food sector. Particularly in the agri-environmental policy domain, bureaucracy increased rapidly due to tightening of requirements and monitoring norms, which have led to adverse outcomes.

4.5.4. Capabilities Failure

Although compliance with N and P emission caps has improved in both countries, policy goals were not met, and EU norms were even exceeded. In The Netherlands, emission standards were met until the early 2000s. However, non-compliance has increased ever since (in particular in 2015). Given the policies and enforcement capacities in place, this raises questions. Non-compliance with manure regulations by livestock holders (notably pig farmers) is still a major issue [47], as sample-wise enforcement actions have shown [36,50]. In addition, especially in the Dutch case, it was shown that central government bargains for less drastic national policy targets when negotiating with the EU for implementation of the nutrients directive. Not (entirely) surprisingly, years later the country was criticized for non-compliance with EU regulations, and was forced to abandon its domestic policy approach.

4.5.5. Infrastructural Failure

Related in a sense to the capabilities failure, there are problems concerning a lack of appropriate infrastructure to store, process, distribute, market, and dispose of nutrient-intensive organic streams. Although policy responses to the severe manure problems in both countries in the 1980s spurred innovation and upscaling of infrastructure supporting manure collection (e.g., the MINAS system in The Netherlands, and later on the manure distribution optimization programs in both countries), infrastructural conditions are still sub-optimal. For instance, manure distribution in Finland remains troublesome, and the same applies to upscaling innovative pro-nutrient farm barns for livestock in The Netherlands. In addition, centralized wastewater treatment, despite being efficient in collection and processing, has not been connected to considerations of circular economy and nutrient recycling to agriculture (e.g., hazardous elements such as antibiotics and persistent organic pollutants (POP) generally, and the choice of purification chemicals and technology can hamper recycling).

4.5.6. Demand Articulation Failure

Historical sustainable nutrient programs and policies tend to emphasize the supply side of the nutrient system (e.g., targeting livestock holders and industries with a plethora of policies). Moreover, there appears to be a lack of attention to the consumer side and food waste along the consumption chain, until very recently. Both countries made little effort, for instance, to market low-nutrient products and encourage cutting food waste (although food waste has recently received increased attention, with promising start-ups in both countries). Potentially, such an effort could go hand-in-hand with an ecological farm products marketing approach. This might be related to the proportion of people consuming ecological food products and beverages in both countries, which is rather small compared to other countries. Moreover, large-scale retail food companies tend to have neglected sustainable nutrient management.

4.5.7. Reflexivity Failure

Due to its complex, multi-sectoral nature, the sustainable nutrients issue appears to be poorly recognized and poorly monitored, particularly by those setting political and policy agendas. If one is to take the nutrients issue seriously, one has to acknowledge its multi-sectoral drivers and interconnectedness. It appears that reflection on the issue is only starting now that P is becoming scarce and expensive, and N is becoming more of a serious problem to (intensive) livestock holders and water boards. As a result, initiatives like the Dutch P-network (and the similarly named multilateral agreement) have been established, reflecting the inter-sectoral nature of the nutrients issue. However, even in this multi-sectoral configuration, the agricultural sector appears to be quite absent. Moreover, there is no such thing as an (integrated) sustainable nutrients innovation program, as innovation projects are all carried out within their own respective sectors. Aside from the successful (water and sludge purification) innovation in the industrial sector, there is little evidence of upscaling successful low-nutrient best practices (e.g., innovative farm barns with conveyor belts to capture "fresh" manure).

5. Discussion

Weber & Rohracher's failures framework [13] was useful to the analysis because it allowed us to qualify the numerous problems that occurred and together form considerable barriers *vis-à-vis* the establishment of sustainable nutrients management systems in The Netherlands and Finland. The added value of using the failures framework, as compared to the more commonly used problem-oriented approaches in the policy studies literature ([20–22]), is that it (a) classifies environmental problems (like the nutrients problem), more than previous conceptual approaches do (instead of framing an issue as a "wicked problem" [20]; or "poorly structured" [21]); and (b) it integrates transition and innovation studies insights into policy-oriented research). However, our experiences here are twofold: both positive and negative. The former have been mentioned, and the latter are described in more detail below.

First, the sheer amount of failure Weber and Rohracher [13] identify leaves empirical researchers with a cornucopia of choices of how to code and classify problems and challenges that appear from the data analysis. Moreover, certain "failures" appear to be interrelated. For instance, the directionality failure (lack of commonly shared vision and expectations) seems related to the policy coordination failure (which can perhaps be viewed as results of the former) and the institutional failure (for instance, as poorly aligned regulatory frameworks can be viewed as the result of a lack of directionality in the period when these policies were drafted). Both of these two failures might, in fact, have their roots in networking (or interaction) failures. The latter appear in turn to be rooted in institutionalized inertia and sector-specific interests and storylines to which the sector's main actors adhere. In a sense, the lack of a proper infrastructure that livestock holders can use to disperse and transport manure, and the lack of an infrastructure to collect and store nutrient-rich waste streams, might not be termed an "infrastructure failure", but also a result of a lack of directionality and policy (making) coordination. In sum, we believe it is mostly inter-sectoral communication and collaboration, and the general absence of a nexus approach in managing deeply-rooted contradictions between economic and environmental goals that appear to be challenges that make developments leading to the framing of an integrated sustainable nutrients policy framework troublesome.

Second, although the use of key notions and concepts from the discipline of policy studies appears to be absent, many concepts from this literature do appear, in our view. For instance, the network/interaction failure appears conceptually to be related to a lack of network management [86]. Other key concepts (which were in fact quite important in understanding policymaking in the domain of nutrients), like "discourse coalitions" [87] or "advocacy coalitions" [88], however, appear to be absent from the framework. In a similar vein, the failure of coordination between different sectoral domains might perhaps be due to a lack of "boundary work" [89] or "boundary spanning" [90]. Perhaps Weber & Rohracher might wish to consider "importing" some failure notions related to these areas of the literature into their framework. Another key concept that is missing is leadership, or to put it in policy studies terms, the "policy entrepreneur" [91,92]. The same holds for the policy literature trying to find explanations for the phenomenon of "policy innovations" [93,94]. This emerging conceptual field—empirically developed in the area of the environmental issue of climate change—would be of great importance in furthering insights into the institutional domain regarding Weber and Rohracher's failures framework [13]. In a similar vein, adding insights to the institutional dimension using Ostrom's Institutional Analysis Design framework [95] might be worth considering. This would be of particular use in understanding "failures" in operational sustainability policy implementation processes. Furthermore, there might be room to expand the conceptual scope of the failures framework when looking into earlier attempts in the policy studies literature to integrate key concepts in integrative frameworks; for instance, the Policy Arrangements Approach [96], or the "Governance Assessment Tool" [97]. Weber and Rohracher might wish to explore synergies between their failures framework and these integrative conceptual frameworks.

An additional conceptual problem we encountered during our analysis of the sustainable nutrients cases was the fundamental issue of what "failures" actually are. Do they relate to failures in a physical sense (e.g., "outcome": over-emission of nutrients causing severe environmental problems such as eutrophication) or rather failures in the policy/institutional framework causing negative side-effects when implemented (e.g., "output": selecting the wrong set of interventions to solve a perceived nutrients problem; [21])? In sum, we wonder what the "dependent variable" is when using the sustainable transitions failures framework in empirical research.

Finally, as a suggestion to apply the comprehensive set of "failures" in empirical research, Weber and Rohracher might consider introducing a concise classification of failure types that allows problems to be structured, which perhaps might one day permit researchers to conceptually (and empirically test) relate (and perhaps predict) the use of certain types of governance modes and "policy mixes" (in a way that perhaps resembles "wicked problems" in relation to a non-hierarchical networked governance mode [86]).

6. Conclusions

This article started with two research questions: (1) what are the key systemic and policy failures that occurred in the N and P systems in The Netherlands and Finland between 1970 and 2015?; and (2) what lessons can be drawn when addressing the policy responses in the two respective countries to cope with the previously mentioned failures?

In answering the first research question, besides the obvious market failures (over-exploitation of the commons, externalization of costs), our analysis revealed that nutrient management of N and P has failures that relate to: directionality, policy coordination, institutions, capabilities, infrastructure, demand articulation, and reflexivity. Certain "failures", however, appear to be interrelated. We perceive that the majority of them, in the end, relate to a lack of directionality and a lack of cross-sectoral (policy) coordination. Due to these persistent problems, attempts to design an integrated sustainable nutrients policy framework encounter considerable sectoral challenges. The problem of interconnected failures, first and foremost, has to do with policy coordination, institutional inertia, and the poor way in which the agricultural sector is involved in (integrated) nutrient management. The sector appears inflexible, and hard to approach by nutrient advocates from other sectors (e.g., water, waste, and environment).

However, history has shown that the agricultural sector is sensitive to programs using strict regulation and flexible economic incentives. Perhaps attempts to align the agenda of the agricultural sector with other sectors (water, waste) can be undertaken when instrumentation also includes these types of policy instruments (which are less voluntary), alongside the rather "soft" instruments that have already been used, like establishment of the P network and the multilateral agreement on P use. Regulation can be efficient; it could be strict but simple, and set as close to the real roots of the problems as possible, e.g., introduction of excess nutrients into the system. In addition, the interrelatedness of failures is linked to the multi-functionality of agriculture, *i.e.*, it is related to the production of food, land and ecosystem stewardship, and rural livelihoods. However, the dominating trajectory is based on global competition for returns to capital, which forces defense from the advocates of the other aspects of agriculture, pulling policies into different directions. Therefore, food policy that would link primary production to final consumption, as well as heavily regulated agriculture to global market driven retail-sector and environmental impacts of feeding people, is greatly needed.

In answering the second research question, the policy responses in both countries resulted in severe policy frameworks that were, on the one hand, sufficient to tackle nutrients problems from point sources, such as industry and municipalities, and to a large extent contributed positively to a substantial lowering of nutrient emissions by (manure producing) livestock holders in the agricultural sector. In both countries, the construction of these frameworks was only possible after long and intensive negotiations between agricultural sector advocates and those of environmental movements. Moreover, EU directives urged strict implementation of stringent domestic policies. Although this spurred comprehensive policy approaches that were to a great extent successful in attaining their specific goals, on the other hand, in both countries, policies have been ineffective in addressing diffuse sources in agriculture due to the absence of system-wide integrated policy frameworks until this day. Furthermore, policies urging improved recycling in the entire food system (from waste and residues back to the production) that would require a trans-sectoral approach were non-existent. More research into this issue is needed to: (i) further understanding of the deeper rooted problems regarding sub-optimal nutrients value chains, and (ii) examine best practices of policies and other intervention strategies that have shown promising signs of improving sustainable nutrient management.

Finally, we would like to reflect on the use of Weber and Rohracher's failure framework for sustainable transitions [13]. Although this comprehensive framework offers a broad array of concepts that are useful to analyze practical cases *vis-à-vis* sustainable transitions, we have two criticisms that call for attention. First, the framework appears over-comprehensive and difficult to use when applied to case studies (let alone other research designs that typically require more simplified conceptual frameworks). Many of the failure concepts turn out to be inter-related, and there might even be a causal relationship or a hierarchy between them. Second, although we appreciate the use of valid variables from transition and innovations studies, we miss concepts from policy studies (a discipline that we consider highly relevant to an understanding of systemic and policy failures). When studying problems/failures that prevent sustainable transitions from happening we feel that these concepts would be very useful.

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