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Coverage of nitrogen reduction strategies in the scientific and agricultural press

Thematisierung von Stickstoffminderungsstrategien in Wissenschafts- und Fachpresse

Astrid Artner-Nehls* **and René Méité**

Leibniz-Zentrum für Agrarlandschaftsforschung (ZALF) e.V., Müncheberg, DE

**Correspondence to:* artner-nehls@zalf.de

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Summary

Agriculture substantially contributes to nitrogen pollution in Germany. Yet, reduction potentials provided by researchers are only partially communicated into practice. This paper aims to identify gaps between scientific knowledge of farm-level strategies for reducing nitrogen emissions from slurry and its uptake in the German agricultural press. A review of scientific literature presents the development of research since 1986, text mining analysis shows coverage of abatement measures in the agricultural press from 2010 to 2020. We found increasing coverage while also differences in the choice and changes in the use context. We identified 62 different abatement measures in the scientific journals while in the agricultural press, 80% of the articles dealt with slurry application measures. In both press types, discussion focused on air pollution reduction since 2014. The results of our study can help to communicate scientifically scrutinized strategies and their reduction potentials to farmers.

Keywords: manure management, abatement measures, text mining, media analysis, nitrogen

Zusammenfassung

Die Landwirtschaft trägt erheblich zur Stickstoffbelastung in Deutschland bei. Die von der Wissenschaft ermittelten Minderungspotenziale werden jedoch nur teilweise in die Praxis kommuniziert. Ziel dieses Beitrags ist es, Lücken zwischen den wissenschaftlichen Erkenntnissen über betriebliche Strategien zur Reduktion von Stickstoffemissionen aus Gülle und deren Aufnahme in der deutschen Agrarpresse zu identifizieren. Eine Literaturrecherche dokumentiert die Entwicklung der Forschung in den letzten 31 Jahren. Eine Analyse der wissenschaftlichen Literatur zeigt die Entwicklung der Forschung seit 1986, eine Text-Mining-Analyse die Berichterstattung in der landwirtschaftlichen Presse von 2010 bis 2020. Wir fanden eine zunehmende Artikelzahl, aber auch Unterschiede in der Auswahl und Veränderungen im Gebrauchskontext. In den wissenschaftlichen Zeitschriften identifizierten wir 62 verschiedene Minderungsmaßnahmen, während sich in der landwirtschaftlichen Presse 80 % der Artikel auf wenige Maßnahmen zur Gülleausbringung konzentrierten. In beiden Pressearten konzentrierte sich die Diskussion auf die Reduzierung der Luftverschmutzung seit 2014. Die Ergebnisse unserer Untersuchung tragen dazu bei, Landwirt:innen wissenschaftlich geprüfte Strategien und deren Minderungspotenziale zu vermitteln.

Schlagworte: Güllemanagement, Minderungsmaßnahmen, Textmining, Medienanalyse, Stickstoff

1 Introduction

Agriculture in German agriculture is characterized by high nutrient surpluses, which are associated with negative effects on climate and on the resilience of the environment and ecosystems (Umweltbundesamt, 2014). In intensive livestock farming excessive accumulation of slurry is particularly responsible for nitrogen emissions. Slurry, as defined by the German word "Gülle" is a mixture of urine and faeces with a marginal addition of cropped straw.

Science suggests a variety of abatement measures that reduce nitrogen emissions from farming, particularly in the form of ammonia, nitrous oxide and nitrate. In the 1960ies the debate on negative environmental effects of excessive slurry application started up among scientists and in the 1980ies considerable knowledge has already been accumulated. Politics followed this development, leading to the adoption of the European Union Nitrate Directive (European Commission, 1991) and the German Fertilizer Ordinance (BMELF, 1996).

However, as Germany failed to comply with the Nitrate Directive since, the European Court of Justice initiated a lawsuit against Germany in 2016 leading to the 2017 amendment of the Fertilizer Ordinance with stricter fertilizer legislation obliging farmers to adapt their farming practices. Due to high emission losses broadcasted slurry application particularly became prohibited (e.g., splash plates), and had to be replaced by soil-near strip-wise application. Further legislation, such as the new Fertilizer Ordinance of 2020, the EU Directive on the reduction of national emissions of certain atmospheric pollutants (2016/2284) and the German Technical Instructions on Air Quality Control ("TA Luft"), require further adaptation of emission-reducing practices in the future.

Information provided by the agricultural press reflects and improves the level of knowledge, interest, and acceptance of farm level innovations to reduce excess nitrogen and emissions (Church et al., 2017). By favouring certain abatement measures over others and highlighting certain aspects specialized farming magazines shape the farmers' opinions and preferences for certain techniques. Scientific knowledge is translated for consumption (Boykoff and Boykoff, 2007) and embedded in contexts of use that provide meaning to the farmers.

This contribution examines which abatement measures were considered in the scientific literature and which of these measures were discussed in the agricultural press. The analysis covers a period of 31 years from 1989 to 2020 for the scientific literature and eleven years from 2010 to 2020 for the agricultural reporting in order to map developments in research and agricultural reporting. While we found scientific articles from the last three decades reporting of the agricultural journals reached a sufficient number only in the last eleven years, a period when policy efforts to reduce nitrogen emissions have gained momentum.

2 Material and methods

We applied a quantitative multi-method approach to explore the uptake of abatement measures by the scientific and agricultural press as well as the use context in which this is embedded. The scientific literature was analyzed by a systematic literature review in order to identify abatement measures that reduce nitrogen surplus or emissions on farm-level in cow and pig production. For deeper analysis of the scientific literature and the analysis of specialized farming magazines we used text mining methods in the statistical programming environment R.

First, we identified possible abatement measures along the on-farm manure management chain (MMC), i.e., the stages of feeding, housing, storage and application of slurry or digestates. Second, we searched for studies via Scopus and Google Scholar that assessed or reported on the reduction potentials of those specific measures, comprising peer-reviewed and grey literature. Third, we counted and classified the different abatement measures discussed in 179 publications into the different stages of the MMC.

After that we investigated the peer-reviewed publications (110) with the bibliometrix package (Aria and Cuccurullo, 2017) in R in order to map research streams in the field of nitrogen reduction in slurry management. Abstracts were analyzed for frequencies of terms that were used in relation to the abatement measures. Such an approach can reveal changes of the research focus with regard to abatement measures studied and the use context. For example, research may be initiated in order to reduce soil degradation or to combat climate change.

We compared the results of three time periods (P0: 1989-2009, P1: 2010-2015, P2: 2016-2020) with the focus on 2010 to 2020. P1 represents coverage in the run-up of the 2017 amendment of the German Fertilizer Ordinance, while P2 maps reporting under changed conditions. Yet, we decided to include earlier publications (P0), since they set the course for recent studies.

In order to contrast the scientific literature with the agricultural press, the three highest-circulation specialized farming magazines in Germany *topagrar*, *agrarheute*, and *DLG-Mitteilungen* were examined with regard to the coverage of abatement measures as suggested by the scientific literature. We assembled a corpus of 4,227 articles from the three magazines published online between January 2010 and December 2020 that matched the search query "Gülle".

We applied frequency and co-occurrence analysis in the computational environment R. With frequency analysis we tracked the appearance of N-abatement measures over time using the quanteda package (Benoit et al., 2018). With co-occurrence analysis we investigated which terms showed up more than randomly in the vicinity of the investigated abatement measures. We applied a log-likelihood function (Wiedemann and Niekler, 2017) in order to explore the topics and context within which the techniques were discussed and which changes took place. We created semantic networks from co-occurring terms and their linkages and visualized

them with the igraph package (Csardi and Nepusz, 2005). For revealing potential changes we used the two time periods introduced above (P1: 2010-2015, P2: 2016-2020).

3 Results

3.1 Literature review

In the scientific literature, we found 62 specific abatement measures with the potential to reduce surplus or emissions to a large extent from different MMC stages. The identified measures mainly targeted ammonia but can also reduce nitrous oxide emissions. Following, we briefly summarize the measures and – where available – their reduction potentials grouped along the MMC stages (see table 1).

In the stage of feeding, ***alternative protein sources***, e.g., insects, duckweed and algae, can substitute conventional protein sources by up to 33% and thereby lower the environmental impact of feed production (Bleakley and Hayes, 2017; Madeira et al., 2017; Makkar et al., 2014). The ***crude protein (CP) reduction*** in animal diets reduces the amount of excrements and their N-content with a saving potential of up to 40% of ammonia (Eurich-Menden et al., 2011). ***Feed additives*** lower the formation and the release of ammonia from digestion and slurry by 26% (pig) to 47% (cow) (Lewis et al., 2015).

In the stage of housing, the ***housing type*** contributes to great parts to the release of N-related emissions, for example, tie stall housing emits by four times higher amounts of ammonia than cubicle stables (Jungbluth, 2016). ***Grazing*** can reduce ammonia emissions by 15%, due to the fast infiltration of urine in pasture, thus, separation of excrements (Wulf et al., 2017). Stable adaptations have a particularly high ammonia reduction potential of 50 to 70%, e.g., ***manure removal techniques*** (Kroodsma et al., 1993), ***low-emitting surfaces, slurry cooling*** (Wulf et al., 2017) and ***optimal stable climate*** (LfL, 2020). ***Exhaust air purification*** reduces ammonia emissions by up to 90% (Wulf et al., 2017).

Slurry storage tank covers offer the possibility to reduce the release of emissions (Emmerling et al., 2020). Permanent ***enclosed tank covers*** are the most efficient means to retain nearly all gaseous emissions with only minor losses (KTBL, 2017; Hou et al., 2015). Low-emission application techniques, e.g., ***injection*** and ***incorporation*** mainly reduce ammonia emissions from applied slurry by up to 97%, compared to broadcasted slurry (Wulf et al., 2017). Slurry additive systems for stable, pasture, storage and slurry application can broadly reduce ammonia and nitrous oxides emission by up to 88% and 35%, respectively (Akiyama et al., 2010; Fangueiro et al., 2015; Wulf et al., 2017). ***Acidification*** decreases the slurry pH, whereas ***nitrification inhibitors*** hinder the activities of soil microorganisms and thus the nitrification process. ***Urease inhibitors*** limit the hydrolysis of urea, applicable in stable or on pasture (Wulf et al., 2017; Zaman and Nguyen, 2012).

Precision fertilization using N-measurement methods, e.g., N_{min} ***soil analysis***, ***near-infrared spectroscopy (NIRS), N-sensors*** or ***imagery*** provided by drones or satellites derive data of the status of soil, crop or slurry to optimize fertilization and decrease N surplus (Argento et al., 2021; Osterburg et al., 2007).

Table 1: Abatement measures along the manure management chain, compared to no treatment, comprising results for slurry from cow and pig (excerpt)

MMC stage	Measure	Max. reduction potential	Source
Feeding	Alternative protein sources	unknown	Bleakley and Hayes, 2017; Makkar et al., 2014
	Crude protein (CP) reduction	-40%*	Eurich-Menden et al., 2011; Hou et al., 2015
	Feed additives	-26%* (pig)	Lewis et al., 2015
		-47%* (cow)	Lewis et al., 2015
Housing type	Housing	-67%* (cow)	Jungbluth, 2016
	(cubicle stable compared to tie stall housing)		
	Grazing	-15%*	Wulf et al., 2017
Stable adaptation	Low-emission surfaces	-60%*	Wulf et al., 2017
	Removal techniques	-70%*	Kroodsma et al., 1993
	Ventilation with partial purification	-83%*	Wulf et al., 2017
	Optimal stable climate	-70%*	LfL, 2020
	Exhaust air purification	-90%*	Wulf et al., 2017; Eurich-Menden et al., 2011
	Acidification	-64%*	Wulf et al., 2017
	Urease inhibitor	-50%*	Wulf et al., 2017
Slurry storage	Enclosed cover	-98%*	Hou et al., 2015; KTBL 2017

	Permeable cover	-68%*	Emmerling et al., 2020
	Acidification	-88%*	Fangueiro et al., 2015
	Cooling	-60%*	Wulf et al., 2017
Application techniques	Trailing hose	-30%*	Wulf et al., 2017; Webb et al., 2009
	Trailing shoe	-60%*	Wulf et al., 2017; Webb et al., 2009
	Slurry cultivator	-80%*	Wulf et al., 2017
	Open slot injection	-80%*	Wulf et al., 2017; Webb et al., 2009
	Closed slot injection	-97%*	Wulf et al., 2017; Webb et al., 2009
	Incorporation (<1h)	-60%*	Wulf et al., 2017; Webb et al., 2009
Additives (application)	Acidification	-80%*	Fangueiro et al., 2015
	Nitrification inhibitor	-35%**	Akiyama et al., 2010
	Urease inhibitor on pasture	-38%*	Zaman et al., 2012
Precision fertilization	Site-specific fertilization with N-measurement	-30kg N/ha***	Osterburg et al., 2007
	Near-infrared spectroscopy (NIRS)	unknown	Cabassi et al., 2015

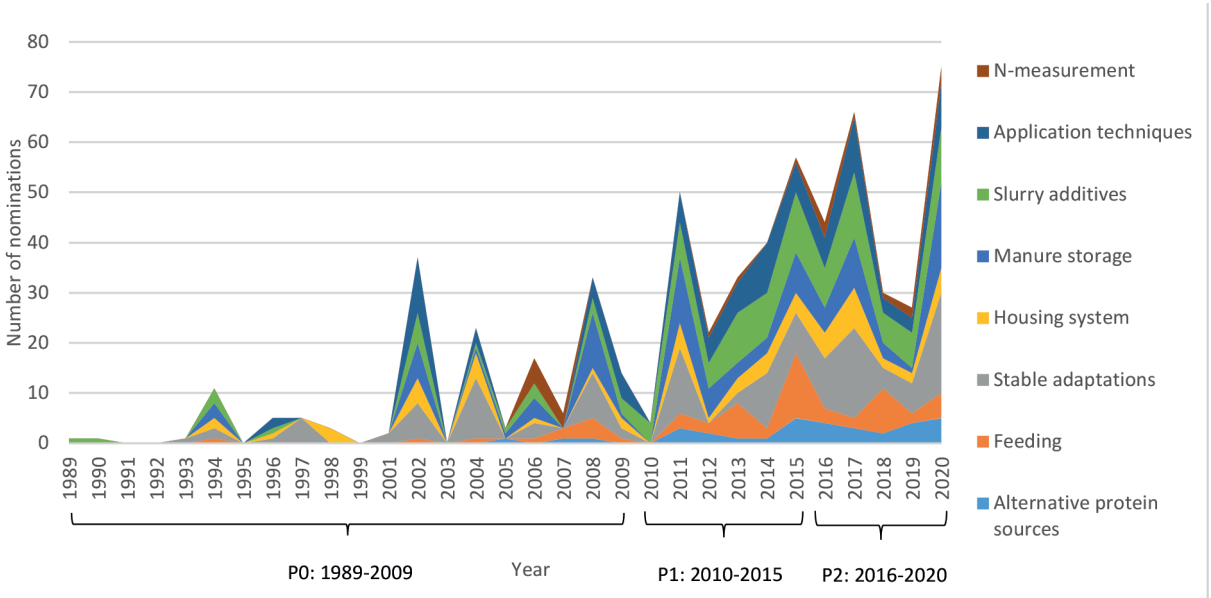
Reduction potential: *NH3 (ammonia), **N2O (nitrous oxide).
*** refers to evaluation of site-specific fertilization with mineral fertilizer
Source: own compilation

In the analysed literature, nominations for stable adaptations were most often found (136), followed by slurry additives (115), slurry storage (97) and application techniques (90). Fewer nominations were identified for the MMC stages of feeding (59), housing types (59), alternative protein sources (33) and N-measurement methods (21).

Research on abatement measures goes back about 30 years, e.g., for CP reduction, manure removal techniques or additives (Hartung and Phillips, 1994; Stevens et al., 1989) and formed the base of knowledge for possible action. However, before 2001, only few publications were identified, not least due to a probable lower availability of online publications in earlier years and a lower research interest.

Nominations increased since 2010, interrupted by a sharp decline in the years 2018 and 2019 (see figure 1). The highest annual number of nominations was found in 2020 (75).

Figure 1: Number of nominations of nitrogen-related abatement measures at farm-level in scientific publications and grey literature from 1989 to 2020



Source: own analysis

Over the last decade the number of articles on abatement measures increased in most MMC stages. Only nominations in the stage of feeding declined, due to less engagement in research on feed additives. Regarding slurry additives, only nominations of acidification increased over the last five years. Application techniques and housing types were constantly reported, while slurry injection gained in importance. Precision fertilization methods had the lowest nominations.

An increasing trend towards mechanization and automatization of measures is noticeable, particularly in the stages of stable adaptations, e.g., cooling systems, self-closing flaps or cleaning robots (Wulf et al., 2017), and precision fertilization methods, e.g., imagery provided by drones or satellites (Argento et al., 2021; Osterburg et al., 2007).

Most publications focused on the effects of one single measure in one MMC stage. Only 23 publications assessed the effects of combinations over different stages. Moreover, there has been a slightly increasing trend in the consideration of side effects of pollutants over the last few years.

With the bibliometric analysis (Aria and Cuccurullo, 2017) we found that over the entire investigation period terms such as "ammonia", "nh" and "emissions" were constantly most mentioned but "nh" and "emissions" rapidly increased since 2014. The term "abatement" gained in importance in P2.

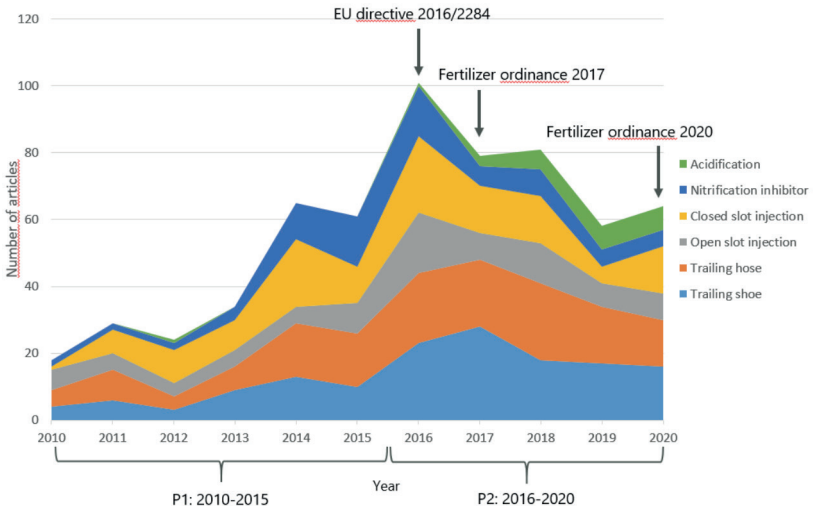
Regarding the frequency of measures, in all periods, "application" was found frequently. The terms "bedding" and "housing" dominated in P0, while P1 was characterized by "biochar", "feed", "larvae" and "inhibitors". "Storage", "protein" and "acidification" were frequently referred to in P2. "Soil" seemed to come into closer focus in P1 and P2. Terms related to water, e.g., "leaching" were hardly mentioned.

3.2 Agricultural press analysis

Although a wide variety of abatement measures were discussed in the scientific literature only a small proportion was covered by specialized farming magazines. We found a total of 3,098 nominations in the stages of the MMC. Nominations of application measures account for more than 80% (47% application, 24% additives, 12% precision). All other abatement measures of the remaining MMC stages played a minor role in the specialized farming magazines and were too few for further meaningful analysis. Therefore, this analysis is limited to application measures and its most frequently covered measures, namely trailing shoe, trailing hose, open slot injection, closed slot injection, nitrification inhibitors and acidification.

Figure 2 shows that the abatement measures investigated were increasingly discussed in farm magazines over time, peaking in 2016. In the baseline year 2010, there were less than 20 articles available, while in 2016, about 100 articles reported on those measures. In P1 there was an average of 38.5 articles per year, while in P2 there were twice as many. The development was particularly strong for acidification. It had no relevance until 2016 from when on it steadily increased. In P1, it appeared only once, whereas in P2 it was discussed in 24 articles. It can be observed that the number of articles increased in the run-up of the amendments of the fertilizer ordinance and the EU directive on the reduction of national emissions of certain atmospheric pollutants (2016/2284).

Figure 2: Number of articles on nitrogen reduction techniques in three farming magazines during the investigation periods P1 (2010-2015) and P2 (2016-2020)



Source: own analysis

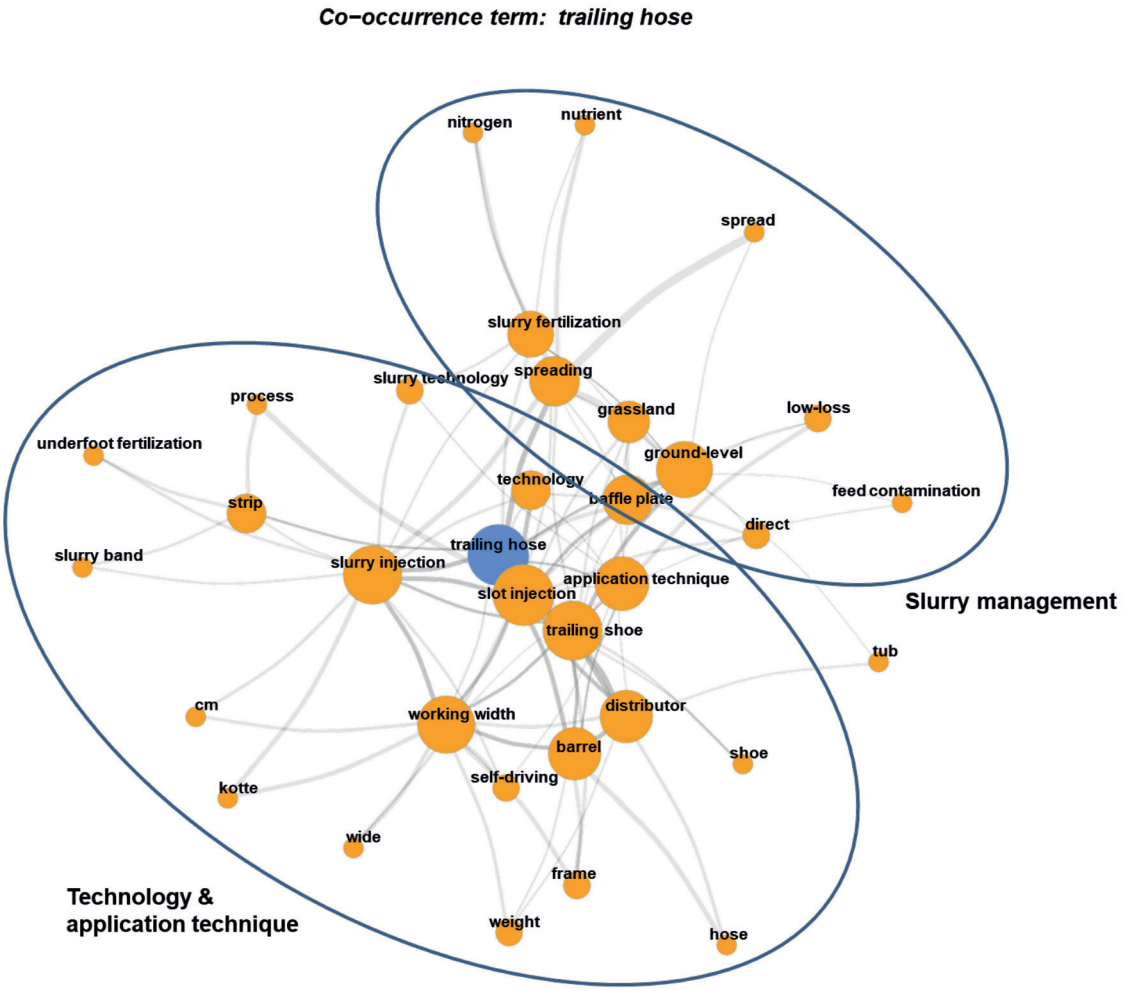
With co-occurrence analysis we explored the context of reporting of the measures. The studied application techniques co-occurred with each other in both periods with high significance. But despite a considerable reduction potential of combined measures, only "slot injection" was significantly related to "additives", i.e., with "nitrification inhibitors" in P1, and "slot injection" with "acidification" in P2.

Figure 3 and figure 4 show exemplarily the network visualizations for the abatement measure "trailing hose" in P1 and P2. They illustrate that the co-occurring terms of the investigated techniques remained mostly the same in the course of time. The magazines continuously dealt in the first place with practice-oriented topics: slurry management, application techniques and technology. The strategies are in most cases framed by a management and technological language.

Interestingly, although we found a clear temporal relationship between the amendments of laws and the number of articles the articles on the studied techniques only referred to a small extent to policy issues. In P1 only "trailing shoe" and "open slot injection" referred to the fertilizer ordinance. In P2 the fertilizer ordinance found entry into the co-occurrence networks of "trailing hose" and "closed slot injection" only. "Open slot injection" and "acidification" referred to the EU directive 2016/2284 (European parliament and Council of the European Union 2016). Overall, the significance of co-occurrence of measures and policy-related vicinal terms was low.

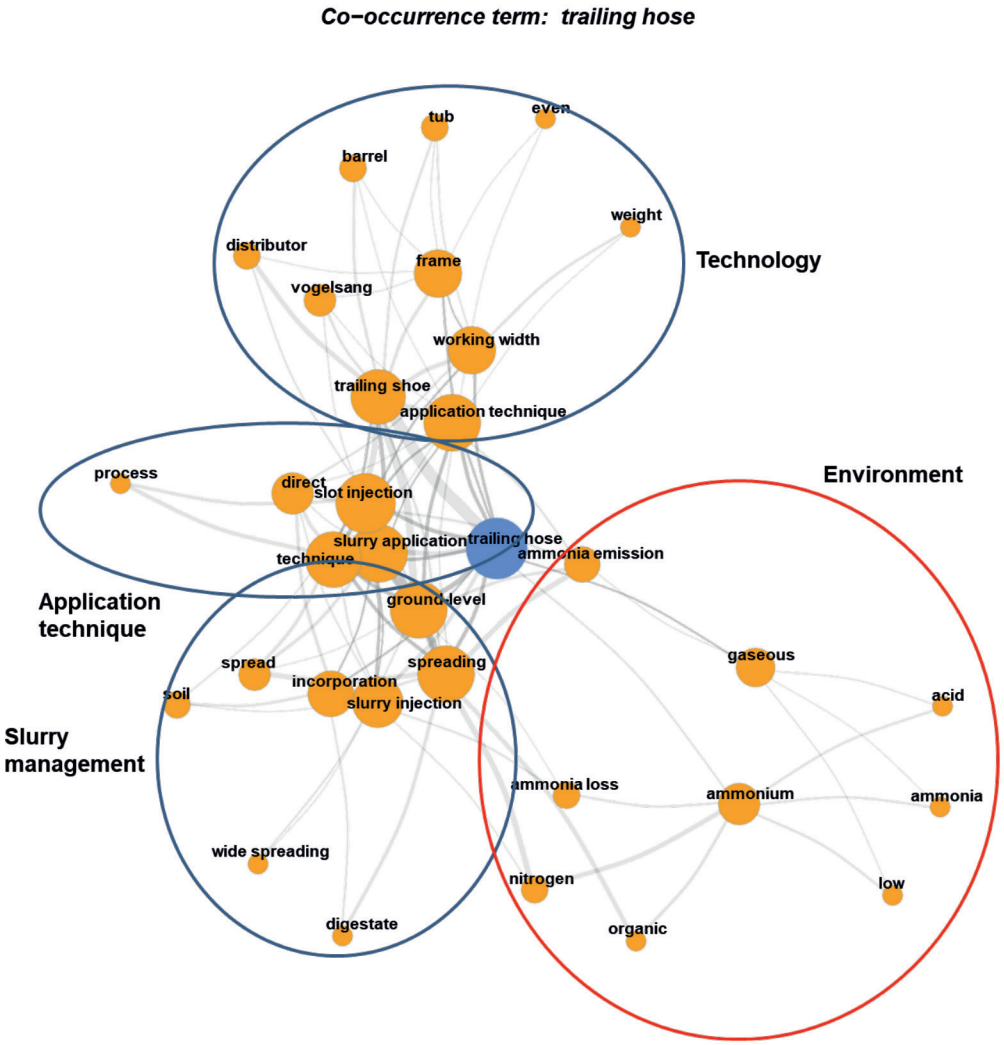
With regard to environmental resources one might assume that environmental aspects were significantly often discussed in connection with measures that serve to reduce emissions. Yet, the results show a low level of coverage of the impacts of abatement measures on the environment. However, in P2 we found that the use context changed. This is reflected by how the farm magazines framed the reporting on the abatement measures. The strong reference to aspects of air pollution in P2 is striking. Terms such as ammonia emissions, air, N losses, etc. were discussed in P2 for all techniques, while in P1 they were addressed only in the case of nitrification inhibitors. Acidification also co-occurs with environmental issues in P2, i.e., ecosystem and climate protection.

Figure 3: Co-occurrence network for trailing hose in period 1 (2010-2015)



Source: own analysis

Figure 4: Co-occurrence network for trailing hose in period 2 (2016-2020)



Source: own analysis

4 Discussion and conclusions

With the combination of a review of scientific literature and an analysis of farm magazines, we showed that a large number of abatement measures described in the scientific literature offer high emission reduction potentials. Only a few have comprehensively found their way into agricultural reporting while most other measures were only marginally communicated by the farm press although they are highly effective in mitigating emissions (e.g., low-emission surfaces, acidification). While the most important abatement measures in scientific journals were related to stable adaptations, additives, slurry storage and application techniques, the coverage of measures in farm magazines were essentially limited to additives and application techniques.

The overall coverage of the topic, however, increased in both the scientific journals and the farm magazines. The rising number of research publications can be interpreted as the response to an increasing need for data of potential abatement measures to meet and shape policymaking. The trend of increasing coverage of application techniques and additives in the agricultural press coincides with the 2017 and 2020 amendments to the German Fertilizer Ordinance and the EU directive 2016/2284. The influence of science is, on the contrary, limited (Hurlimann and Dolnicar, 2012). Our results leave room for investigating the modes and motivations for certain techniques to be selected by the agricultural press. However, despite the scientific knowledge having been available for a long time, implementation of stricter policies takes decades. It wasn't until the 2007 Fertilizer Ordinance that the German government hesitantly began to enshrine low-emission applications, and only in the TA Luft 2016 and 2021, further gaseous emissions were included with consideration of the best available techniques (BAT) in TA Luft 2021 for adapting stables.

Our contribution shows that over time the use context changed in both scientific and agricultural press. In recent years we found stronger references to environmental re-

sources, particularly emissions to the air, in the farm magazines. In the scientific literature we observed a turn towards consideration of complexity: Impacts of combined abatement measures as well as pollution swapping effects were investigated. Furthermore, modeling approaches increasingly included economic calculations.

With this practice-relevant knowledge, science can inform policy and the media on combinations of strategies that are environmentally effective and economically feasible. The discourse-shaping position of the agricultural press could be used to communicate strategies with a scientifically proven high reduction potential to stimulate the farmers' adoption of abatement measures.

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