ENVIRONMENTAL RESEARCH
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To cite this article: Luisa Stuhr *et al* 2021 *Environ. Res. Commun.* **3** 085002

Environmental Research Communications

PAPER

German pig farmers' perceived agency under different nitrogen policies

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OPEN ACCESS

RECEIVED
28 February 2021

REVISED
19 July 2021

ACCEPTED FOR PUBLICATION
28 July 2021

PUBLISHED
18 August 2021

Keywords: agricultural nitrogen emissions, agriculture, nitrogen policies, farmer typology, perceived agency, ammonia emissions, German Pig farmers

Supplementary material for this article is available online

Abstract

Agricultural nitrogen (N) emissions represent the most substantial N source in Germany. Even though multiple policies have been introduced at the EU and German national level to reduce agriculturally sourced reactive Nitrogen (N), Germany is exceeding the target of the government's national sustainability strategy to limit N surpluses. To form a better view of the current N policy challenges, this paper seeks to identify what constrains family-managed pig farmers in Germany from adopting N-reduced farming practices. Our study applies a practice-based approach and reconstructs farmers' practice and individual perception of the possible capability to change practices (*perceived agency*) through problem-centred interviews. The study identifies different ideal types of farmers based on their reported farming practices and *perceived agency*: The first type feeling overburdened and weary of the current requirements, the second type acting based on routine and incremental improvement efforts, and the third type adapting early and inventing. However, regarding the *perceived agency* to adopt N-reduced farming practices our results show that all three farmer types report only low to little agency. Based on the findings, the study identifies type-specific and type-spanning constraining factors. To resolve farmers' perceived contradictions and inconsistencies which result in the unwillingness to accept further N reduction measures, we argue that policies need to address these factors. To enhance long-term paths for sustainable N-reduced farming practices, this study concludes that N policies need to shift towards outcome-oriented policies to create a collective and holistic understanding of the desired outcome while considering their embeddedness into regional and individual contexts.

1. Introduction

Multiple policies have been introduced at the EU and German national level to reduce agriculturally sourced reactive Nitrogen (N) emissions that harm the environment by causing eutrophication, air and water pollution, greenhouse gas emissions and soil acidification (Erisman *et al* 2008, Liu *et al* 2016). Still, Germany is exceeding the target of the government's national sustainability strategy to limit the N surplus to 70 kg N ha^{-1} utilized agricultural area (UAA) - for the years 2013 to 2017 on average by 24 kg N/ha (Häußermann *et al* 2019). Already charged by the European Commission for exceeding nitrate (NO_{3-}) limits in groundwater, Germany might face another lawsuit on ammonia (NH_3) emissions soon (DUH 2020).

As elaborated in literature, especially farmers' widespread use of synthetic N-fertilizers (Smil 2004) and highly concentrated manure application, as well as insufficient N fertilizer use efficiency and poor management of animal manure, represent the primary sources of agricultural N surpluses (Oenema 2006, Sutton 2011, Erisman *et al* 2018). Consequently, various measures and farming practices on how to reduce agricultural N

have been evaluated and discussed (Finck 1985, Sutton *et al* 2013, Bodirsky *et al* 2014, Kanter and Searchinger 2018). While the sources of agricultural N surpluses and possible reduction measures are well researched, the implementation of sufficient N reduction practices is currently inhibited at the political level. To comply with national and EU N surplus limit values, the Fertilizer Ordinance (FO) was amended in 2017 and 2020. Yet looking at the process of the latest amendment to the FO and the debates concerning the reform of the Common Agricultural Policy (CAP) of the EU, the political discourse is becoming 'increasingly polarized' (Awater-Esper 2020). While many environmental associations (BUND *et al* 2020) urge much stronger regulations regarding agricultural fertilization and farming practices[4], many farmers—primarily led by the movement 'Land schafft Verbindung' that were inspired by Dutch farmer protests in 2019- vehemently reject any additional burden and further enforced changes of practices[5] (Deter 2020, Ploeg 2020). From an environmental perspective, it is already anticipated that the current mix of policies which aim to reduce agricultural N surpluses [N policies] will not be able to enforce sufficient reductions. Further N-reduced farming practices must be adopted to reach national and EU target values.

While our study focusses on the German context, insights may be transferable, given similar policy challenges in other EU countries to reconcile food production and environmental boundaries for N (Stokstad 2019, de Vries *et al* 2021, Schulte-Uebbing and de Vries 2021), often also accompanied by farmer upheaval (Ploeg 2020). Due to the scope and local heterogeneity of agricultural N flows, multiple options for international and EU governance (Oenema *et al* 2009, Morseletto 2019), as well as national policy instruments and adjustments (Wegener and Theuvsen 2010, SRU 2015) have been proposed. However, there are comparably few studies that focus on family farmers' (both entrepreneurial and peasant-like) perceptions and practices regarding their N use, and the connection to farmers' perception of N policies. Looking at the design of current policies that address German farmers, Feindt *et al* (2019) argue that most policies are based on a simplified understanding of farmers' motivation. Accordingly, N policies are either based on financial incentives, thus reducing farmers to profit-maximizing agents, or they impose universal measures to all farmers, thus portraying them as a homogenous group. Additionally, most policies address farmers/farms as an individual unit, rather than as members of social networks (Feindt *et al* 2019). In contrast, a growing body of literature recognizes the heterogeneity of farmer attitudes (Willock *et al* 1999, Gorton *et al* 2008) and decision-making (Huber *et al* 2018). This has also been found with respect to how farmers perceive their roles in relation to environmental responsibility and management (Fairweather and Keating 1994, Davies and Hodge 2007). While there have been repeated calls for interventions that are not purely based on monetary allocations (Burton and Wilson 2006, Burton and Paragahawewa 2011, Grüner and Fietz 2013), the work of Lokhorst *et al* (2010) represents one of the few studies that experimentally test the effect of non-monetary incentives on farmers.

To form a better view of the current N policy challenges, this paper seeks to identify what constrains farmers from adopting N-reduced farming practices. Investigating (1) farmers' individual perception of the possible capability to change practices (*perceived agency*) of farming, (2) farmers' specific *perceived agency* to adopt new N-related farming practices (N practices), and (3) farmers' perception of N policies, this study draws on Anthony Giddens (1984) understanding of agency as being inevitably linked to structure (N policies). According to Giddens, there is a recursive relationship between structure (external forces such as rules and resources) and agency (capability to make a difference), both determining human practices and vice-versa.

In the context of the various N policies, we investigate the heterogeneous perceptions of agency of pig farmers in Germany. With Germany being the world's third largest pork producer and exporter (GermanMeat 2019, Wagner 2020) and the livestock sector contributing severely to N pollution (BMEL 2019), the effect of N policies on pig farmers' practices is particularly important (for Germany). Based on the farmers' general perception of agency and their reported farming practices, we first identify three types of farmers: the 'Weary', the 'Routine' and the 'Inventive' type. Classifying farmers into types can help elaborate different perceptions, motivations and practices of farmers towards a particular issue (Walder *et al* 2012) and allows more efficient targeting for policy purposes (Barnes *et al* 2011). In our case the typology is used to subsequently analyze farmers' perceived agency to adopt N-reduced farming practices and the connection to farmers' perception of N policies.

In line with the general critique on the insufficient effectiveness of the current policy mix (SRU 2015, Feindt *et al* 2019), our findings show that the three farmer types report low ('Weary'/'Inventive') to little ('Routine') agency to adopt N-reduced farming practices. Comparing this to farmers' general *perceived agency* to adopt new farming practices, our results demonstrate the variety of constraining factors. Public N policies are perceived as contradictory to the farmers' local condition ('Routine') and their own knowledge ('Weary'), leading to limited or even counterproductive N practices. Private N policies are perceived positively by the 'Inventive' type, yet do

[4] BUND, DNR, DUH, Germanwatch, Grüne Liga, Greenpeace, NABU and WWF published a common statement on the FO draft in January 2020, stating that it is not sufficient to reduce the increasing NO_{3^-} pollution and the resulting problems in water protection and drinking water supply in a targeted and sustainable manner (BUND *et al* 2020).

[5] 'Land schafft Verbindung' also submitted a constitutional complaint against the new FO in 2020 (Deter 2020).

not include binding N reduction targets. All farmers report to miss a coherent long-term strategy regarding N-reduced farming in Germany.

To enhance long-term paths for sustainable N-reduced farming practices, policies need to build on a collective and holistic understanding of the desired outcome, while embedding regional and individual contexts that shape the heterogeneity of N practices. We propose to evaluate and re-design current and upcoming N policies in the context of the perceived contradictions, while considering the heterogeneity of farming practices and perceptions of agency. To that end, our typology can serve as a starting point, contributing to the literature on heterogeneous farmer attitudes and practices.

We structure this study in six parts: After introducing our theoretical framework in section 2, including an overview of current N policies, we outline the methods used to study farmers' *perceived agency* under N policies in section 3. Section 4 presents our results by first describing the developed farmer typology and the types' *perceived agency* to adopt new N practices and their perception of N policies. In section 5, we discuss our results in the context of recent literature by analyzing the relationship between the types' perceptions of N policies and agency, identifying type-specific factors that constrain (and enable) farmers to adopt N-reduced practices. Finally, section 6 presents our resulting policy-oriented conclusions.

2. Theoretical framework

This section reviews the literature and provides a classification of current N policies. In the second part we present the theoretical approach of the study, defining the term *perceived agency*.

2.1. Policy literature review and classification of N policies

In Germany, policy instruments including both multi-level and multi-sectoral are set in place to reduce agriculturally sourced N emissions. With the CAP being introduced in 1962, the national fertilizing law was implemented the same year in Germany. Similarly, many of the later imposed policies are sourced in European legislation. In 1996, Germany passed the first FO to implement the European Directive 91/676/EEC (Nitrates Directive) into national law. This was followed by adaptations of national environmental and spatial planning law to enforce EU law. However, only in the last decade, Germany started to consistently address N surpluses at the national political agenda (SRU 2015). The SRU report defines environmental policy instruments as policy tools that are created and used by a governmental or supranational entity (ibid.). Extending its scope, we define policy instruments as public and private tools of governance that 'are intended to ensure that technical and organizational adjustments which directly affect the environment are implemented in practice' (ibid., p. 221). Drawing on literature on policy instruments (Cobb and Elder 1983, McDonnell and Elmore 1987, Bemelmans-Videc *et al* 2011) as well as on policy analyses by SRU (2015) and Feindt *et al* (2019), we distinguish between five groups of N policy instruments: (1) Agenda-Setting, (2) Public Regulation, (3) Economic, (4) Capacity-Building and (5) Private Regulation & Co-Regulation (figure 1).

2.1.1. Agenda-setting

In the literature, 'agenda-setting' is often referred to as the stage in which issues get politically problematized and first brought to the attention of policy-makers (Cobb and Elder 1983). Agenda-setting instruments affect the behavior of actors involved in policy-making in order to pursue preferred policy initiatives (Shivakoti 2014). While some agenda-setting instruments explicitly set N-related target values and thus contribute directly to N reduction (e.g., EU Farm to Fork Strategy), others only implicitly mention N-related quality or emission reduction targets as requirements to achieve the primary target (e.g., German Climate Action Plan 2050). Most recently, as part of the European Green New Deal, the Farm to Fork Strategy proposed a legislative framework for sustainable food systems that includes the reduction of N losses (European Commission 2020). On the national level, the German Sustainability and Biodiversity Strategy (BMUB 2017) formulated a target value of 80 kg N/ha for the annual N balance, which was to be achieved by 2010, yet could not be reached. The ensuing Federal Nitrogen Strategy further defined an integrated indicator and has calculated a national N target (Heldstab *et al* 2020).

2.1.2. Public regulation

Public regulations refer to measures legislated by governmental entities to 'influence people by means of formulated rules and directives which mandate receivers to act in accordance with what is ordered in these rules and directives' (Bemelmans-Videc *et al* 2011, p. 31). On the national level, regulations for N reduction range from agricultural, environmental to spatial planning law. The most notable and visible in recent years is the FO which represents an important component in achieving the objectives of the legally binding EU Directives

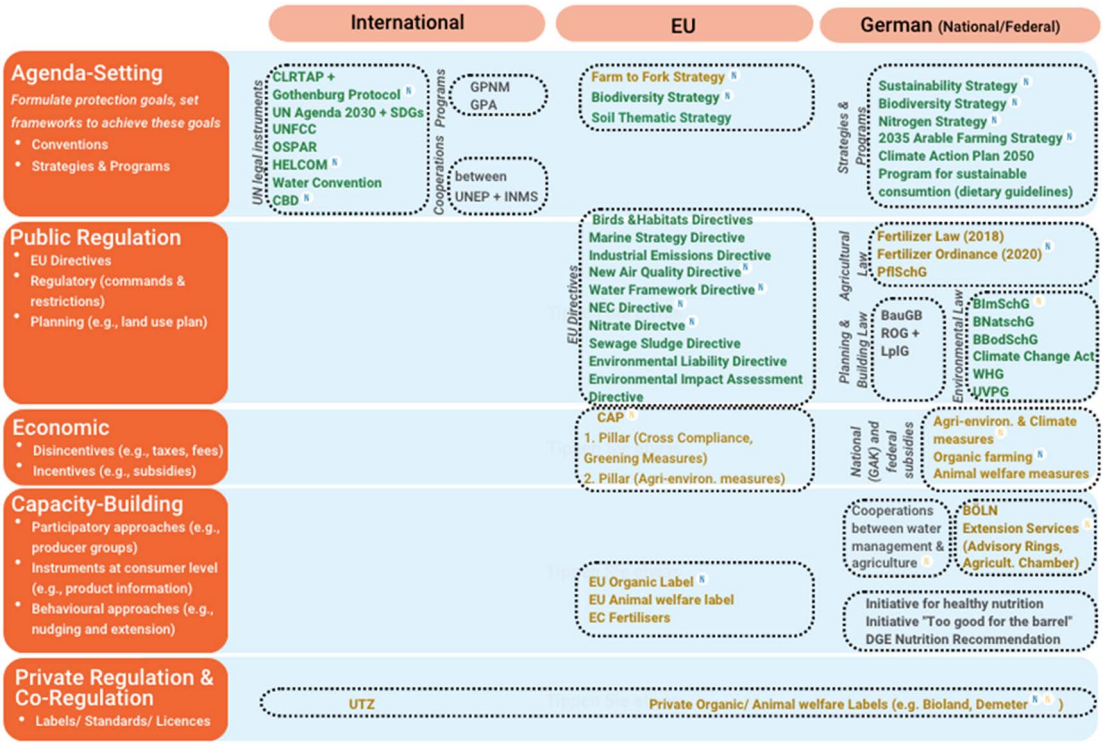

Figure 1. German agricultural N policy framework. Mapping of all policy instruments that explicitly and implicitly influence the management of agricultural N flows in Germany, listed according to instrument type and policy level (International, EU, German (national/federal)). The green N label marks instruments, which explicitly formulate N target values; the yellow N label marks instruments, which only partially formulate explicit N targets. Instruments without any label only implicitly address N in the sense that N reduction is necessary to achieve their formulated objective. Instruments are colored based on their political affiliation: agricultural (brown), environmental (green) or neither (black). [Acronyms: CLRTAP = Convention on Long-range Transboundary Air Pollution, SDGs = Sustainable Development Goals, UNFCC = UN Framework Convention on Climate Change, OSPAR = Convention for the Protection of the Marine Environment of the North-East Atlantic, HELCOM = Helsinki Convention, CBD = Convention on Biological Diversity, GPNM = Global Partnership on nutrient Management, GPA = Global Program of Action for the Protection of the Marine Environment from Land-based Activities, UNEP = United Nations Environment Program, INMS = International Nitrogen Management System, PflSchG = German Plant Protection Act, BImSchG = Federal Immission Control Act, BNatSchG = Federal Nature Conservation Act, BBodSchG = Federal Soil Protection Act, WHG = Federal Water Act, UVPG = Act on the Assessment of Environmental Impacts, Bau GB = Federal Building Code, ROG + LplG = (Federal) Regional Planning Act, 'EC fertilizers' = Regulation (EU) 2019/1009, GAK = Joint Task for the Improvement of Agricultural Structure and Coastal Protection, BÖLN = Federal Scheme for Organic Farming and Other Forms of Sustainable Agriculture].

(Nitrates, Water Framework and NEC Directive). Some regulations only apply to large holdings, such as the BImSchG (Federal Immission Protection Act) that can enforce an installation of exhaust air purification systems[6] to reduce NH_3 emissions (NH_3 filter). Many regulations, e.g., from environmental and building law, also only implicitly include N targets through referring to Good Farming Practice[7] (GFP).

2.1.3. Economic

Public economic instruments refer to state incentives that aim to alter agents' actions through compensations such as subsidies (to incentivize wanted action) or taxes (to disincentivize unwanted action) (Bemelmans-Videc *et al* 2011). In contrast to regulations, addressees are not obligated to adjust, rather it is up to them whether to take an action or not (Bemelmans-Videc *et al* 2011). However, some disincentives, such as taxes, do hold an obligatory force; yet the difference to regulations remains that the action itself is not forbidden, only rendered more expensive. In Europe both types of economic instruments are in use. Specifically, two different regulatory taxes to reduce N are in place (Wegener and Theuvsen 2010): taxation of synthetic fertilizers (Sweden, Finland and Austria) and a tax on N surpluses (Denmark and Netherlands). The latter, also proposed by the SRU, aims at reducing negative external effects of N emissions while allowing for better ecological targeting and lower

[6] A BImSchG procedure is not required for a new barn construction with up to 1500 fattening pigs, between 1500- 1999 a simplified BImSchG procedure and from 2000 fattening pigs a comprehensive procedure with public participation is required (Stoffels *et al* 2019). However, an amendment to the Technical Instructions on Air Quality Control (part of the BImSchG) should soon ensure that the retrofitting of exhaust air purification systems will also become mandatory for existing, larger stables within five years (Lehmann 2019).

[7] Also referred to as 'good professional practice' or 'good agricultural practice', is an undefined legal term. It constitutes minimum environmental standards for farm management and serves as a precondition for payments of the EU Common Agricultural Policy (Bergschmidt *et al* 2003) In the German context, the term is used in environmental, agricultural and planning law.

abatement costs per kilogram of N compared to the taxation of synthetic fertilizers (Wegener and Theuvsen 2010, SRU 2015). The largest economic policy instrument in the agricultural sector is the income transfer and subsidy policy of the CAP.

Income transfers ('direct payments') are achieved through subsidies linked to the input factor land, which are supposed to have little effect on output prices to comply with international trade regulations and minimize market distortions (Feindt *et al* 2019). To improve environmental performance, direct payments are bound to cross-compliance requirements to contribute to an area-unspecific, comprehensive reduction of N inputs. While the operationalization of 'good agricultural and environmental conditions' in the agricultural payments' commitments regulation stays rather vague, cross-compliance also binds its funding to statutory management requirements. 'Greening' and 'Rural development' subsidies for agri-environmental measures, organic farming and contractual nature conservation are paid on an area- or site-specific basis and are intended to contribute locally to meet more demanding protection standards or to the targeted reduction of emissions in highly polluted areas (SRU 2015).

2.1.4. Capacity-building

Rather than regulating or incentivizing certain actions, capacity-building aims at influencing people through the provision of immaterial, intellectual or human resources (McDonnell and Elmore 1987), also simply referred to as information or knowledge (Bemelmans-Videc *et al* 2011). The transfer can be initiated by the government (McDonnell and Elmore 1987) as well as private actors or institutions. Beyond informing, capacity-building aims at enabling citizens in their agency to act as wished. In contrast to economic instruments, capacity-building 'focuses mainly on longer-term development objectives rather than short-term compliance' (McDonnell and Elmore 1987, p. 9). It includes behavioral approaches, such as public or private agricultural extension services[8], offered by agricultural chambers, farming associations or collective advisory rings. Furthermore, the initiation of voluntary co-operations between local water management and farmers are examples of participatory instruments, formulating N targets through N reductions plans.

2.1.5. Private regulation & Co-regulation

Private regulation refers to a legal regime[9] characterized by setting standards, auditing and law enforcement which is, at least in part, separate from government influence (Feindt *et al* 2019). Behringer and Feindt (2019) argue that in recent decades, the governance of the agri-food system has increasingly involved private actors, leading to a shift from public authority to hybrid food governance. This practice of 'co-regulation' describes the process where private and public norms and standards interact with public policy and regulation in complex ways (ibid.). In the case of N regulation, there are private organic (e.g., Demeter label) and animal welfare labels and standards which explicitly (ban synthetic fertilizers) or implicitly (reduced number of animals per hectare) address the use of N.

2.2. Theoretical approach

To identify what constrains farmers from adopting N-reduced farming practices, this paper applies a practice theory approach, analyzing farmers' perceptions of their capacity to act. In response to the social theory debate whether it is individual agency (internal motivation), or structure (external force) which determines human action, practice theory seeks to explain the recursive relationship between human action, agency and social structures (Bourdieu 1977, Giddens 1984). Following Giddens' approach of practice theory, practices are the repetition of acts (routines) of individual agents, while agency is the 'capacity to make a difference' (1984, p. 14). Agency thus further implies the capacity to reflexively monitor actions, but with structural limitations. According to Giddens' theory of structuration (1984), agency and structure are intertwined: social structures, including rules and resources, are not opposed to actions of individuals but are incorporated into them. Structures are not pre-existent and unilaterally produce action, but potentially change in the course of action. Structures can thus enable or constrain action; at the same time, they only come into being through human action (ibid. p. 18–20).

Drawing on Giddens, we understand farmers' practices (farming and N practices) to be shaped by both; farmers' agency and social structures, which in turn have a reciprocal relationship (figure 2). N Policies are part of farmers' social structures that potentially enable or constrain farmers' agency and practices. For our analysis, we consequently focus on farmers' perceptions and descriptions: the described farming and N practices on the one hand, and their perception of agency and N policies on the other hand. To underline the study's narrow focus on farmers' perception of their capability to act, and to denote the intertwining relationship of agency and

[8] Often also referred to as agricultural advisory services.

[9] Legal regime refers to a system or framework of rules governing some physical territory or realm of action that is at least in principle rooted in some sort of law (Hurst 2018).

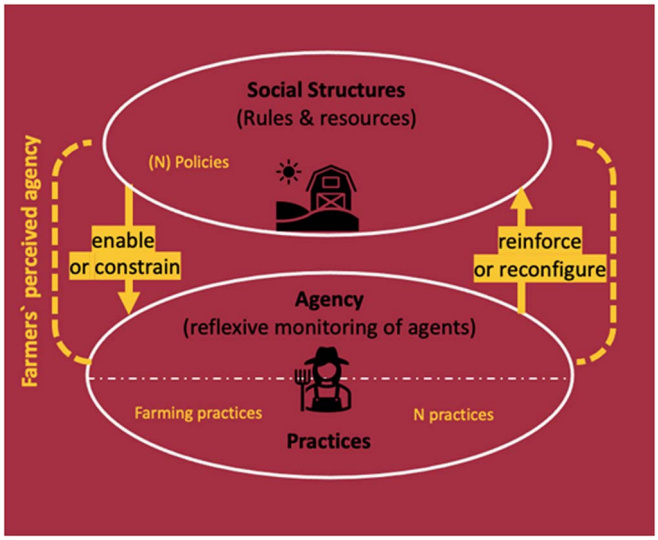

Figure 2. Theoretical approach of perceived agency based on Giddens structuration theory.

structure, we use the term *perceived agency*. As an analytical tool, *perceived agency* is defined as the individual perception of the possible capacity to change action.

By comparing farmers' *perceived agency* to adopt new farming practices (general *perceived agency*) with their *perceived agency* to adopt new N-reduced farming practices (specific *perceived agency*), this study sheds light on N specific constraining factors. Besides the analysis of N policies as a factor, further constraining (and enabling) factors regarding the adaptation of N-reduced farming practices were reported by the farmers within the course of the study. According to our theoretical approach, these factors could be assigned to farmers' social structures (e.g., availability of employees, public discourse, and land access/ownership) or individual agency (e.g., self-identity, future perspectives, and knowledge). However, demonstrating the reciprocity of structure and agency, we discuss them in section 5 as either constraining or enabling factors.

3. Methods

The following section outlines the methods used to study farmers' *perceived agency and their perception of N policies*. To integrate an in-depth perspective on the practices and perceptions of farmers, we conducted problem-centred interviews (PCIs) (Witzel 2000) with pig farmers. Applying the Grounded Theory (GT) methodology, we created portraits of the farmers' practices and perceived forms of agency based on the interpretation of the interviews. This led to a classification of the interviewed farmers into three types.

3.1. Problem-centred interviews

We used PCIs to focus on the practices and perceived agency of farmers within their general farming and specific N practices. PCIs attempt to capture the interviewee's ways of processing social reality and aim at the development of theoretical knowledge on a given societal and everyday life problem in the dialogue between interviewer and interviewee (Witzel 2000). The dialogue integrates the interviewer's prior theoretical knowledge and the interviewee's practical knowledge in a research process that is both inductive (theory-generating) and deductive (theory-testing) (Bloor and Wood 2006). By designing an open and narration-generating interview manual, the interviewee is stimulated to unfold their everyday life perceptions and routines, while the interviewer tries to generate scientific knowledge by ad-hoc questions and specific probing questions.

3.1.1. Sampling

To pre-select our sample, we limited our study to full-time farmers that exclusively manage pigs[10], including sow, piglet, and fattening farming[11]. In accordance with our research aim, we decided to interview family-

[10] Depending on the farming type (organic/conventional) this excludes farms with less than 400/1000 pigs, as these are either profitable if part-time managed or if they include the management of other livestock.

[11] Exceptions were made when farmers managed other livestock as a hobby (e.g., sheep, cattle). Also, crop-production was no reason for exclusion.

Table 1. Distribution of pig farm sizes (including piglets, breeding sows and boars) in Germany (BMEL 2016) and placement of our interviewed farmers within this distribution. Number of holdings (grey boxes + number) and total number of pigs (blue outlined boxes) of the eight farmers of our sample (farmers are colored according to the assigned typology [Farmer 1 + 2 = first type, farmer 3 + 4 = second type, farmer 5–7 = third type, farmer 8 = reference data]. [Green outlined boxes = official category of holding(s); grey colored boxes = category according to total number of pigs managed by the farmer].

			Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5	Farmer 6	Farmer 7	Farmer 8
Farming type			Conventional	Conventional	Conventional	Conventional	Organic	Conventional, Outdoor stable	Conventional	Conventional, Organic
Total number of pigs			1000 - 1999	1000 - 1999	2000 - 4999	1000 - 1999	400 - 999	2000 - 4999	2000 - 4999	2000 - 4999
Distribution of pig holdings and number of pigs in Germany (BMEL 2016)										
Number of Pigs	**Holdings (in %) in Germany with x number of pigs (2016)**	**... with a share of Pigs in % (2016)**	**Matched with number of holdings (green outlined + number) and total number of pigs (grey box) of the eight farmers of our sample**							
1 - 49	36,8	0,5								
50 - 99	5,9	0,6								
100 - 399	14,7	4,8								
400 - 999	19,1	**18,8**	**1**				**1**	**1**		
1000 - 1999	16,5	**32,9**	**1**	**1**	**2**	**1**		**2**	**2**	**2**
2000 - 4999	5,7	**23,8**								
> 5000	1,3	18,6								

managed farms (both entrepreneurial and peasant-like), targeting the decision-makers of the pig farm businesses. Farms with different sizes were considered, excluding profitability as a selection criterion. In accordance with this pre-selection, 28 inquiries were sent to potential interviewees by e-mail and telephone. We received 12 positive answers of which we made our selection based on representativeness (BMEL 2016) for the sector (farming type[12], total number of pigs[13], location). After reaching a certain level of 'theoretical saturation' (see section 3.2) from the interviews, we closed our sample. Table 1 shows our selection of farms matched with the distribution of pig farms in Germany, representing the three size-categories with the highest overall share of pigs in percent in Germany. The interviewed farmers are distributed over five federal states, including those areas with the highest number of pigs (Lower Saxony).

A total of eight farmers were interviewed, with the first three interviews taking place on site and the other five by telephone[14]. The last interviewee (farmer 8) was employed on a research farm and worked as a pig farming consultant. This data was excluded from the typology classification and used as a reference point for the validation of the generated ideal types. The interviews were conducted in March 2020 and varied between 1:20 and about 2:30 h.

3.1.2. Realization

The interviews were based on a semi-structured manual (appendix I, see supplementary material (available online at stacks.iop.org/ERC/3/085002/mmedia)). All interviews were recorded and anonymized for the purpose of this publication. As applied from the interview manual, the interviews included questions about pig farming practices, specific N practices (figure 3) of the farmer ((daily) routines), the farmers' biography and motivation for their job (education, former professions, reason to become farmer) and information on the farm (size, heritage, ownership relations). As applied from the interview manual, the interviews included questions about any past events that changed the farmer's practices or *perceived agency*. Following the interviews, we recorded additional remarks and comments as well as the interviewer's observations in postscripts, which were included in the analysis. The interviewer's observations comprised impressions of the atmosphere, the relationship between interviewer and interviewee, as well as peculiar features of the interview.

[12] With only 0.5 percent of the pork produced in Germany coming from organic farms (Zinke 2018), we decided to interview only one organic farmer to however include this perspective.

[13] It was only during the interviews that the official number of holdings of each farmer were named, which revealed that seven of the eight chosen farmers officially subdivided their farm in more than one holding. As seen in table 1, most interviewed farmers own at least one holding in the official category of 1000-1999 pigs. For the sampling of our interviews, we stuck to the representation regarding the total number of managed pigs per farmer, as we assumed that farmers apply the same farming practices on their multiple holdings.

[14] While it was planned to interview all farmers on their farms, to gain further impressions of their N practices, we decided to switch to telephone interviews due to the start of the COVID-19 Pandemic during the conduction process of the interviews.

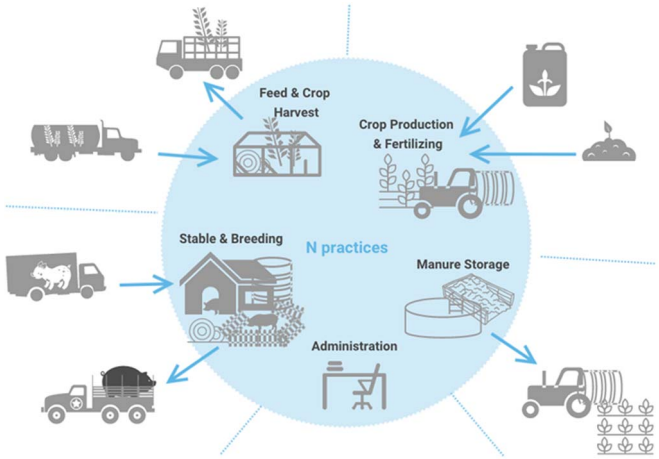

Figure 3. Simplified illustration of pig farmers N practices (practices related to N use including processes that occur on and off the farm).

3.2. Analysis and typology development

The analysis of the interviews is based on the coding procedure of the GT methodology (Strauss and Corbin 1994), as recommended for the analysis of PCI (Witzel 2000). GT aims at the development of empirically grounded theoretical knowledge and integrates theoretical concepts from previous research with new thematic aspects and insights gained in the analysis of the material. The GT approach does not rely on big samples but on 'theoretical saturation' (Glaser and Strauss 2017, p. 61). In other words: If you find repeating patterns and new cases do not provide new insights, you have reached a certain level of saturation. The aim of this study was to find some major differences and the small sample size already demonstrates the significant differences in cognition and production characteristics of the illustrated three types of farmers to a sufficient level.

The process started with an open coding-phase, where text passages that related to the research questions were coded with either descriptive codes or codes derived from the literature mentioned above. Based on the open codes, we created portraits of the farmers' practices and perceptions. In the axial and selective coding, we identified recurring patterns between the portraits, which led to the elaboration of the following type-categories: structure of farming systems, types, and reasons for the adoption of new farming practices and farmers' *perceived agency* regarding general farming practices.

4. Results

In this section, we present the results of the pig farmer interviews in three parts: First, by introducing the farmers along the typology categories. In a second step, we depict and compare the three types' *perceived agency* regarding the adoption of new N practices. Lastly, we present the farmers' perception of N policies, drawing on the classification of current N policies (see section 2.2).

4.1. Identification of farmer typology

The farmer types ('Weary', 'Routine' and 'Inventive') are classified according to three overarching categories, identified from the interviews: (1) the *structure of their farming system*, (2) *types and reasons for adoption of new farm practices* and (3) their *perception of agency with regards to their farm practices.* The 'Weary' type is represented by farmers W1 and W2, both living in a livestock-intensive agricultural area in Lower-Saxony. While W2 already quit farming some years ago and lives off the leases from their farm and land now, W1 is still actively farming, yet considering quitting as well. The 'Routine' type is represented by the farmers R1 and R2 from Schleswig-Holstein. The 'Inventive' type is represented by I1, I2 and I3 who have their farms in Bavaria and Mecklenburg-Western Pomerania. Table 2 provides an overview of the type-specific structure of the farming system (farm system, farm inheritance, farmer specific farm structure), types and reasons for adoption of new farm practices (former changes, upcoming changes, perception pf changes) and their perception of agency (perceived (in) dependency, perceived agency, farmer specific agency) with regards to their farming practices.

Table 2. Overview of classification aspects of farmer types.

	'Weary'	'Routine'	'Inventive'
Structure of farming system	***Farm system***		
	Conventional specialized production, 'open-system' farm: purchasing piglets and selling the fattened pigs to local slaughterhouses (W1) or livestock trade (W2)	**Conventional specialized production, 'open-system'** farm + - **add-on services:** purchase piglets and sell the fattened pigs as member of a producer group (R1) or to livestock trade (R2), have additional income from machinery rental (R1) and house rental (R2) services.	**Rather unconventional, specialized distribution, partially 'closed-system'** farm: partially grow their own feed, purchase feed, with partially specialized distribution solutions
	Farm inheritance		
	Both farms are inherited from their fathers, have been in **family ownership for many generations**, families live on site	Both farms are **inherited from their families**: R1's family looks back to a tradition of farming for over 300 years, R2´s father was a newcomer	All three farms are **inherited from their families**: I1 and I2 took over the farm from their parents-in-law, I3 from their father.
	Farmer specific farm structure		
	W1 manages less than 50 ha of land (partially leased) grows and sells grains, liquid animal feed is bought externally, works without employees, sometimes with the help of their father	R1 manages the farm and more than 400 ha of land (partially leased) together with one family member, has 2 permanent employees, several short-term employees and one trainee, liquid animal feed is bought externally, manages a slurry spreading business	I1 is the only **organic farmer** of the sample, decided to breed piglets because her/his association consultant identified a market gap, grows and mixes own feed (additional feed is bought externally) on their (partially leased) land (70 ha), practicing 'a very close interlocking' (I1 #00:16:31-6#) with their distribution-partners
	W2 grew and sold grains, bought liquid animal feed, worked with multiple employees, now lives off the leases from their farm and land (less than 50 ha)	R2 runs the farm alone, sometimes with the help of her/his father, with 50 ha land (partially leased), grows and mixes own feed, but also needs to buy feed externally, builds and rents out houses	I2 , together with their partner, manages the biggest farm of the sample, a **conventional but outdoor stable, distributes via** direct contracts with a big supermarket that pay for their outdoor and animal friendlier production, grows their own feed on their (partially leased) land (180 ha), has 2 permanent employees and several short-term employees
			I3 manages a sow and pig fattening farm with 20 employees/trainees, with more than 300 ha land on their own property, **grow their own feed, mix the feed on-site, have a slaughterhouse and sell parts of it on-site in a farm shop,** majority of pigs and crops are sold to traders
	Former changes		
	(1) **Adjustments to legal requirements**: stable and machine upgrade, implementation of greening measures (W1)	(1) **Adjustments to legal requirements:** stable and machine upgrade, implementation of greening measures (R1, R2), R1 recently started to grow cover crops	(1) **Adjustments to legal requirements:** stable and machine upgrade, implementation of greening measures (I1, I2, 13)
	(2) **Incremental alterations for financial improvement:** change of crops for greening measures,	(2) **Incremental alterations for financial improvement:** xpansion of dairy cows due to milk	(2) **Incremental alterations for financial improvement:** straw in stables (I2), local slaughtering (I3)

Table 2. (Continued.)

	'Weary'	'Routine'	'Inventive'
	N/P (phosphorus) optimized feeding, closing of dairy farm in 2019 (W1)	quota (R1, R2), closing of dairy farms to enable an expansion of fattening pigs (R1, R2), increase of house building and renting (R2), decision to buy bigger machinery and start a service business to rent out agricultural services (R1), R2 experiments with efficiency upgrades such as N/P optimized feeding and the change of distributors and piglet sellers	
	(3) **Intrinsically-motivated:** planting of cover crops for humus production, keeping of cattle for a hobby (W1), decision to stop farming (W2)	(3) **Intrinsically-motivated:** closing of dairy farm also due to personal dislike of dairy farming and preference to build houses (R2)	(3) **Intrinsically-motivated:** changeover to organic and 'Naturland' label (I1), GMO-free feeding and implementation of pigport (I2) (4) **Society-oriented:** urge for more transparent and animal friendly stables after mad cow scandal/ other epidemics (I2, I3) (5) **To increase independence:** photovoltaic system for increased self-supply (I1), Purchase of land (I3), own feed cultivation (I3), (6) **Future-oriented decisions:** buying machinery even before it became legally enforced, building stables and slaughterhouses according to EU conditions (I3)
Types & reasons for adoption of new farm practices	***Upcoming changes***		
	Maintenance measures W1 speaks of a standstill	Maintenance measures (R1, R2)	Maintenance measures (I1, I2, I3), reduce number of pigs because several current employees quit and the difficulty of finding new ones (I3)
	Perception of changes **Mostly negative**	Generally **positive if financial benefit is seen**	Generally **positive,** rather described as **innovation**
	Perceived (in)dependency Perceive a **strong dependency on external forces**, such as the bank, subsidies, and agricultural policies	**Rely on externals**, such as piglet sellers (R2) and market prices (R1, R2), feel **self-determined** regarding their farming practices and optimization efforts	Especially because of their individual distribution solutions, they feel (partially) **independent of the varying market prices**
	Perceived agency Perceive to have **low agency** and regard the current farming state as **frustrating**, because of externally imposed pressures and directives that **prevent the farmer from doing the job they want to do:** Increased amount of office and documentation work (burdening and increasingly unmanageable) versus working in the stable or on the field (recovery, fun, reason they - used to - like their job)	Perceive to have **medium agency,** portray their current farming condition as **generally optimistic** as they believe that there will always be **demand for conventional pig farming, and** feel keen to experiment with **incremental changes to increase farming efficiency**	Perceive to have **high agency,** highly valuing their independence

Table 2. (Continued.)

	'Weary'	'Routine'	'Inventive'
	See a **possible future, including agency, only for big farms or (organic) niches,** not for small farms like theirs (W1, W2)		Using this privilege, they feel **capable of observing policies/demands of society** and thus prepare for, **or even shape, upcoming political and societal requirements** Experience their way of farming **as generally approved of by society (and politics)** and feel keen to experiment and **implement their own ways of agriculture**
	Farmer specific agency		
Perception of agency	**W1** **feels left behind like a minority/ unsupported by government:** missing infrastructure (slow internet) and missing perspective (machinery for modern farming systems is made only for big farms), only feels independent when speaking of **needing no employees** (does not want to rely on them)	**R1** self-identifies as **'too conservative or too orthodox'** (R1 #01:12:56-8#) **to change to organic farming,** yet feeling 'confident' (R1 #01:19:48-9#) that conventional farming will also be in demand in the future	**I1** regards unconventional farming as **'exciting'** (I1 #00:04:57-3#), feels capable of acting due to the clear framework of conditions in organic farming
		R2 feels to have **earned agency due to (financial) success** in competing on the world market: **'I'm practically in the upper quarter'** (R2 #00:10:01-4#) as well as the expansion of steady income from add-on services outside of pig farming	**I2** feels even **'missionary'** (I2 #00:26:40-6#), because **'nobody knew if that was possible or not'** (I2 #01:05:59-2#)
	W2 feels self-determined and satisfied to have **escaped the 'rat race'** (W2 #01:30:17-0#), living from her/his lease now		**I3** is more cautious in respect to the dependency on private labels/ contracts, **looking for long-term security:** instead of a profitable biogas plant, I3 decided to invest in own fodder production to increase independence from state payments and feed sellers to be financially and decision-wise independent: **'I do not need to ask a bank'** (I3 #01:32:03-3#)

W1, W2, R1, R2, and I3 manage conventional pig farms which include indoor stables with slatted floors and fully automated feeding systems (liquid feed). I1 and I2 manage non-conventional farms, either farming according to organic standards (I1) or keeping pigs in outdoor pigport[15] stables (I2). I1, I2, and I3 describe their farming as a rather 'closed-system' that includes various production steps (e.g., pig breeding, own feed production). According to the farmer's statements, 'closed-system' farms[16] focus on specialized distribution as compared to rather 'open-system' farms (W1, W2, R1, R2) that specialize on single production steps (pig fattening) and rely more on market inputs, as they do not grow their own feed or breed their own piglets.

[15] Pigport is a concept for outdoor climate stables that was strongly coined by Rudolf Wiedmann in Germany. The stalls are divided into two areas: the 'warm area' with a lying and feeding area and the outdoor area as a 'cold area'. The stalls are not forced-ventilated but are ventilated by opening and closing flaps (Bockisch and Van den Weghe 2008).

[16] However, it must be noted that it is never a closed system, given that they rely on external ecosystem services and provide products for the market. Circular system could describe it better, as some flows go in circles.

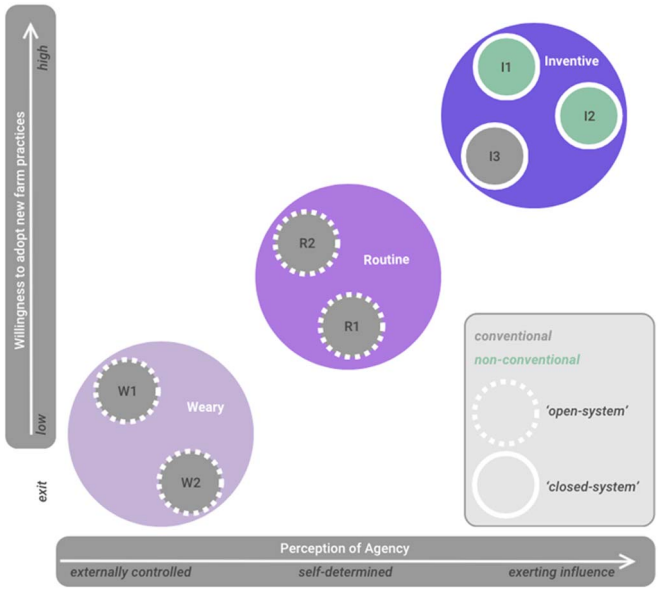

Figure 4. Classification of farmers to the farmer types ('Weary', 'Routine', 'Inventive') based on structure of farming system (open versus closed), willingness to adopt new farm practices and their perceived level of agency.

As portrayed in figure 4, farmers with both low *perceived agency* and few reported adoptions of new farm practices are categorized as the 'Weary' type. This group includes farmers W1 and W2 who tend to feel overburdened and suspended. They perceive their scope of action as limited and externally controlled and report only minor changes to their pig farming practices. The 'Routine' type farmers are characterized by a moderate perception of agency and willingness to adopt new farm practices. Farmers in this class act based on routine and incremental improvement efforts. The 'Inventive' type reports the most radical changes and high autonomy in their decision making. This third type tends to adapt early to new business situations and is inventive in their actions and practices.

4.2. Farmers' perceived agency to adopt new N practices

Through asking about current N practices and farmers' *perceived agency* to adopt new N practices, we identify certain differences between the types reported practices (appendix II, see supplementary material). While currently some N practices are similarly applied by all farmers (e.g., grow cover crops, use open manure pit), others showed strong deviations between the farmer types (e.g., fodder procurement, distribution) (see supplementary material). Nevertheless, all farmers report low to little agency to adopt further N-reduced practices. The 'Weary' type, that has a generally low *perceived agency* regarding their farming practices, has implemented only the legally enforced N practices (cover crops, manure spreading) and reports similarly low agency regarding further changes to adopt N-reduced practices. The 'Routine' farmers already adopted further N-reduced practices (e.g., multi-phase feeding).

Regarding the adoption of additional N-reduced practices, the 'Routine' type reflects that there is more reduction potential and perceives to have agency for change if its own advantages (financially/ socially) are anticipated. The 'Inventive' type reports a general high agency, yet their *perceived agency* to further adopt new N-reduced practices is rather low, presumably due to their perception that they have 'no N problems'.

A comparison of the types' general *perceived agency* with their specific *perceived agency to* adopt further N-reduced practices, as illustrated in figures 5+6, indicates a disparity of constraining factors that only in some cases is bound to the general perception of agency. If farmers' general *perceived agency* is low, N practices are at the minimum requirements and further N reductions are unlikely to be adopted ('Weary'). However, even if farmers' *perceived agency* is high(er) ('Routine'/'Inventive'), it does not automatically lead to an increase of the *perceived agency* to adopt new N practices.

4.3. Farmers' perception of N policies

Our results demonstrate that most farmers report only on a very small number of policies, even though various policy instruments, including both multi-level and multi-sectoral, are put in place to reduce agriculturally sourced N emissions in Germany (see section 2.1). All farmers report to be influenced by public regulations (FO,

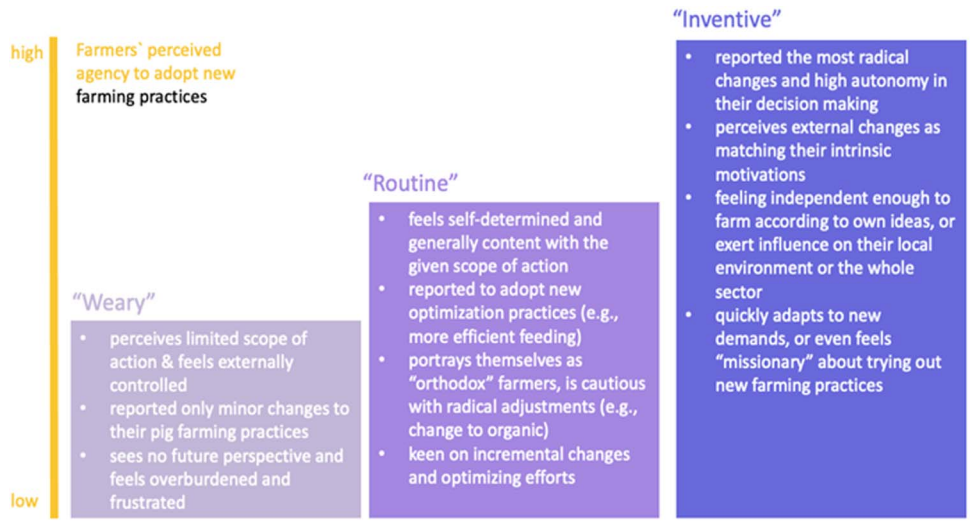

Figure 5. Farmers' perceived agency to adopt N farming practices, illustrated by farmer type.

Figure 6. Farmers' perceived agency to adopt N-reduced practices, illustrated by farmer type.

spatial planning law), and economic instruments (CAP). The 'Routine' and 'Inventive' type's practices are also shaped by capacity-building instruments such as private and public extension services. Only the 'Inventive' type reports to also be influenced by private regulations, such as private labelling and direct sales programs. While public regulations and economic instruments are predominantly perceived as burdensome, contradictive, or ineffective by all farmers, capacity-building, private regulation, and agenda setting instruments enjoy a remarkably positive perception (figure 7). Besides the voluntary character of the latter policy instruments, they are perceived as enabling farmers scope for action: being either 'helpful to stay competitive' ('Routine'/public extension services) or 'matching own ideas of agriculture' ('Inventive'/private extension services and regulations).

Regarding the FO, all farmers claim that many of the required measures do not align with their knowledge of GFP and further contradict their local climate and soil conditions. However, the degree of criticism and the reported coping with the required measures varies. W2 reports to feel forced to put all their manure on the field at once. Both 'Routine' type farmers denounce the missing scope for action for local conditions, as they see greater local N reduction potential in longer manure storage time and less autumn fertilization. Perceiving the FO the least negative, R1 and R2 report to believe in regulations, admitting that they currently would not implement further N-reduced practices from their own initiative. I1 further reports to miss exceptions for organic farms, and I1 und I2 criticize the FO's focus on single aspects instead of tracking the whole N circulation.

Furthermore, our results indicate that all farmer types perceive contradictions between the requirements and aims of the various policies, reporting that a reliable direction and perspective is missing. Especially regarding public policies, one perception expressed by all farmers is that they miss a long-term perspective regarding the future of farming in Germany.

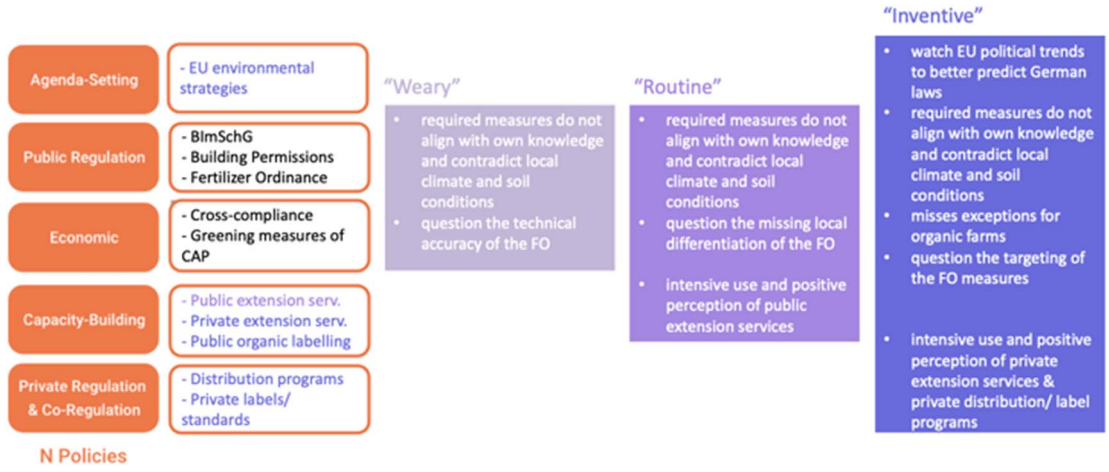

Figure 7. Overview of farmers' perception of N policies, matched with agricultural N policy framework.

5. Discussion

Our study classifies family-managed pig farmers based on their past and current farming practices as well as their perception of agency to adopt new farming practices. Through the analysis of the interviews, the heterogeneity of farmers' practices, perceived agency and perception of N policies are highlighted. Seeking to identify what constrains farmers' from adopting new N-reduced practices, our analysis reveals different constraining and enabling factors which we discuss in the context of recent literature, after a brief identification of the study's limitations.

5.1. Limitations

Socio-demographic characteristics such as the age and gender of the interviewees were not explicitly asked for during the interviews. However, previous literature (Schleyerbach 2009) displays their large role regarding the self-identity and future perspectives of farmers, given the perception of some farmers to not want to make any substantial investments due to their age. Concerning gender, Mölders (2008a) has identified the exceptional relevance of analyzing gender relations in the context of how 'nature' is perceived by farmers and proposes to include gender as a basic category of sustainability research (Hofmeister and Mölders 2006).

As this study focuses on perceptions and self-descriptions of farmers' practices, a social desirability bias[17] (Valor 2007) cannot fully be precluded. To minimize these biases, the interview focuses on past practices and adoptions, by asking them to recall the processes. To compare farmers' perceptions (e.g., 'Inventive' types' perception of having 'no N problem') with data of farmers' reported N budgets (nutrient and/or material flow balance) could be part of a subsequent study to provide insights into potential discrepancies between the claimed practice and the actual practice.

Although the small sample size of the study already showed recurring and contrasting patterns, thus reaching a certain level of saturation, it is disputable whether the types are a good representation of the chosen scope of pig farmers. Given that most of the interviewees volunteered themselves, they may all take part in a similar sample that is not representative of the larger pig farming community, resulting in a level of sample bias. However, as we show in section 5.2, our farmer types are similar to classifications of other studies (Schleyerbach 2009, Barnes *et al* 2011). Future research should add to this classification by considering a larger sample of farmers.

Focusing only on small and medium-sized family-managed full-time farmers, perspectives of agribusinesses and part-time farmers are missing. Given the ongoing trend in Germany that the share of farm holdings with more than 1000 pigs increases, and farms with more than 5000 pigs manage 18.6 percent of all pigs in Germany even though they only account 1.3 percent of all pig holdings (BMEL 2016), a subsequent study could analyze N-related practices of large pig farmers and cooperation.

[17] This bias has been found in regard to sustainability research, when interviewees tend to give the socially desirable answer, although it may not be entirely true (Valor 2007).

5.2. Finding I: We observed that farmers adopted new practices differently in reaction to the increase of external pressures, leading to very divergent perceptions of agency, which formed the basis for our typology

Our results demonstrate that pig farmers perceive their general agency regarding farming practices differently and that this goes along with heterogeneous farming structures and practices. While N regulations (FO and CAP) came up as a dominant influencing factor to their farming practices, farmers reported of many other regulations and external demands that they must deal with. All farmers currently perceive an increase of external pressures; demands and expectations from society and local environment, increased price competition, environmental and animal welfare requirements. In the challenge of dealing with this multitude of demands, the different perceptions of agency can be located.

While the 'Weary' and 'Routine' type similarly operate 'open-system' farms that work and optimize one part of the production chain (fattening pigs), the 'Weary' type feels overburdened and externally controlled without any future perspective. In contrast, the 'Routine' type feels self-determined and generally content with the given scope of action, yet portrays themselves as 'orthodox' farmers, being cautious with radical adjustments, rather focusing on incremental changes and optimizing efforts. The 'Inventive' type covers multiple production processes (breeding, fattening, slaughtering, selling), and focuses on specialized distribution services. This type perceives the external changes and demands as matching their intrinsic motivations, feeling determined and adventurous enough for radical changes, quickly adapting to new demands, or even feeling 'missionary' about trying out new farming practices.

Other typology-based studies identified similarly diverse perceptions and attitudes towards (environmental) adaptations of farmers both in the German as well as the EU context. A survey by an agricultural publisher company (Schleyerbach 2009) analyzed 2927 crop and livestock (pig or cattle) farmers throughout Germany to derive types of farming entrepreneurs. Among other aspects, the analysis included farmers' attitudes towards risk-taking and future orientation. It identified four types: (1) The professionally flexible orientation seeker, (2) the dynamically engaged entrepreneur, (3) the down-to-earth farmer under pressure to change, (4) and the resigned farmer in retreat. Comparing their typology with the one used in this study, farmers of the 'Weary' type match the 'resigned farmer in retreat', the 'Routine' type classifies between 'down-to-earth farmer' and/or 'professionally flexible orientation seeker, and the 'Inventive' type fits well into the 'dynamically engaged entrepreneur'. Showing great overlaps, both typologies also highlight the contrast between farmers that feel dynamically engaged and those that no longer feel included. Drawing on both typologies, the heterogeneity of reactions to the external demands and expectations become visible.

Regarding the connection between attitudes towards the environment and farmers' behavior, another typology-based study by Barnes *et al* (2011) identifies different farmer groups based on the farmers' willingness to implement water quality management practices. Deriving their farmer typology based on attitudes and perceptions towards water quality management within the designated nitrate vulnerable zones in Scotland, the authors identified three types: the (1) multifunctionalist, the (2) resistor and the (3) apatheists. Like the 'Weary' type, the resigned farmer in retreat and the apatheist showed a lack of uptake of voluntary measures and indifference towards the aims of the regulation and to water quality management in general. While our typology did not use 'perceptions towards the environment' as a type-deriving factor, the overlap of the 'Weary' and the apatheist could suggest further research on the connection between farmers' perceptions towards the environment and the farmers that currently consider quitting.

5.3. Finding II: Farmers' general perception of agency does not automatically correlate with farmers' perceived agency regarding their current N practices and further adoptions of practices to reduce N. Varying by type, farmers' N practices are constrained and enabled by different factors

A comparison of the types' general *perceived agency* with their specific *perceived agency to* adopt further N-reduced practices, shows that even if farmers' general *perceived agency* is high(er) ('Routine'/'Inventive'), it does not automatically result in an increase of the *perceived agency* to adopt new N practices. Only in the case of the 'Weary' type, the general low *perceived agency* explains why this types' N practices are at the minimum requirements and further N reductions are unlikely to be adopted. Drawing on this comparison, we conclude that farmers' N practices are constrained and/or enabled by multiple factors, of which some we want to discuss here.

We detect that farmers' described self-identity ('minority'/'orthodox'/'missionary') currently works as a constraining factor for all three types' N practices. Thus, it should be further researched to which degree adoptions of new N routines could be enhanced through fostering nature conservation attitudes within farmers' self-identity. Drawing on our typology, the 'Weary' type, feeling as a left-behind minority, reports to be portrayed to do everything wrong anyway (by the media and local community). Our results suggest that even if

the 'Weary' type would perceive nature conservation as part of their own identity, other structural factors (e.g., limited finances, local soil conditions) might currently impede a change of practice. As for the 'Routine' type who feels orthodox regarding current farming practices, fostering nature conservation as part of their own identity could enhance further N reduction routines, as their willingness to upgrade their slurry spreading machines already demonstrates a certain capability for change. According to our results, the 'Inventive' type - who feels missionary about how to organize their farming practices - might already perceive nature conservation, or at least sustainability, as part of their self-identity. However, given their one-sided focus on animal welfare and organic farming aspects, feedback mechanisms and differentiated knowledge about N reduction is needed.

While studies have highlighted the influence of the prospect of farm-successors on farmers' decision making[18], in our interviews farmers rather highlighted their focus on their (financial) independence, neither wanting to rely on their children's decision (even though W1, R1, I1 and I3 have children that are currently undergoing training in agriculture) nor on external financing (e.g., via banks). Accordingly, the trend of addressing a 'closed-system' and alternative retail structures (especially the 'Inventive' type), also underline the urge for independence and autonomy that shape farmers' N practices. Regarding N surpluses, autonomy from others may however lead to an adverse outcome, since it can imply that livestock farmers over-fertilize their fields with manure, reaching the maximum application rate, instead of providing their manure to arable farms which could save inorganic fertilizers. The reported alternative retail structures (organic label, private contract with supermarket) only partially enable N reduction practices. Thus, it should be further researched if the detected trend of independence might be a consequence of (partially) missing prospects of farm-successors and if it will continue to prevail in the long term.

Our analysis further indicates, that in the case of the 'Weary' and 'Inventive' types, a missing distinct knowledge to act better constrains N-reduced practices. Deriving their farmer typology based on perceptions towards the environment, Barnes *et al* (2011) suggest that the farmers' water quality management behavior could be mainly encouraged by emphasizing favorable perceptions through targeting of information. Regarding pig farming, there is much research available on various N reduction potentials for farming practices. These include increasing efficiency in fertilizer use (e.g., storage and application), livestock feeding, and animal husbandry (Finck 1985, Sutton *et al* 2013), enhanced-efficiency fertilizers (Kanter and Searchinger 2018) and lower consumption of N-intensive animal products (Bodirsky *et al* 2014). Targeting information on specific N reduction potential of each practice, beyond the 'positive-negative perception of organic versus conventional' (farmer E), could enhance N reduction potential for all three farmer types. Regarding the 'Inventive' type, a more distinct and holistic knowledge on the conflicting goals of animal welfare and N-reduced practices should be fostered to avoid unwanted side-effects, such as higher emissions due to straw beddings, outdoor stables, and more space per pig (farmer E). At this point the different N reduction potential of switching to organic crop versus switching to organic livestock production must be considered (Osterburg and Runge 2007, Bach *et al* 2016).

However, our results confirm that solely the individual knowledge and perception about ´being a little bit over the balance' ('Routine') does not automatically result in a change towards N-reduced practices. Regarding the 'Routine' types' decision to upgrade their slurry spreading machines to please the social environment, it should be evaluated how social factors based on self-commitment can enable voluntary N reduction measures. Experimentally testing the effect of non-monetary incentives on farmers, Lokhorst *et al* (2010) found that especially the combination of feedback and self-commitment was effective for behavioral change. Thus, more distinct knowledge on N-reduced farming practices linked with positive feedback from the local community, could possibly enhance further N-reduced practices. However, considering more radical changes (e.g., switching to organic farming), multiple constraining factors must be addressed, including self-identity and access to employees.

Regarding enabling factors, our results, again, indicate that even if farmers adopt equivalent N practices, e.g., new fertilizing machines, they are enabled by different factors: legal enforcement ('Weary'), social environment ('Routine'), business opportunities ('Routine' and 'Inventive') or self-identity as future-oriented farmers ('Inventive'). Also, some factors, such as retail structures and farmers' self-identity, can possibly be both: constraining as well as enabling. Given the variety of factors on N practices, addressing farmers in their local embedded context offers potential to enhance adjustments of current N routines and detect obstacles of change.

[18] All interviewees came to speak about their farm successors, many of them saying that they do not know (yet) if their children will take over the farm (W1, R1, I2). Those with children had in common that they did not want to push their children into taking over the farm, rather aiming at having a debt-free farm not to rely on the children's work or willingness to take over the farm (W1, W2, R1, I1, I2, I3).

5.4. Finding III: If named, capacity-building instruments, private regulations and agenda-setting instruments are perceived positively, whereas public regulations and economic instruments are perceived contradictory and inconsistent. To enable further N reduction practices, there is potential for all N policies to address farmers' heterogenous constraining/enabling factors

Our results demonstrate that the N practices of all three farmer types are influenced by public regulations (FO, spatial planning law), and economic instruments (CAP), while the 'Routine' and 'Inventive' type's practices are also shaped by capacity-building instruments such as private and public extension services and private regulations ('Inventive'). Here we discuss three examples of how N policies can address constraining factors and consequently enable further N reduction practices for all three types.

Example I. Include specific N targets in private regulations and especially co-regulation ('Inventive'). As for the positively perceived policies (capacity-building, private regulations), our analysis illustrates that some potential is already used while much remains untapped. The case of the 'Routine' type illustrates how public extension services serve as information and participation processes that influence farmers' knowledge and self-identity and increase coherence with other policies, such as the requirements of the FO and CAP. However, regarding the 'Inventive' type, our results indicate that especially private and public labelling and distribution programs are in need for N-specific targets to reliably reduce N. This could include, for example, the inclusion of minimum N-use efficiencies into organic labels, which currently have no thresholds for the application of organic N.

Example II. Give space for local/type differences in regulations ('Routine'/'Inventive'). Regarding the FO, all types claim that many of the required measures do not align with their knowledge of good GFP and further contradict their local climate and soil conditions. We argue that the much of the perceived inconsistency is driven by the measure-oriented instead of output-oriented design of the FO, which gives little space for local conditions ('Routine'), exceptions for organic farms ('Inventive') and places its focus on single aspects instead of tracking the whole N circulation ('Inventive'). Regarding the perceived contradiction to farmers' knowledge of GFP, we highlight the need to revise and concretize the GFP on what the current good and best N practices include and what not (anymore) (Hermann *et al* 2020). Various public regulations (spatial planning and environmental law) currently refer to GFP. Yet in stark contrast to the FO, the GFP stays vague and does not include explicit measure and target values regarding N (SRU 2015).

Example III. Provide overarching reliable vision of agriculture, that includes N targets ('Weary'/ 'Routine'/ 'Inventive'). Our results indicate that all farmer types perceive contradictions between the requirements and aims of the various policies, reporting that they miss a reliable direction and perspective. While the missing of a long-term perspective sounds like an easy excuse to relinquish responsibility for their action, it leaves behind questions of: why do the current policies not make clear where the journey goes, so that farmers can make investment decisions and transform to N-reduced farming practices? Are the policy agendas not transparent enough? Do they change too often? Are they not followed by enforcement? A study about the Dutch farmer protests in 2019 concluded that 'nitrogen and ammonia were used as a battleground for a completely different fight' (Ploeg 2020, p. 592) highlighting the deep divisions within the Dutch agricultural sector. Our findings suggest that the situation in Germany shows similar aspects which makes the contextualization of N policies within the broader agricultural policies thus worth considering.

Drawing on the farmer types, we argue that the current mix of N policies that represents the historically grown and changed orientations of agricultural policy reproduces inconsistencies and contradictions. Feindt (2008) argues that the environmental and social conflicts which we are facing in the agricultural sector are the result of years of inconsistencies in the catalogue of objectives of national and European agricultural policies, including its path dependencies and paradigm changes. Hereby, four agricultural policy paradigms are described, which shape agricultural policy and thus agriculture itself (Feindt *et al* 2019, p. 60): (1) productivist/ protectionist, (2) market liberal/ competitive, (3) multifunctional including social/ ecological functions and (4) globalized agriculture (to be understood as a further development of the market-liberal paradigm under conditions of globally integrated value chains).

Comparing the different paradigm strands with our farmer types, most clearly, the 'Weary' type follows the paradigm of a protectionist agriculture, being artificially built up based on subsidies. The 'Routine' type further aligns with the market-liberal/competitive paradigm. Their focus on efficiency and competitiveness shows their urge to break free or distinguish themselves from the protectionist paradigm. Given the international orientation of the pork industry, including world market prices, the 'Routine' type is, however, automatically affected and shaped by the global paradigm. For pig farming the differences between the global

and the competitive paradigm seem blurry, instead representing an expansion of the market-liberal to the global paradigm. The 'Inventive' type appears to be shaped by the multifunctional paradigm, as they view their farming success is based on including ecological and/or social claims. However, their farming is entrenched by the market-liberal and globalized paradigm that enables farming through either national, European, or international private market opportunities rather than government subsidies for environmental or social functions. In conclusion, given the diverging paradigms of agriculture, the increasing hegemony of industrial farming (Ploeg 2020), and the need for an ecological transition of agriculture, it seems necessary to systematically - not on the single farm level - evaluate how N-reduced family pig farming in Germany and in the EU can look like. This could consequently include considering measures such as a relocation of pig production between regions in the EU (van Grinsven *et al* 2018) or a pay-off for farmers ('Weary'), as done so in the Netherlands, to reduce the absolute numbers of pigs (Ministry of agriculture nature and food quality 2020).

6. Conclusions

(1) **N reduction solutions can be found more easily in a collective than a single farm environment.** Our findings underline the importance to address the embedded context of farmers if wanting to enhance further N reduction practices. Exploring that most farmers only interacted in local communities, Mölders (2008b) demands space for communication between multiple actors of the system. Instead of addressing farmers as individuals, studies have proposed to push regional, socially embedded organizations, such as the environmental cooperatives in the Netherlands, that handle farmers in groups to facilitate collective agri-environmental and climate measures (Burton and Paragahawewa 2011). Also, in regard to improving sustainability of the CAP, an upscaling from the current focus on single farms to a landscape- and community-level approach, such as through better spatial targeting, has been proposed (Pe'er *et al* 2017). Addressing farmers as a collective on regional scales could e.g., allow negotiation processes about manure distribution, focusing on what is needed and wanted in a certain region rather than leaving the manure spreading/export to the individual. Similarly, the implementation of certain policy targets could be coordinated by local policy platforms that include next to the farmers also the relevant stakeholder like water works, environmental NGOs, and citizen representatives to enable a social learning process and to find solutions that are optimized to the local context. This is best possible for local externalities such as groundwater pollution; regional and global externalities (ammonia and N_2O emissions) may require representation of remote stakeholder interests, e.g., through state-level representatives. We conclude that collective policy approaches have the potential to embed the heterogeneous contexts and practices of farmers, thus increasing coherence and effectiveness of policies. This would allow implementing reliable, locally embedded, practices to encounter structural barriers (e.g., access to land) and overcome limitations of individual actions.

(2) **Long-term N policies can enhance N-reduced practices if they are legally binding and decrease farmers' perceived inconsistencies and contradictions between existing policies as well as local farming conditions.** Given the numerous policies and N practices, as well as the perception of all farmers that policies are constantly changing and are perceived as incoherent, there is a need for long-term strategies regarding N emissions, on which farmers can rely their adoption of practices on. We propose that the missing overarching policy directions should be communicated and implemented by the given agenda-setting instruments. An integrated N strategy with overall headline targets proposed by Salomon *et al* (2016) was promised by the German government and a first official report was published in 2017 (BMUB 2017). The very ambitious N targets of the national sustainability strategy, whose achievement would require a substantial transformation of agricultural policies and practices, are not yet converted into further measures. Exceeding the target values is still accepted without consequence.
While the implementation of the N strategy is still pending, Hermann *et al* (2020) propose the introduction of a nitrogen law. A legally binding policy framework would require reflecting on the internal and external coherence of the given policies (Pe'er *et al* 2017): is there a clear set of coherent, overarching, well-justified objectives? Are the instruments and more reliable indicators aligned with the objectives of the strategy? Are overlapping and interconnected policy fields considered? Highlighting a need for a systemic view, a consistently implemented N strategy could decrease inconsistencies between the existing and upcoming policies (Hermann *et al* 2020). In this context, the German Farmers' Association, with its historically strong influence on agricultural policies and their power of lobbing against the enforcement of environmental policies must be addressed (Niemann 2003). If consistently followed through, a legally binding N strategy has the potential to consider the heterogeneous environmental conditions and local thresholds, embed local

and regional farming conditions and provide planning reliability for the farmers. Especially with regard to the 'Weary' and 'Inventive' type, a clear roadmap (Taube *et al* 2020) and increased consistency of N policies could enhance farmers' *perceived agency* to reduce N emissions.

(3) **Outcome-oriented instead of measure-oriented policies increase farmers *perceived agency* to adopt new N-reduced farming practices.** Our results indicate that the *perceived agency* of farmers is low if measures are required which seem inconsistent to the local context of farmers. Instead, if there is clarity and a common understanding of the wanted outcome, while providing space for individual action and local conditions, the *perceived agency* of farmers increases. Therefore, policies need to shift from measure-oriented policies (prescribing certain farm practices) towards outcome-oriented policies (prescribing a desired environmental outcome) (Bach *et al* 2016). Especially concerning the FO and CAP, both imposing concrete measures, a change towards output-oriented efforts seems promising for all types. Currently the CAP subsidizes certain management practices, independently of whether they achieve the mitigation effect or not, instead of supporting the mitigation of environmental externalities. Payments with no environmental requirements further undermine the efforts to address environmental challenges (Pe'er *et al* 2017). Instead, Pe'er *et al* (2019) propose that policies should include targets and indicators for improved performance against clear baselines (in our case: N surplus or even the emission of specific pollutants like ammonia or nitrate), which are coherent with international agreements. As such, policies would give farmers the agency to decide the most appropriate measures to achieve a reduction. Outcome-oriented policies allow farmers to include their knowledge and therefore reduce the inconsistencies that may arise if measures conflict with the farmers' perception of good practice. Moreover, confronting the practices with the measured environmental outcome, they also provide the stimulus to revise knowledge and kick off a dynamic learning process.

Again, outcome-oriented policies may have a very different impact on the different farmer types. They might be least effective for the 'Weary' type, who is reluctant to autonomous change and may not be willing to change their farming practices voluntarily. To become effective, outcome-oriented policies need to be aligned with guidance and collective knowledge-production on all levels, e.g., through agencies, training, and extension services. They would also be valuable to the 'Routine' type, who is willing to adopt new practices if they have a desirable expected outcome, but who prefers incremental changes. Finally, if joined with a collective learning approach, outcome-oriented policies would be most effective for the inventive type, who so far is restricted to pre-defined practices that allow for little innovation. Outcome-oriented practices would give space and incentivize further (radical) changes of practices and the development of new solutions.

Acknowledgments

The farmers are highly appreciated for their willingness to take part in the interviews. The publication of this article was partially funded by the Open Access Fund of the Leibniz Association.

Data availability statement

The data generated and/or analysed during the current study are not publicly available for legal/ethical reasons but are available from the corresponding author on reasonable request.

Funding information

Quitterie Collignon and Claudia Hunecke receive funding from the Food System Economics Commission, which is funded by the Rockefeller Foundation (2020 FOD 008) and the Wellcome Trust (221362/Z/20/Z). Felicitas Beier has received funding via a scholarship from the German Federal Environmental Foundation (DBU).

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