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Agricultural Nitrogen Pollution of Freshwater in Germany. The Governance of Sustaining a Complex Problem

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Abstract: The nitrogen pollution of freshwater heavily affects social–ecological systems. To reduce negative effects, research calls for an integrated approach, including a coherent and diverse set of governance instruments. Thus far, however, the effects of (non-)integration have been blurry. Taking Germany as an example, this study sheds light on the actual complexity of the problem along five dimensions of complexity (goals, variables, dynamics, interconnections, and uncertainties). It also sheds light on related governance instruments (rules, information, and economic incentives) and their impacts on problem-solving (implementation of specific measures). Analyses include expert interviews on complexity, European water and agricultural policies, and official data on the planning and implementation of measures to reduce nitrogen concentrations. Results show Germany's path of sustaining a complex problem by using a non-coherent and low diversity governance approach, avoiding rigorous rules, and barely using economic instruments to deal with nitrogen surpluses. A stronger integration of water and agricultural policies, as well as a better use of economic instruments, are suggested to enhance water quality in the future.

Keywords: Common Agricultural Policy; European Water Framework Directive; Nitrates Directive; water pollution; water quality; wicked problems

1. Introduction

Nitrogen is a crucial element for agricultural production. Its application via fertilizers or livestock manure supports the growth of plants such as crops and pastures. Nitrogen certainly helps to intensify agricultural production to meet the United Nations Sustainable Development Goal (SDG) 2 on ending hunger and achieving food security. However, its use in agricultural production also comes with the danger of doing too much, with a possible negative impact on water quality, biodiversity, and human health. Such possible negative impacts move both researchers and practitioners to call for a more efficient use of the nutrient in agricultural production [1–4].

However, farmers have often used more nitrogen in the past than can be absorbed by plants. On the global level, the use of both synthetic and organic fertilizers has increased significantly [2]. By consequence, nitrogen is, in fact, amongst the parameters that has failed most in meeting national targets related to the SDG 6.3.2 indicator on good ambient water quality [3]. In Europe, agriculture continues to be an essential source for discharge into the environment. By consequence, the pollution of freshwater is still severe, with only slight improvements in nitrate concentration in general and a deterioration of already strongly polluted areas since 2008 [5,6].

There have been many attempts to reduce nitrogen pollution from a policy perspective. On the global level, the Sustainable Development Goals—SDG 6, in particular—address the pollution of freshwater resources [7]. Moreover, different regional areas have designed regulatory frameworks. In Europe, for instance, the European Water Framework Directive [8] and the European Nitrates Directive [9] constitute legal frameworks for handling the problem. Within such frameworks, a diversity of technical measures has been put forward, amongst them the Codes of Good Practice and additional rules such as organic farming or nutrient planning at the farm level [5,10]. However, pollution is persistent, and an important question is how policy-makers can design governance in a way to better implement measures for a balanced application of the nutrient in the future [5].

Research has come up with a set of assumptions on how to address this complex problem area. Such arrangements can include both general governance strategies for the formulation and specification of policies and specific governance instruments to implement such policies. Concerning strategies, research has intensely discussed the role of different scales, inter-agency cooperation, or participation of stakeholders in decision-making, mainly supporting a multi-level-/multi-actor approach [11]. Regarding instruments, both their coherence and diversity play an important role. Coherence means that the fields of water and agriculture should be harmonized [5,12–14]. Diversity calls for a mix of instruments, including economic incentives and consultations, in addition to traditional forms of hard law [5,11,15,16].

In particular, economic instruments may be quite effective to deal with environmental objectives, in general, and water quality, more specifically. Whereas traditional legislation may create resistance on the part of the affected stakeholders, economic instruments can not only be used to tax polluting activities but to provide incentives to reduce or avoid such activities, e.g., compensating for income losses. Economic instruments generally allow actors to reduce adjustment costs in the best possible way. Hence, economic instruments can effectively support adjustment needs to enhance water quality beyond legislation.

However, the links between various governance strategies and instruments, on the one hand, and solutions to problems, on the other hand, are not clear; this is, in particular, true for the role of instruments. While studies have generally discussed the link between governance and the status of resources, they do not necessarily address the link between governance instruments and their effects. How coherent and diverse are the respective instruments, and how does the coherence and diversity influence the planning and implementation of measures?

This paper aims to trace how the design of governance instruments in the water and agricultural sector (role of regulations, economic incentives, information) affect actual problem solving (the planning and implementation of measures) related to diffuse pollution in agriculture. The case in point is Germany's handling of nitrogen pollution, which is based on the following reasons: Germany has an unusually high level of nitrate concentrations in groundwater that has led to negative impacts on ecosystems and human beings, as well as an infringement procedure by the European Commission [12,14,17,18]. Research has increasingly emphasized this case [11,19] but still needs to provide combined knowledge on the complexity of the problem, the design of instruments, and the problem's effects on problem-solving.

Section 2 takes debates on complex problem solving as a starting point and provides theoretical insights into how governance instruments can be best designed to reduce diffuse pollution from agriculture. Explanations are based on literature in the field of diffuse pollution from agriculture and are flanked by related debates in public policy literature on complex problem-solving. Section 3 introduces both the German case study and the diverse set of methods used to analyze the complexity of the problem, the diversity of instruments, and the problem-solving activities (planning and implementing measures). Section 4 shows the results, revealing a particularly complex problem area in terms of goals and system complexity that is approached by non-coherent, low diversity governance, resulting in some paralyzed problem-solving activities. Section 5 discusses specific avenues for strengthening instruments for overcoming the paralysis in this problem area, hinting at more coherence and diversity.

We conclude that Germany will reduce nitrogen pollution only if a more coherent and diverse set of governance instruments is encouraged.

2. Conceptual Background

2.1. The Complexity of the Problem

The starting point for identifying appropriate governance instruments is the understanding of the problem at hand [20,21]. Research often understands diffuse (nitrate) pollution of freshwater as a wicked or complex problem [13,15,22]. Of particular importance is the role of conflicting interests between stakeholders and policies, hinting at the nexus dimension of the problem. The focus is on conflicts between agricultural production (e.g., for livestock farming) and energy production (e.g., for the production of biogas), as well as the provision of safe drinking water quality (nitrogen pollution) [11–13,23]. It has been argued, for instance, that economic incentives for renewable energy production have resulted in ineffective persuasion targeted at reduced pollution [16]. Coming to the field of measures, such conflicts may be more or less severe, depending on the type of measure states implement. Source-oriented measures (e.g., the efficient use of fertilizer), for instance, can lead to particularly severe conflicts with farmers, whereas effect-oriented measures (e.g., wastewater treatment) seem more feasible [11]. In the same line, research showed that measures with a direct impact on safe drinking water are more feasible than those aimed at reducing diffuse pollution from agriculture [24–26]. More recently, such conflicts have led to understanding pollution with nitrogen as a 'nexus' problem, characterized by interlinkages and trade-offs between different sectors, systems, or resources [27,28].

2.2. Integration and Diversity of Instruments

To address complex or wicked problems associated with conflicting interests, research first considers the 'multi-sector dimension of governance,' which 'entails the extent to which different sectoral policies are integrated and connected or rather differentiated and separated from each other' [11] (p. 13). Here, research generally argues for coherence, meaning that governance instruments related to nitrogen pollution should be harmonized. Most prominently, research calls for the reduction of trade-offs and the creation of a win–win situation between the sectors of water, energy, and food at the policy level [13,16,29]. As an example, the European Commission has argued for aligning water and agricultural policies more vigorously to achieve more sustainable agriculture and water management [5]. For the German case, research and practice have prominently called for an integrated and thus less fragmented strategy to tackle the particularly severe pollution of freshwater with nitrogen [12,14].

Assumption 1. *In case of complex problems, governance instruments in line with policy coherence foster the reduction of nitrogen in freshwater resources.*

As a second prominent strategy to address complexity, research has discussed the mix of policy strategies or instruments, including economic incentives, persuasion, and traditional forms of hard law [11,30]. While governments have traditionally focused on coercion, the current debate on diffuse pollution has revolved around hybridity and, thus, the right mix of the governance instruments. Based on this literature, a synergistic mix is generally desirable, given different benefits of instruments [11,15,16]. Most prominently, current advisory, or information strategies need to be expanded with measures such as tailor-made incentives [31–33]. Given the widespread acknowledgment of policy mixes in the literature, the European Commission has also advised using a diverse set of instruments, here referring to legislation, incentives, and information to achieve sustainable agriculture [5]. Additionally, research has shown that EU member states implement a diverse set of policy mixes to reduce nitrogen pollution from agriculture [11]. Concerning Germany, research has acknowledged a mix of instruments for different regions. However, Germany and

Lower Saxony, as one example case, mostly build on consultations and partly on coercion rather than on economic incentives. If used, economic instruments partly aim at incentivizing energy production [11,16]. Examples for economic incentives only exist for specific sub-cases such as drinking water protection zones in particular settings [34].

Assumption 2. *In case of complex problems, a mix of governance instruments that puts particular emphasis on economic incentives fosters the reduction of nitrogen in freshwater resources.*

Based on this literature, integration across policy fields and diversity are likely to result in positive outcomes in complex and particularly conflict-laden situations. However, it is unclear how different strategies can be best combined. As Pahl-Wostl [16] p. 15, highlighted: "There is only little empirical knowledge on the performance of different governance arrangements and the role of combinations of governance modes." In the following, this question is taken up by discussing how coherence and diversity of policy instruments result in specific nitrogen patterns.

3. Materials and Methods

3.1. Case Study Selection: Nitrogen Pollution in Germany

The assumptions are analyzed taking nitrogen pollution from agriculture in Germany as an example. This case is particularly interesting to study since nitrogen levels are high and above the thresholds advised for good water quality, particularly in areas of intense livestock farming such as the north-western part of the country (see Table S1). These high levels have resulted in the deteriorated chemical and ecological quality of groundwater and surface water bodies as well as adjacent marine waters. Poor water quality again has had detrimental effects both on biodiversity and the provision of safe drinking water quality [12,14].

The consistently high levels of nitrogen pollution from agriculture in Germany have also resulted in failed targets as pronounced in European environmental directives. One example is the European Water Framework Directives' goal of a good chemical and ecological status by 2027. Here, analyses of the management process indicate a failure in achieving such a good status given a lack of implementation of agricultural measures, among others [35]. Another example is the European Nitrates Directive (91/676/EEC). Germany has, in fact, continuously failed to meet the goals of the EU's Nitrates Directive by exceeding the limit of 50 mg/L nitrate in groundwater in many regions, and this is predominantly due to intensive agriculture and fertilization (see, for instance, https://water.jrc.ec.europa.eu/portal/apps/opsdashboard/index.html#/8b12fb8f3f544edfb4db52e4bbf72901 (accessed: 21 October 2019)). The European Commission launched an infringement procedure in October 2013; it has presented its reasoned opinion on why the Commission considers that the country was breaching EU law in July 2014, and it brought the matter to the European Court of Justice in April 2016 [36]. The European Commission has criticized subsequent approaches of Germany to reduce pollution, and at this point, a second infringement procedure against Germany is becoming more likely [37]. Such failures also have let researchers describe the German case as being particularly complex, which is above all coined by conflicts between different types of actors [12,13].

Next to these reasons, the German case is particularly well-suited for our analysis given detailed data on the complexity on the problem at hand [24,25] and the planning and implementation of relevant measures based on the reporting obligation according to Water Framework Directive via the German internet platform WasserBLIcK (see Section 3.2).

3.2. Data Gathering and Analysis

Different methodologies were combined to analyze the complexity, governance, and problem-solving processes related to diffuse nitrogen pollution of water (mainly groundwater) from agriculture.

In terms of complexity, this work built on interview data on the complexity of pollution-related problems in Germany. These interviews were conducted between November 2014 and January 2016 by the first author and have been partly been published elsewhere [23–25]. In these interviews, the experts assess complexity along 9 categories which were based on (i) five dimensions of complexity ('goals', 'variables', 'dynamics', 'interconnections', and 'uncertainty'), (ii) with each three occurrences ('simple', 'complicated', and 'complex'). The degree of complexity was evaluated based on criteria suitable for the relevant dimensions. In terms of goals, their number and relationship were of relevance; variables differed along with their number; dynamics and interconnections were contrasted based on the strength of development and connections of variables; uncertainty was evaluated based on how much information was missing for problem-solving. A detailed description of the operationalization was provided by Kirschke and colleagues [23–25]. Based on this operationalization, the original data set analyzed the complexity of 37 water pollution problems based on 65 expert interviews made with water quality experts.

Here, the focus was on data provided by ten experts, all dealing with the diffuse pollution of groundwater from agriculture. Experts had diverse backgrounds, coming from public authorities on the sub-national level (5), from river basin authorities (2), and science (3). Interviews were conducted both face-to-face (5) and by phone (5), and they lasted 114 min on average, considering that within this sub-group of interviewees, about four problems were discussed per interview. Interviewees provided both numerical (0–1 scale) and qualitative information on the five dimensions of complexity. The numerical assessment was averaged over all interviewees, and the standard deviation was analyzed. The qualitative data were coded in a multi-step coding process, resulting in 28 codes and 223 text segments for these ten interviews. While the results of the complete analysis of 65 interviews have already been published, the results in Section 4.1 provide more in-depth and focused information on diffuse pollution of groundwater resources from agriculture.

To analyze the governance instruments used in Germany to tackle this problem, we mainly referred to legislative texts, adding further documents and literature where appropriate. The analysis focused on three significant policies: (i) the water policy as a critical policy field for Water Framework Directive (WFD) implementation, (ii) the fertilizer policy as a critical policy field for implementation of the European Nitrates Directive, and (iii) the Common Agricultural Policy (CAP) as the critical policy field for the agricultural sector. For each policy, we identified primary legal arrangements and analyzed diversity and coherence, considering the 'classical' differentiation of instruments into the legal framework, economic incentives (or disincentives), and information and cooperation. For each policy, the focus was on the federal level, but some striking differences between federal states were taken into consideration as well.

Problem-solving can be measured at different steps of the effect chain, from the design of specific measurement programs, via indicators for a behavioral change up to actual nitrate concentrations in freshwater bodies. The most appealing indicator for effects is the concentration of nitrate in groundwater and surface water bodies. However, the WISE database provides data on nitrate concentration for surface water bodies until 2012 only. More recent data are part of member states' internal surveys or relate to some specific nitrate hot spots only. Indicators for the behavioral change of the polluter, such as changes in the application of fertilizer by farmers, are equally appealing since policies can only affect human behavior, not natural processes. However, behavioral information is hardly accessible in Germany, given a lack of appropriate control mechanisms. The focus was thus on proxy indicators to discuss the effects of policies on nitrate levels, namely the planning and implementation of typical measures to reduce diffuse pollution from agriculture since 2012. Mainly considered were 12 types of measures that are meant to reduce diffuse nutrient pollution from agriculture for both surface waters and groundwater (see Table S2). Data on the planning and implementation of these types of measures are available in the database WasserBLIcK for 2012, 2015 and 2018. Data from 2012 provided information on the status of implementation at the water body level along a four-point scale from not yet started, in planning, in construction up to completed [38]. In contrast, data from 2015 and

2018 only show which measures had been planned to achieve water quality goals by 2021 and thus provide no information on the status of implementation. This lack of information goes back to lacking requirements to report on the status of implementation in 2015 and 2018, in contrast to 2012.

4. Results

4.1. The Complexity of Diffuse Pollution from Agriculture

The expert interviews provided interesting insights into the complexity of the problem discussed here. Experts generally described diffuse pollution from agriculture as a complicated to a complex problem, with an averaged complexity degree of 0.69 (on the scale between 0 = simple and 1 = complex). The complexity of the problem varied along the five dimensions, with the dimensions of goals being particularly complex (0.8), followed by the dimensions of interconnections (0.78), variables (0.70), uncertainty (0.63), and dynamics (0.55) (Figure 1).

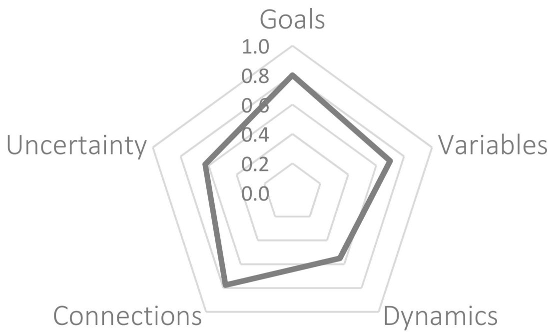

Figure 1. Complexity degree of diffuse pollution from agriculture in Germany, along with five dimensions. Source: own compilation based on published data [24,25].

Interviewees varied slightly in their description of the complexity degree of the five dimensions, with a standard deviation over all dimensions of 0.37. Standard deviation also varied slightly between the dimensions, with the highest values for goals and variables (0.42), followed by interconnections and uncertainty (0.34), then dynamics (0.31). In case of goals, however, the high standard deviation was explained by two outliers, with a majority of respondents opting for intense goal conflicts and only a minority opting for no goal conflicts between actors. From this, we could understand that interviewees mostly agreed on intense goal conflicts, whereas they were a bit more uncertain about the complexity of the four remaining dimensions (see data in Table S3).

Further, interviews provided qualitative arguments to substantiate the numerical evaluations of complexity. Text segments mostly related to different variables; this was followed by the dynamics, uncertainties, and interconnections related to the variables; and these were finally followed by the different types of goals (Figure 2). Table S4 presents the main qualitative arguments.

In terms of variables and dynamics, interviewees emphasized natural, technical, and social-related aspects. The first group of factors regards natural locational factors such as changing weather and climate conditions, or more static quantities and qualities of soil conditions. Another group is non-natural locational factors that influence the amount of nitrate, such as the amount and type of fertilizer. Another group refers to solution options, indicating varying application techniques for fertilizers, among others. Concerning the social dimension, the role of actors and their interests was discussed, such as a large number of responsible institutions and affected stakeholders. Additionally, experts mentioned governance-related factors, namely different governance strategies, the diversity of legal frameworks, and the change of market prices such as for fertilizer. These different dynamic variables are afflicted with uncertainties, such as the impacts of climate change on temperature and rainfall. There are also connections between the variables. A straightforward process chain is the impact of consumer behavior and market prices on the application of manure and mineral fertilizer, with a diverse impact on nitrate concentrations based on soils, weather conditions, and types of plants.

Finally, experts identified several goals. On the one hand, there are typical environmental protection goals such as water protection through the reduction of nitrogen discharges and associated nature conservation and biodiversity goals. On the other hand, agricultural production goals for food and energy security are prominent, including related goals of maximizing the benefits of farmers.

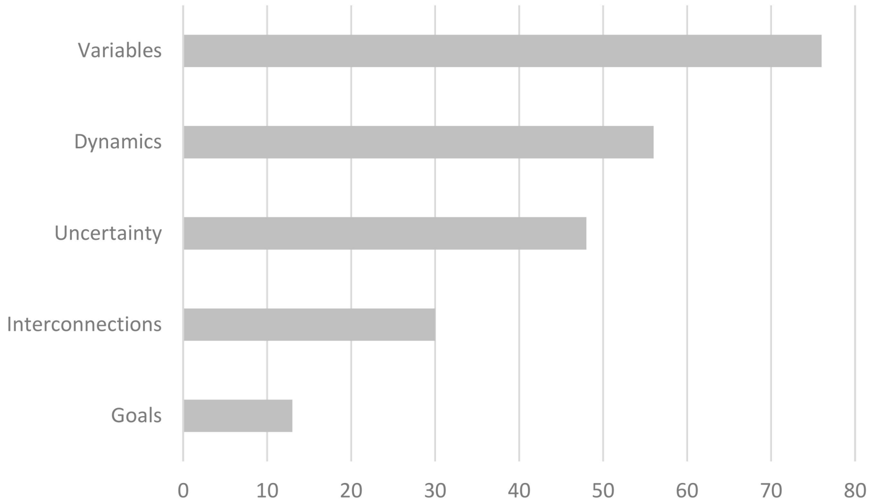

Figure 2. The number of text segments per dimension of complexity. Source: own compilation based on qualitative interview data.

The number of variables, their dynamics, and interconnections seemed quite challenging to interviewees, resulting in a need for models, scenarios, and, potentially, decision support tools. Experts saw little context-dependency, since changes are only relevant for the shape of variables rather than the existence of the variable as such. However, the scale (water body, country, basin) may render the problem more or less complex.

Experts also highlighted some unavoidable uncertainty (in terms of control), although some uncertainties seem to decrease over time, and certainty levels seem to suffice for improving the situation (in terms of the theoretical effects of measures). Additionally, uncertainty levels seem to be more context-dependent than the dimensions of variables, their dynamics, and interconnections.

Finally, in terms of goals, interviewees generally highlighted conflicts that do not necessarily depend on the specific context in Germany. However, the intensity of the conflicts may also depend on the region and the type of businesses, given varying nutrient surpluses or possibilities for more efficient management (reduction of nitrogen surplus with stable yields). Additionally, conflicts with regards to groundwater are potentially lower as compared with surface waters, given a reduced need for interregional problem-solving.

4.2. Governance Instruments to Address Nitrate Pollution from Agriculture in Germany

Which governance instruments have been used to address the complex problem of diffuse nutrient pollution from agriculture in Germany? The starting point is water policy, which is the critical policy field for WFD implementation. A policy field of similar importance is fertilizer policy, which is discussed next. Then, the Common Agricultural Policy (CAP) is considered as the critical policy field for the agricultural sector, which may contribute to or hamper WFD implementation. The discussion along these three policies shows diversity, with the water policy focusing on rules and partly on information, the fertilizer policy pursuing a rules-oriented approach, and the Common Agricultural Policy focusing on economic incentives in its second pillar. Furthermore, the discussion shows little coherence between these policies. The policies partly relate to each other but do not sufficiently support the reduction of nitrogen application. The fertilizer policy indeed refers to water quality goals but focuses on rules only, which are not implemented effectively. The Common Agricultural Policy relates to environmental questions in Pillar 2, Priority 4, and Priority 5, but it mainly refers to the existing rules of good practice rather than providing the means to further reduce nitrogen application (Table 1). The following sub-sections further develop these results.

Table 1. The relevance of governance instruments in three policies [1].

Governance Instrument	Water Policy	Fertilizer Policy	Common Agricultural Policy
Rules	High relevance	High relevance	Low relevance
Economic incentives	Low relevance	Low relevance	High relevance in the second pillar
Information	Medium relevance	Low relevance	Low relevance

[1] Relevance relates to the dominance of a specific instrument (rules, economic incentives, and information) in the respective policy, along with an ordinal scale with three occurrences (low, medium, and high).

4.2.1. Water Policy

The critical legal framework to implement the German water policy is the Water Management Act (WMA) [39]. In addition to the WMA, the ordinance for surface waters (OGewV) [40] addresses the quality of surface water and the ordinance for groundwater (GrwV) [41] the quality of groundwater. The WMA is specified in the federal states by State Water Acts (SWAs). The WFD is implemented based on this legal framework. Together, this policy typically sets rules for the appropriate use of water and ensuring water quality. Apart from setting rules, there seems to be a preference for information and cooperation, whereas economic incentives or disincentives are rarely discussed or used.

The WMA constitutes basic rules for water resources management in Germany. Concerning agriculture, both water withdrawals and water quality play a role here. In terms of water quality, some regulatory restrictions have been introduced, which have also partly been combined with compensations. An essential rule is the duty of care in cultivating agricultural areas in relation to water resources in order to avoid a deterioration of water quality [42] (p. 177,178). Moreover, the WMA emphasizes riparian stripes (WMA §38) and storage facilities for water-endangering substances (WMA §62 and §63). Riparian stripes' requirements result in cultivation constraints for agriculture, and there are some differences between the federal states' rules concerning width, land use, fertilizer and pesticide use, and compensation payments. With respect to storage facilities for water endangering substances, the WMA does not require suitability assessments for agricultural storage facilities like slurry, manure, and silage effluents. Special regulations are applied according to the ordinance for water-polluting substances (AwSV) [43].

Furthermore, a potentially important aspect for agriculture is the determination of water protection areas and related compensations for farmers. According to the WMA, the federal states may determine such areas, and they may do so in different ways. While the German average is circa 15% of total land area, particularly high shares can be found in Hesse (56%), Baden-Württemberg (26%) and Thuringia (23%). Some federal states with important agricultural sectors have a low share of water protection areas like Bavaria (5%) and Schleswig-Holstein (4%); the share in Lower Saxony (17%) is about the German average [44] (p. 163). Agricultural cultivation in water protection areas may be compensated for additional expenses and income losses according to the WMA and the SWAs, which is typically the case. Baden Wuerttemberg, for instance, uses a flat-rate compensation scheme (SchALVO §11–13) [45], whereas in Bavaria, specific compensation amounts are calculated for individual agricultural areas (BLFfL 2016) [46]. As a rule, it is the beneficiaries (waterworks and other users of water protection areas), and thus the consumer, who have to bear the compensation payments, with the exception of, for instance, Baden-Württemberg, where the federal state finances compensation payments (§45 SWA Baden-Wuerttemberg; §11 SchALVO) [47].

Furthermore, federal states have been experimenting with taxing water use in various ways. However, water pricing has not been a popular policy field in Germany, and activities have mostly related to water withdrawals rather than to water quality. If water quality is addressed, instruments mostly reflect the idea of cost coverage for public water services, as suggested by the WFD. There is little intention to consider and use water pricing for achieving water-related objectives under the WFD, and this is, in particular, correct with respect to agriculture.

Beyond the regulatory framework and with widely missing economic incentives or disincentives, information and cooperation seem to be a more prominent governance approach in German water policy. Many SWAs suggest information and cooperation to enhance and ensure water quality. For instance, North Rhine Westphalia suggests that riparian stripes do not have to be defined by authorities if cooperation between actors achieves the goals pursued (SWA North Rhine-Westphalia §31 (5)) [48]. In Hesse, voluntary arrangements are preferred to legal obligations when defining water protection areas (SWA Hesse §33 (2)) [49]. Additionally, in Saxony-Anhalt, voluntary arrangements concerning water protection areas may receive public financial support (SWA Saxony-Anhalt §76) [50]. Additionally, water-related cooperations have become quite popular in some federal states like North Rhine-Westphalia [51]. It is difficult, of course, to assess how effective they have been in achieving their pursued goals.

In summary, German water law presents itself rather moderate with respect to agriculture. Some rules like riparian stripes or water protection areas specifically affect agricultural activities, but there are various exemptions for the agricultural sector. Information activities exist, but their effectiveness is unclear, and economic incentives hardly exist. Thus, in its present form, this legal framework hardly constitutes significant constraints for agriculture. Beyond water law, other aspects and policy fields may also be relevant with respect to water quality and agriculture. A key point is the EU and German fertilizer policy, which is discussed next.

4.2.2. Fertilizer Policy

Fertilizer policy mainly relates to the EU's Nitrates Directive (91/676/EEC), which aims to reduce nitrate pollution in Europe. In Germany, the most important legal basis for implementing this Directive is the Fertilizer Law (DüngG) [52] and the Fertilizer Regulation (DüV) [53], which were both reformed in 2017 as a reaction to the infringement procedure in 2013. This legal framework offers mainly rules—economic incentives and information are somewhat neglected. Since the fertilizer policy is mainly implemented on the national level, there is also no differentiation in governance instruments between federal states. However, federal states had to formulate country-specific regulations until June 2019 based on the new legal framework; they are responsible for identifying the so-called vulnerable zones; they may formulate particular demands, and they are responsible for control.

According to the Nitrates Directive, member states have to identify 'vulnerable zones' (91/676/EEC article 3), develop 'action programs', and present reports to the commission on preventive actions taken. The Fertilizer Law suggests various measures to reduce nitrate pollution from agriculture, amongst them periods and ceilings for fertilizer application, as well as particular constraints for endangered areas (e.g., steep slopes, frozen or waterlogged soil). The Fertilizer Regulation specifies these.

In Germany, the Fertilizer Law sets a clear legal framework and provides a suitable toolbox to achieve water quality and the goals of the Nitrates Directive (and of the WFD). If applied rigorously, the measures could drastically reduce nitrogen application and pollution, but the implications for agricultural land use, animal production, and farm income would also be drastic [54,55]. There is a clear trade-off between water quality and farm income. In avoiding such negative consequences for agriculture, German executive authorities have chosen to formulate a rather moderate Fertilizer Regulation. This regulation has been criticized because the specific rules and constraints for fertilizing are hardly able to deal with nitrate pollution [56], and recent developments seem to confirm the critics. In their judgment from 21 June 2018, the European Court followed this argumentation.

The amendment of the Fertilizer Regulation from 2017 has led to increasing constraints for fertilization. Examples are extended periods during the year when fertilization is prohibited; an increased minimum distance for fertilizing with respect to water bodies; and upper limits for fertilizer use, including all mineral and organic fertilizers; and the provision of nutritional balance [57]. There have been several more detailed and specific amendments in the new Fertilizer Regulation that have affected the fertilizer practice and possibly contribute to water protection and quality, but there has been no real paradigm change in the German fertilizer policy.

The revision of the German fertilizer policy was criticized right from the beginning. Taube [58] reviewed the amended Fertilizer Law and Fertilizer Regulation in detail and pointed to some interesting shortcomings like exaggerated fertilizer needs calculations, underestimated organic fertilizer effects, and excessive upper limits for fertilizer levels and balances, in particular for vulnerable zones. He argued that the revision does not reflect the current scientific evidence and challenges of the European environmental and water policy; instead, it responds to farmers' concerns and interests. He concluded that the amended Fertilizer Law and Fertilizer Regulation will not reduce overfertilization and nitrite groundwater pollution in a significant way [58] (p. 4). Similarly, Härtel [36] argued that the revisions do not meet the European court's criticism of the former Fertilizer Law and Fertilizer Regulation. Accordingly, a further revision will be necessary.

Following the judgment of the European Court, the European Commission examined the new German fertilizer law, and it was not convinced that the revisions will be sufficient to meet the goals of the Nitrates Directive. The Commission has requested the German government to provide proposals for a further revision. In view of a new infringement procedure with threatening financial penalties, the German Federal Ministry of Food and Agriculture (BMEL) and the Federal Ministry of Environment, Nature Conservation and Nuclear Safety (BMU) have to work out a proposal for a further revision of the Fertilizer Regulation. This revised version will then have to be negotiated with the European Commission [59–61]. Some important proposals are aggravated time limits for solid manure fertilization, further constraints for fertilization use on slopes, and a general 20% cut of fertilizer use in vulnerable areas [62,63]. There is much debate on such proposals, as well as vehement protests of farmers and their representatives [64]. Currently, the European Commission is again criticizing Germany's handling of nitrogen pollution, and a second infringement procedure against Germany is becoming more likely [37].

4.2.3. Common Agricultural Policy

The CAP in the EU and Germany is the most crucial policy framework for agriculture. It has turned from the protectionist policy it was until the 90s into a more direct income support policy for the agricultural sector and a policy for rural areas. Since the 90s, environmental objectives have also continuously gained importance. The CAP follows a two-pillar-structure: The first pillar comprises direct income payments to farmers, and these are basically decoupled from production. The second pillar on rural development comprises a sectoral component to support the development of the agricultural sector, an environmental and resource protection component, and a regional development component. The CAP is basically a fiscal policy with a considerable budget volume as compared to other EU policy fields. Economic incentives are the dominant governance strategy in the second pillar. Direct income support for farmers is the major CAP policy instrument absorbing circa 75% of the EU budget during the financial period 2014–2020, whereas second pillar instruments only obtain circa 25% [65]. The question here is: To what extent the instruments within CAP support water protection and water policy under the WFD [66].

The first pillar comprises direct income payments to farmers. These payments are basically decoupled from production and thus do not represent an economic incentive even though effects on farmers' production processes are not entirely excluded. Furthermore, the payments initially had nothing to do with environmental objectives that have emerged and have been pursued under the CAP. Some environmental perspective has been added to the concept of direct payments since 2000 (voluntarily), and this is the idea of 'cross compliance' (compulsory since 2005) and 'greening' (compulsory since 2014). Based on these instruments, farmers have to meet ecological requirements to receive direct payments. However, the ecological requirements mostly represent basic requirements for farm management and various standards for the good agricultural and environmental condition of the land. Overall, the implications of cross compliance and greening on water quality have been vague at best. Thus, the first pillar does not directly provide economic incentives for tackling poor water quality.

In contrast, the second pillar of the CAP seems to more directly address environmental effects and water quality. The second pillar policy is a mixture of structural policies to support farm competitiveness, pursue environmental objectives, and contribute to rural development (Regulation (EU) No. 1305/2013) [67]. The general principle is that farmers may receive payments if they participate in activities under the second pillar. Since 2013, this policy has differentiated six priorities for rural development. The environment is addressed in Priority 4 (restoring, preserving and enhancing ecosystems related to agriculture and forestry) and Priority 5 (promoting resource efficiency and supporting the shift towards a low carbon and climate resilient economy in agriculture, food and forestry sectors). Water quality under the second pillar is addressed explicitly under Priority 4b (improving water management, including fertilizer and pesticide management). Several other measures related to Priority 4 may directly or indirectly impact on water quality, but it is difficult to assess their relative importance.

The second pillar policy translates into rural development programs (RDP) for member states and regions. In Germany, environmental activities have become quite important, and they absorb 52% of the total budget of the second pillar (for Priorities 4 and 5 including national co-financing, which is obligatory for this policy approach) (see the RDPs of federal states, Chapters 5.4). All 13 RDPs in Germany prioritize agri–environment–climate measures and organic farming according to EU classification [17]. There is a specific Natura 2000 measure and Water Framework Directive payments, which directly relates to the WFD, and yet this measure is only implemented in five German RDPs, none of whom explicitly address the WFD. Concerning financial volumes, the RDPs indicate the importance attributed to Priority 4, and there is a specific indicator related to Priority 4b that describes the percentage of agricultural areas with administration agreements for water quality improvement.

Table S1 gives an overview of selected agricultural indicators and second pillar Priority 4 intervention indicators for the 13 German RDPs, i.e., federal states. Unfortunately, there are no figures for Priority 4b interventions available; hence, the Priority 4 figures, indeed, overemphasize a potential importance of this priority area on water quality. On the other hand, Priority 5 expenditures are not presented because they do not directly address water problems. With regards to agricultural indicators, there is an apparent coincidence between high livestock densities and nitrogen surplus: High values can be found in North-Rhine Westphalia, Lower Saxony, Schleswig-Holstein, and, to a less extent, in Bavaria. Concerning the second pillar Priority 4 intervention indicators, the table also reveals some interesting differences between the federal states. Priority 4 expenditures are relatively high in federal states like Baden-Wuerttemberg and Bavaria, and they are low in Lower Saxony. The percentages of agricultural areas with administration agreements are particularly high in Rhineland-Palatinate and North Rhine-Westphalia, whereas the figures for Mecklenburg-Vorpommern, Sachsen-Anhalt, and Lower Saxony are particularly low. It is difficult to derive a clear picture and interpretation from these figures, but some state examples suggest that the CAP's second pillar can be used to deal with poor water quality. On the other hand, this option could be pursued more rigorously.

4.3. Effects of Policies

Which effects have these policies on reducing nitrate pollution of freshwater from agriculture in Germany? As discussed in Section 3, the focus is on the planning and implementation of typical measures as proxy indicators for behavioral change of farmers and nitrate concentrations in freshwater. These typical measures have been summarized by German water authorities, as laid down in Table S2. They directly refer to the three policies, since they can be understood as an integrated product or intersection of those activities offered in the water, fertilizer, and the Common Agricultural Policy (see Figure 3). They typically comprise both basic and supplementary measures. Basic measures mostly refer to obligatory activities ('sticks') as laid down in the three policies. Supplementary measures are necessary if the basic measures are not sufficient to achieve the objectives of the WFD, and they mostly refer to information and economic incentives ('sermons' and 'carrots'). While their effects are partly unclear, research has widely assumed that the implementation of an appropriate amount and combination of such measures reduces nitrogen pollution in freshwater.

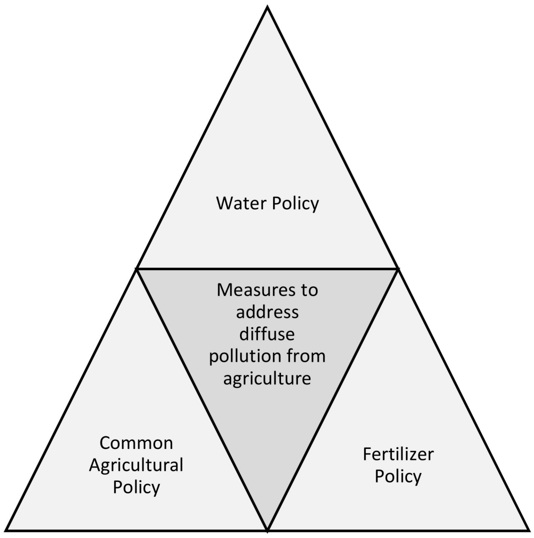

Figure 3. Measures to reduce nitrogen pollution from agriculture as an intersection of three policies. Source: own representation.

Federal states reported on measures to reduce the diffuse nitrogen pollution of freshwater from agriculture in 2012, 2015, and 2018 on the platform WasserBLicK. While the data in 2012 provide information on the degree of implementation, data from 2015 and 2018 only provide information on the number of measures planned. In sum, the data show that planning has abounded at various points in time, but implementation has been somewhat limited or unlikely.

For 2012, specific data on surface waters and groundwater bodies are available. In terms of surface waters, federal States have reported on the implementation status in 2012 for some 75% of water bodies. Within this data set, 35% of planned measures are related to the reduction of diffuse nutrient pollution from agriculture. Out of this 35%, most (73.3%) directly relate to the reduction of nutrient inputs through leaching from agriculture, closely followed by those to reduce agricultural nutrient inputs (59.9%) and the creation of buffer strips (40.5%) (see Figure S1). These types of measures have only partly been implemented, with quite equal shares of measures not yet started, in planning and completion (see Figure S2). Substantial delays have been reported for about 28% of the measures, mostly with regards to the reduction of nutrient inputs by drainages (93.6%) (see Figure S3). Further, the main reasons for such substantial delays in the field of diffuse nutrient pollution have been said to be the lack of financial and human resources (1386 mentions), as well as new findings with regards to impact (1350 mentions) (see Figure S4).

In terms of groundwater, federal states have reported on the implementation status in 2012 for some 60% of water bodies. Within this data set, 73% of planned measures were related to the reduction of diffuse nutrient pollution from agriculture. Out of this 73%, were most related to the reduction of nutrient inputs through leaching in agriculture (74.1%), and a much smaller percentage were related to the reduction of nutrient inputs in water protected areas (23.1%) (see Figure S5). These measures had only been implemented to a limited extent, with most being in the planning stage in 2012 (93%) (see Figure S6). In contrast to the results of surface waters, substantial delays were foreseen in only 1.8% of the groundwater water bodies in which agricultural measures were planned. The official reasons for the delays were oppositions, as well as the lack of funding and human resources.

In 2015, measures aimed at reducing agriculture pressures were planned for two-thirds of all surface water and groundwater bodies. Most of these were related to the reduction of agricultural nutrient inputs, the reduction of erosion-related nutrients and fine-material inputs, and the creation of buffer strips (see Figure S7) [56]. Furthermore, the planning of agricultural measures differs between surface water and groundwater bodies. For surface water bodies, the reduction of erosion (90.4%), the creation of buffer strips (78.9%), and leaching are particularly relevant (65%). For groundwater bodies, reducing leaching is the most prominent type of measure (95%) (see Figure S7). In 2018, the number of reported water bodies with measures to reduce nutrient pollution from agriculture decreased by some 2% as compared to 2015. This may indicate that between 2015 and 2018, implementation only took place in two percent of all surface and groundwater bodies. However, there are no specific data on the implementation status after 2012.

In sum, a significant number of measures have been planned to reduce the nitrogen pollution of freshwater since 2012. However, implementation was limited in 2012 and has been quite vague since then. In particular, significantly positive effects on reducing nitrate concentrations in freshwater and groundwater are thus unlikely.

5. Discussion

In this paper, we aimed to trace how the design of governance instruments in the water and agricultural sector (the role of regulations, economic incentives, information) affect actual problem solving (planning and implementing measures for reducing nitrate pollution) in the field of diffuse pollution in agriculture. From a theoretical point of view, our entry point was the debate on complex problem solving, highlighting the need for integration and diversity. Taking Germany as an example, we mainly found a complex problem that has been addressed poorly by a non-integrated and narrow set of instruments, ultimately resulting in the sustaining of diffuse nitrogen pollution from agriculture.

Complexity was analyzed along the dimensions of goals, variables, dynamics, interconnections, and uncertainty. Experts mainly understand diffuse pollution from agriculture as a rather complex problem, with goal conflicts between the agricultural and the environmental sectors, as well as interconnections between social, environmental, and technical factors, being particularly challenging. Looking at governance literature on complex problem solving, this calls for an integrated approach of water and agricultural policies, including regulation, economic incentives and information.

Based on our analyses of water policies, the fertilizer policy, and the Common Agricultural Policy, we found quite low levels of coherence and diversity of instruments. In terms of coherence, the three key policy areas have been poorly integrated. Nitrate groundwater pollution, in fact, marks an apparent conflict between environmental and water protection on one side and economic interests and farmers´ income on the other. The CAP offers opportunities to support water quality objectives, in particular concerning the second pillar, but this policy field could certainly be more rigorously developed. In terms of diversity, German policy related to agriculture and water policy has been dominated by rules that comprise various exemptions for the agricultural sector. Additionally, the necessary enforcement of rules has also been challenging to handle. There has been little experimentation using economic incentives/disincentives to improve water quality, which also applies, to a lesser extent, to information and cooperation.

Such a poorly integrated and low diversity governance has also resulted in poor problem-solving. Given a lack of actual data on nitrate pollution in Germany in the database of the Water Information System for Europe (WISE), problem solving was discussed along with key measures to address diffuse pollution from agriculture as laid out in the three policies. Official data from public authorities suggest that relevant measures have continuously been put on the agenda, hinting at a solution to the problem. However, implementation has been lagging behind, suggesting that nutrient loads in groundwater have not significantly been reduced over time.

In sum, we assume that a great deal of non-solutions goes back to the governance instruments provided in water, fertilizer and agricultural policies. In theory, these should have joint overarching goals (coherence) and allow for creativity (diversity). However, our results show that the instruments do not directly relate to each other (low coherence) and focus on rules and norms to implement critical measures, neglecting information and especially economic incentives (low diversity). Based on the theory in the field of governance for complex problem solving, such low coherence and low diversity reduce the likelihood of implementing key measures related to these three policies. A lack of implementation then results in the sustainment of nitrate pollution from agriculture. Economic instruments seem to have been especially neglected in improving water quality. Though economists have emphasized that economic instruments can be quite effective in dealing with environmental objectives, providing proper incentives, and reducing adjustment costs, legal rules have still been given priority.

In consequence, future policymaking should put more emphasis on the proper design of governance instruments in legal frameworks. Here, a more integrated view on water policy and agricultural policy would make sense, as would more emphasis on more diversity. Interesting questions arising here are: Should economic incentives be more widely used to tackle nitrate pollution? Is the 'polluter pays principle' the appropriate approach, or should compensation be used? And could Priority 4b measures under the second pillar be extended and rigorously be used to enhance water quality? Given the challenge to be met, more innovative policy-making seems to be appropriate. Unfortunately, the current debate on solving nitrate pollution in Germany has followed the traditional patterns of policy-making and has mainly argued over the enforcement of the legal framework.

It has to be noted, though, that a more integrated view of water and agricultural policies, as well as a more diverse set of instruments may be challenging to implement. In terms of integration, this implementation challenge goes back to the fragmented institutional landscape of the water and agricultural sector. While research and practice have continuously argued for an integrated perspective, different organizations or departments are responsible for these different policies. Consequently, it is comprehensible that policies are developed and implemented without necessary links to other policies. For policy-makers, it may indeed be more attractive to implement a single approach instead of combined approaches.

Nonetheless, we suggest putting more emphasis on the role of the CAP in the field of water quality management in the future. The CAP has been criticized for contributing to agricultural intensification and thus creating adverse environmental effects and pollution. The argument was valid for the former protectionist design of the CAP. However, the CAP framework has changed and has put more emphasis on environmental problems. It is recommended that the CAP further strengthens its environment-orientated policy in a significant way to better deal with freshwater pollution from agriculture. In the same vein, the Scientific Advisory Board on Agricultural Policy, Food and Consumer Health Protection (WBAE) at BMEL strongly recommends a CAP orientated towards common goods like animal welfare, biodiversity, and climate protection [68]. The board substantiated this idea in a specific report on animal welfare and climate protection [69,70]. Germany distributed about 4.8 mn Euro of direct payments in 2017 [71], and such a financial volume or parts of it could undoubtedly have significant positive environmental or water quality effects.

Future research may add to such discussions by providing a more integrated and diverse set of research approaches. One promising way forward is to provide a better understanding of which specific instruments support the planning and implementation of the proper set of measures in complex and particularly conflict-laden situations. Of particular importance are comparisons of governance approaches and their impacts on solutions along with different types of complex problems in different EU member states. Such research may help to understand how member states act and succeed differently under similar legislation and varying local contexts. Another promising way forward is a more in-depth analysis of the conditions for designing and implementing such fine-tuned governance schemes. Fragmented responsibilities in the water and agricultural sector play a role here, and relevant questions will regard how the distribution of responsibilities has influenced reform processes in the past and how these two interests may be best adjusted in the future by redesigning the institutional landscape or forms of interaction [12]. New paradigms such as sustainable agriculture may play an important role and encourage more multi-faceted discussions.

Supplementary Materials: The following are available online at http://www.mdpi.com/2073-4441/11/12/2450/s1: Table S1: Selected agricultural and second pillar Priority 4 intervention indicators in German federal states. Data source: Own compilation based on indicated sources; Table S2: Types of measures to reduce nitrogen pollution of groundwater and surface waters; Table S3: Interview results: Complexity of the problem 'Diffuse pollution of groundwater from agriculture.' Data source: Own representation and calculation based on Kirschke (2017a,b); Table S4: Qualitative arguments for the complexity of the problem 'Diffuse nitrogen pollution from agriculture.' Data source: Own representations, partly based on Kirschke et al. (2017a,b); Figure S1: Amount of reported measures in surface water bodies with measures to reduce diffuse nutrient pollution (n = 2500). Data source: Berichtsportal WasserBLicK/BfG; last updated 31 October 2012; Figure S2: Implementation status of measures to reduce diffuse nutrient pollution in surface waters. Data source: Berichtsportal WasserBLicK/BfG; last updated 31 October 2012; Figure S3: Substantial delays of measures to reduce diffuse nutrient pollution in surface waters. Data source: Berichtsportal WasserBLicK/BfG; last updated 31 October 2012; Figure S4: Reasons for substantial delays of measures to reduce diffuse nutrient pollution in surface waters. Data source: Berichtsportal WasserBLicK/BfG; last updated 31 October 2012; Figure S5: Amount of reported measures in groundwater bodies with measures to reduce diffuse nutrient pollution (n = 610). Data source: Berichtsportal WasserBLicK/BfG; last updated 31 October 2012; Figure S6: Implementation status of measures to reduce diffuse nutrient pollution in groundwater. Data source: Berichtsportal WasserBLicK/BfG; last updated 31 October 2012; Figure S7: Amount of measures to reduce agricultural nutrient pollution in surface water bodies (n = 5266) and groundwater (n = 718) according to RBMP 2015.

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