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The revision of the German Fertiliser Ordinance in 2017

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Abstract

The Nitrates Directive is the core legislation to reduce nitrate emissions from agriculture to water bodies in the EU. In Germany, the directive is mainly implemented by the national Fertiliser Ordinance (FO) which aims, besides nitrate, at ammonia and phosphate losses. The FO has been currently revised as a reaction to infringement proceedings against Germany by the European Commission. The revision includes considerable changes, among others: a compulsory and clearly specified fertilizer planning, the inclusion of biogas digestate from plant origin in the organic nitrogen application threshold, a new methodology to calculate an obligatory nitrogen and phosphate balance, a reduction of legal nutrient balance surpluses, stricter blocking periods for fertilizer application in autumn, a stepwise introduction of reduced ammonia emission application techniques and the possibility to introduce additional measures in pollution hot spots. Research on the environmental and economic impact of the revision is still rare. The discussion paper at hand contributes a summary of the most relevant changes by opposing the FO from 2007 and 2017. A detailed scientific analysis on the revised FO is necessary to clarify the economic impact on farms and the contribution to reaching existing environmental targets.

Keywords: EU Nitrates Directive, Düngeverordnung, nitrogen, phosphate

JEL classification: Q18, Q53, Q58

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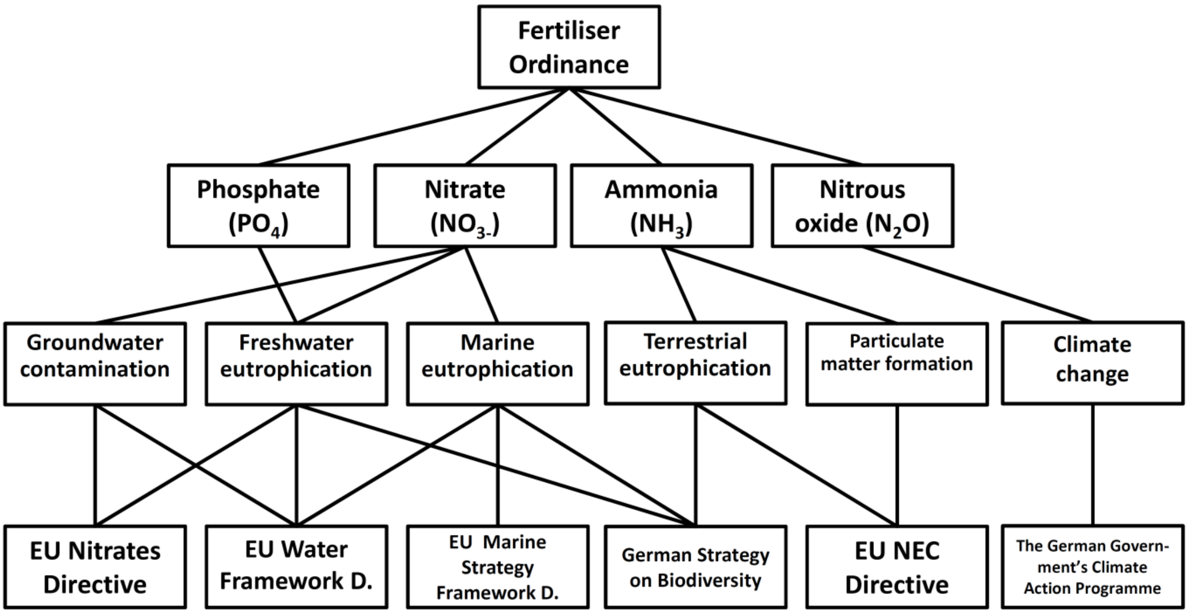
1 Introduction

The loss of nitrogen (N) and phosphate (P) from farming systems to the environment poses a threat to groundwater and surface water quality, biodiversity, and climate (Sutton et al. 2013). In Germany, the Fertiliser Ordinance (FO - Düngeverordnung) is the key command and control measure to limit N and P emission from agriculture. The FO mainly implements the EU Nitrates Directive 91/676/EEC in Germany which aims at reducing and preventing nitrate (NO_{3-}) emissions from agriculture to water bodies. NO_{3-} concentration in groundwater should be below 50 mg l^{-1}, which is also the threshold for the NO_{3-} concentration in drinking water to protect human health from possible harm, as laid down in the EU Drinking water directive 98/83/EC. Furthermore, NO_{3-} emissions to surface waters cause the eutrophication of limnic and marine ecosystems. Related environmental targets are, amongst others, defined in the EU Water Framework Directive 2000/60/EG and the Marine Strategy Framework Directive 2008/56/EC (Figure 1).

To fulfil the requirements of the Nitrates Directive, member states have to identify so-called “vulnerable zones”, develop national action programs to tackle NO_{3-} emission and report in defined periods about the development of NO_{3-} pollution to the European Commission. The Nitrates Directive partly specifies precise measures, as for instance the application limit for organic N of 170 kg $ha^{-1}a^{-1}$, but member states have a considerable freedom in the design of their action program. The FO as the German implementation was revised in spring 2017, triggered by infringement proceedings against Germany. The European Commission criticized among others that the NO_{3-} concertation in groundwater bodies and coastal waters has stopped reducing and partly increased over the last reporting periods and that Germany did not take adequate action (EC 2014). The revision process, started in 2011, was completed by the FO passing the German Federal assembly in spring 2017. In this context, also the Fertilizer law was amended as the introduction of certain measures in the FO required an update of the legal basis.

Figure 1: Simplified overview on emissions, environmental impacts and relevant national and European regulations related to the Fertiliser Ordinance



Source: own illustration

Albeit focusing on NO_{3-}, the FO impacts on nitrous oxide (N_2O), ammonia (NH_3) and P emissions. Because of the inclusion of measures to lower P and NH_3 losses, the FO is crucial to meet environmental targets for freshwater eutrophication as laid down in the EU Water Framework directive, or the prescribed national NH_3 threshold defined in the Directive on the Reduction of National Emissions of Certain Atmospheric Pollutants 2016/2284/EU. Measures of the FO indirectly impact on nitrous oxide (N_2O) emissions from farming systems. This is mainly caused by the fact that the reduction of total N input, as induced by the FO, can lower all emissions along the N loss pathway (Oenema & Velthof 2007, pp. 31f.). Furthermore, NO_{3-} and NH_3 losses are indirect sources of N_2O emissions. Therefore, the revised FO is designated to realize the major share of the greenhouse gas (GHG) reduction requirements from the agricultural sector in Germany (BMUB 2014, pp. 59ff.).

The aim of the discussion paper at hand is to provide a summary of the changes in the FO and a discussion of possible impacts. Furthermore, the scientific literature on the revision is summarized. The provided information is important for future research on the economic and environmental impact of the revision. In addition, knowledge of national policies tackling nutrient loss from agriculture is from special interest for an international audience as similar policies are applied and frequently revised in numerous countries.

2 Measures of the Fertiliser Ordinance

The FO consists of a bunch of measures which are partly interlinked. Generally, one can differ between measures that limit the quantity of applied nutrients (application threshold, nutrient balance) and detailed technical or management specifications (e.g. application techniques). The first are ‘goal oriented regulations’, leaving farmers different abatement options to comply, whereas the latter are ‘means-oriented regulation’ which define a precise measure to adapt (Schröder & Neeteson 2008, p. 418). Furthermore, the FO specifies the sanctions for violations. There are hints of a lack of enforcement regarding fertilizer regulations in Germany (LWK NRW 2014), however, reliable and representative data is missing. As measures of the FO are partly relevant for the cross compliance of payments under pillar one of the EU Common Agricultural Policy, violations are sanctioned by cutting the direct payment. Furthermore, the FO defines which violations are qualified as an administrative offense under national law and are linked to monetary fines. This section explains the most important elements of the FO and the differences between FO 07 and FO 17 which table 1 summarizes. The enforcement of the respective measure is reported in the corresponding section.

Table 1: Most important measures of the Fertiliser Ordinance 2007 and 2017

Measure	Fertiliser Ordinance 2007	Fertiliser Ordinance 2017
Fertilizer planning	Unspecified and not binding fertilizer planning	Clearly defined and compulsory fertilizer planning
Organic N application - threshold	170 kg N $ha^{-1}a^{-1}$	170 kg N $ha^{-1}a^{-1}$
Organic N application – calculation	Only N from animal manure	N from animal and plant sources (biogas digestate from plant origin)
Organic N application – derogation	Up to 230 kg $ha^{-1}a^{-1}$ for grassland when meeting certain requirements.	Planned, design not known.
Nutrient balance – allowed surplus	60 kg N $ha^{-1}a^{-1}$ 20 kg P $ha^{-1}a^{-1}$	50 kg N $ha^{-1}a^{-1}$ 10 kg P $ha^{-1}a^{-1}$; 0 kg P $ha^{-1}a^{-1}$ on highly P enriched soils
Nutrient balance – calculation scheme	Surface balance approach	Surface balance approach, quantification of on-farm forage yields via animal nutrient need; stepwise introduction of farm gate balance approach[1]
Blocking periods – fixed	Grassland 15.11-31.1 Arable land 1.11-31.11	Grassland 1.11-31.1 Arable land 1.10-31.11
Blocking periods – after harvest of the main crop	Organic nutrient application restricted to 40 kg Ammonia N or 80 kg total N for catch crops, winter crops, and straw rotting	Total nutrient application restricted to 30 kg Ammonia N and 60 kg total N for catch crops, winter rapeseed, field forage and winter barley following cereals in crop rotation
Reduced ammonia emission application techniques	Broadcast spreader allowed	Broadcast spreader banned except on fallow land followed by incorporation; compulsory from 2020 onwards on arable, 2025 on grassland
Minimum manure storage capacity	6 month[2]	6 months, 9 months for farms >3 livestock units ha^{-1}
Minimum distance from surface water for fertilizer application	3 meter 1 meter (if working widths equals spreading widths or if boundary spreading devices are used) 3 meter (steeply sloping ground)	4 meter 1 meter (if working widths equals spreading widths or if boundary spreading devices are used) 5 meter (steeply sloping ground)
Additional measures in pollution hot spots (Nitrate in ground- and phosphate in surface waters)	-	The Federal States have to apply at least three out of 14 predefined measures in pollution hotspots; more measures optional

N – nitrogen; P – phosphate; [1] the introduction of the farm gate balance is subject to a separate directive to come; [2] defined in Federal law on requirements for manure storage facilities

2.1 *Fertilizer planning*

The German action program has never included total application limits for mineral and organic fertilizer as for instance the implementation of the Nitrates Directive in the Netherlands or Denmark (Schröder & Neeteson 2008; Kronvang et al. 2008). In the FO 07, it is laid down that nutrient application should generally meet plant need and fertilizer planning has to be done. However, clear specifications on the methodology as well as sanctions for not compliance are missing. To fill this gap, the FO 17 introduces a compulsory and clearly defined fertilizer planning.

Table 2: Exemplary fertilizer planning for nitrogen (Annex 4, FO 17)

Factors of fertilizer need estimation	
Crop	winter wheat
N need [kg N ha^{-1}]	230
Yield level default [t ha^{-1}]	8
Three-year average yield [t ha^{-1}]	9
Yield difference [t ha^{-1}]	1
Correction factors (N delivery, yield differences)	
Mineral N in spring [kg N ha^{-1}]	- 40
Change based on yield difference [kg N ha^{-1}]	+ 10
N from soil pool at humus-rich plots [kg N ha^{-1}]	- 20
N from organic N applied in year before [kg N ha^{-1}]	- 18
N from previous crop [kg N ha^{-1}]	0
N need	162
Corresponding fertilizer application	
N organic applied [kg N ha^{-1}]	60
N organic accounted [kg N ha^{-1}]	36
N chemical applied [kg N ha^{-1}]	126

N – nitrogen; winter wheat after silage maize, yield level of 9 t $ha^{-1}a^{-1}$, use of 10 m^3 pig manure to winter wheat and 30 m^3 to the previous crop (6 kg N m^{-3} manure)

In the FO 17, the obligatory fertilizer planning is restricted to N and P. N needs (“Sollwert”) for different crops and allowed correction related to the yield level is defined by the directive. The yield level, at which farmers are allowed to aim, results from the average yield of the last three years. The allowed chemical fertilizer application is determined by taking N delivery from the soil and a prescribed share of N from organic fertilizer into account. Farmers can either measure the nutrient content of manure or use the default value. Table 2 exemplary shows the fertilizer planning for winter wheat following silage maize with the use of organic fertilizer. The fertilizer planning for P is not further specified by the FO 17 but application must relate to expected yields and P in soil, obtained from obligatory soil testing. The violation of the requirements of the fertilizer planning is sanctioned as an administrative offense. It is only allowed to correct the calculated limit if higher plant need occur due to factors like weather conditions.

A central element of the fertilizer planning is the accounting of N from organic sources, including animal manure and biogas digestates. The compulsory accounting in the first year is between 3% and 90%, depending on the manure type. 10% of organic N has to be accounted in the year after application. Furthermore, delivery from soil, which has been fertilized with manure over longer periods, and N delivery from the soil in spring is included. The utilization of organic nutrients is often measured as Mineral fertilizer equivalents (MFE). Generally, MFE are the amount of chemical fertilizer which can be replaced with organic fertilizer (Gutser et al. 2005, pp. 440ff.). Table 3 summarizes the default MFE values of the most important manure types from the FO 17. The MFE relate to the manure N content measured after storage or calculated based on the default animal excretion minus stable and storage losses (section 2.2). Hence, the MFE only partly represents the farm N efficiency. When applying the default stable and storage loss factors and the described MFE from the FO, around 50% to 60% of the excreted N from pig and cattle manure is accounted for plant nutrition (Klages et al. 2017, p. 56). However, the values in table 3 only represent the short term MFE. As other N sources, e.g. soil from N on humus rich plots, also need to be taken into account in the fertilizer planning, the FO 17 includes slightly higher long-term MFE.

Table 3: Mineral fertilizer equivalents in the Fertiliser Ordinance 2017 (Annex 3)

Manure type	First-year MFE	Second-year MFE
Cattle manure	50%	60%
Pig manure	60%	70%
Pig and cattle liquid manure	90%	100%
Solid manure	25%	35%
Pig solid manure	30%	40%
Dry chicken faeces	60%	70%
Liquid biogas digestate	50%	60%
Solid biogas digestate	30%	40%

MFE – mineral fertilizer equivalents; related to total N

2.2 *Organic nitrogen application threshold*

The Nitrates Directive directly limits the application of manure N to 170 kg $ha^{-1}a^{-1}$. The N use efficiency decreases with higher shares of organic N and the danger of NO_{3-} leaching rises (Osterburg & Techen 2012, p. 51; Gutser et al. 2010, pp. 36ff.). Both, FO 07 and 17, include this threshold. It is calculated from animal excretion minus default values for NH_3 volatilization and has to be met on farm level and not on single plots.

Under the FO 17, the threshold of 170 kg N $ha^{-1}a^{-1}$ persists, but more nutrient sources are included and default loss factors change. First, biogas digestates from plant origin are now taken into account. In Germany, biogas production expanded strongly until 2014 (FNR 2015) with maize silage beeing the major feedstock (DBFZ 2013, p. 55). The use of crops as feedstock leads to an additional production of organic nutrients as digestates. Second, the default values for N losses from stable and application are lowered, e.g. for pig manure from 30% to 20%. For pasture grazing, default loss factors are reduced from 75% to 30%. The reduction of the default loss factors has the same effect as lowering the allowed N application threshold.

Under the Nitrates Directive, member countries can apply at the European Commission for the derogation from the organic N threshold, meaning that under certain conditions higher manure application rates are allowed. In the past, the application up to 230 kg N $ha^{-1}a^{-1}$ was legal for intensive grassland but this exception was linked to requirements like low nutrient balances or the use of certain manure application techniques. The derogation is primarily relevant for intensive dairy farms in Northwest and South Germany. Overall, around 1,100 farms (32,000 ha) applied it in 2011 (Osterburg & Techen 2012, p. 218). It is planned to request for derogation at the European Commission, as stated in the FO 17, but detailed terms and linked requirements are not known yet.

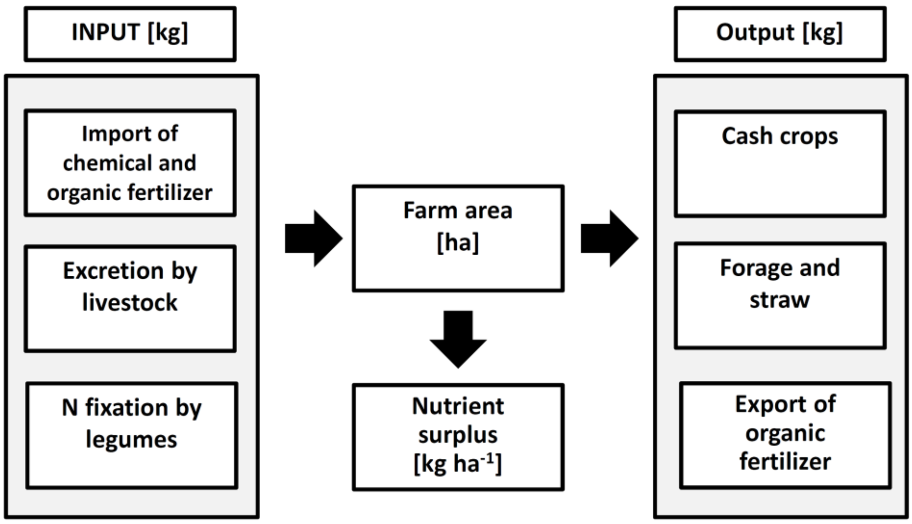
2.3 *Nutrient balance*

The German action programs have always included nutrient balances as an indicator for potential nutrient losses to the environment. Farmers have to calculate an annual, historical nutrient balance and the surplus of the balance is restricted. In the current revision, the methodology, as well as the allowed surpluses and the sanctions, are adapted.

Calculation methodology

Under the FO 07 and 17, the nutrient balance is calculated as a surface balance (Figure 2). N and P input via manure and chemical fertilizer is opposed to the nutrient removal with the harvested product. The difference should not exceed a certain threshold in a sliding multi-year average. There are two general approaches available to obtain the balance: the calculation of surpluses related to certain plots and the aggregation to farm level or the calculation at farm-level. Nutrient input via manure is calculated based on animal excretion. NH_3 losses from the stable and application are subtracted. The FO specifies default values for animal excretion and standard loss factors. The nutrient removal is derived from the content of harvested products which is also defined by the FO. Under both FO, only when exceeding a certain farm size and intensity characteristics, farms are obliged to calculate the nutrient balance. In the FO 07, values for P removal with the harvested product have been missing and were specified by institutions on the federal level.

Figure 2.: Overview on the soil surface balance



Source: own illustration based on VDLUFA (2007, p. 7) and Kolbe & Köhler (2008, p. 40)

The main methodological changes under the FO 17 are for livestock farms growing large share of forage on the farm, hence, especially dairy and beef production. Under the FO 07, the validity of nutrient balances from these farm types is very limited as the nutrient removal with the harvested fodder is often overestimated (Osterburg & Techen 2012, pp. 185ff.). Under the FO 17, nutrient removal via forage production is not specified by the yield but estimated based on the feed need of the present animal stock. This leads to a cross validation of the nutrient removal from forage harvest and animal nutrient need.

Allowed surplus

The restriction of the allowed surplus links the calculation of the nutrient balance to reduction efforts and the limitation of nutrient losses. The relevant surplus relates to the total farm and not to single plots. Under the FO 17, the allowed N surplus, calculated as a three-year sliding average, is lowered from 60 to 50 kg N $ha^{-1}a^{-1}$ from 2020 onwards. This means that surpluses from the year 2018 and the following are relevant. The allowed P surplus, calculated as a six-year sliding average, is lowered from 20 to 10 kg P $ha^{-1}a^{-1}$ from 2023 onwards.

On P-enriched soils, no surplus is allowed. The P status of soils is determined by compulsory soil sampling. For clarification, the FO specifies thresholds of P soil content that are qualified as P-enriched. This surplus restriction is regulated in the fertilizer planning to ensure that the inputs are reduced on the actually affected plots (section 2.1). Institutions on the federal level can further limit P fertilizing in single cases if damage of water bodies due to P fertilizing is present.

Furthermore, the FO 17 includes sanctions for not complying with the prescribed nutrient surpluses which are missing under the FO 07. Exceeding the allowed surpluses is qualified as an administrative offense and leads to a compulsory consultation on the fertilizer practice.

Farm-gate balance approach

In the revision process, policy makers agreed on the stepwise introduction of a balance following the farm gate approach. A farm gate balance, in contrast to a surface balance, opposes nutrient input via purchased feed, animals and fertilizer to nutrient output via sold products. It is seen as a more transparent and valid methodology as more parameters can be approved by farm accounting data (SRU et al., pp. 14f.). The new balance is not part of the FO but will be defined in a separate directive which is planned to come into force in 2018. The revision of the fertilizer law created the legal basis to capture the parameters which are needed for the farm gate approach and includes the following specifications: From 2018 onwards, farms need to follow the farm gate balance if they have a higher stocking density than 2.5 livestock units (LU) ha^{-1} and more than 50 LU units in total or 30 ha agricultural land. Furthermore, farms which import manure from other farms are included. From 2023 onwards, all farms above a certain size are obliged to estimate nutrient surpluses according to the farm gate balance approach. As a draft of the directive is not yet officially available, details on the calculation scheme are not known. An expert group, appointed by the Federal Ministry on Food and Agriculture, makes recommendations in a recent report (Klages et al. 2017).

2.4 *Blocking periods and manure storage capacities*

The application of N fertilizer, especially manure, in autumn and winter is particularly linked to the risk of NO_{3-} leaching (Di & Cameron 2002; Cameron et al. 2013). Therefore, the FO 07 and 17 restricts fertilizer application after the harvest of the main crop and forbids the N fertilizer application in a defined period. This measures only aims at fertilizers containing N but P is affected likewise as both nutrients are combined in manure. With regard to manure, this measure is linked to the maximum manure storage capacity that farms have to prove as livestock excretion during the blocking period must be stored.

Table 4: Blocking periods under Fertiliser Ordinance 2007 and 2017

	Fertiliser Ordinance 2007	**Fertiliser Ordinance 2017**
Blocking periods – fixed	Grassland 15.11-31.1 Arable land 1.11-31.11	Grassland 1.11-31.1 Arable land 1.10-31.11
Blocking periods – after the harvest of the main crop	Organic nutrient application restricted to 40 kg Ammonia N or 80 kg total N for catch crops, winter crops and straw rotting	Total nutrient application restricted to 30 kg Ammonia N and 60 kg total N for catch crops, winter rapeseed, field forage and winter barley following cereals in crop rotation

Under the FO 17, blocking periods for manure application are prolonged on arable and grassland and the application after the harvest of the main crop are more restricted (see table 4 for details). Moreover, they apply for N from organic and chemical sources. Under the FO 07, the use of mineral fertilizer after the harvest of the main crop and before the fixed blocking period was not restricted. Generally, the changes lead to a stronger limitation of manure application in autumn. Blocking periods can be shifted on a regional level for two weeks but the total time of the blocking period is not allowed to change. It has to be noted that there are already regulations present in some federal states which limit the manure application after the harvest of the main crop.

In the FO 07, the minimum storage capacity is not specified because it is defined in the Federal law on the requirements for manure storage facilities. Minimum storage capacity is generally six months. In the 2017 revision, the minimum storage capacity is included in the FO. Generally, the capacity must correspond to the period when a farm is not able to apply manure. The defined minimum storage capacity remains the manure production of six months and applies for animal manure and digestates from biogas production. For farms with more than 3 LU ha^{-1} or without own farm land, 9 months need to be available from 2020 onwards. Farms have not to provide storage capacity directly but can prove it via contracts with third parties.

2.5 *Manure application techniques and manure incorporation*

The application of manure is a major source of NH_3 emissions (Rösemann et al. 2015, pp. 12f.), whereby the used application techniques and management highly impact on the amount of volatilization (Webb et al. 2010). Under the FO 17, broadcast spreaders are banned for the application in crops. Only techniques ensuring the application in stripes or directly in the soil, as for instance drag shoe or injection, are permitted. They become compulsory on arable land in 2020 and on grassland in 2025. On fallow land, broadcast spreading is still allowed. If liquid manure is applied on fallow land, farmers have to incorporate it within four hours. Under the FO 07, the time to incorporate manure was not clearly specified.

2.6 *Further measures*

Solid manure and compost

Under the FO 07, there are no blocking periods and required minimum storage capacity for solid manure and compost. A high share of N is organically bound in solid manure and compost (Gutser et al. 2005, pp. 441ff.) which implies a low risk of NO_{3-} leaching during autumn and winter. Under the FO 17, solid manure and compost application are forbidden from December 15th to January 1st and a minimum storage capacity of solid manure of two months is required from 2020 onwards Furthermore, compost is included in the organic N application threshold but it has to be met in a three-year average which allows application up to 510 kg N ha^{-1} in a single year.

Vegetable and fruit production

Vegetable production is often characterized by low N efficiency as, amongst others, certain crops require high amounts of available N before harvest or are characterized by high residual N after harvest (Cameron et al. 2013, pp. 155f.). Under the FO 07, the additional nutrient surpluses were allowed for certain crops like broccoli or leek. This resulted in a legal surplus of up to 220 kg N $ha^{-1}a^{-1}$. Under the FO 16, additional N surpluses for vegetable production are generally limited to 60 kg $ha^{-1}a^{-1}$. In addition, the compulsory fertilizer planning is also specified for vegetables. Blocking periods for vegetables and certain berries differs from general requirements by lasting only from December 1st to January 1st.

Fertilizer application: soil status, minimum distance, and prevention of runoff

The FO includes specifications on the allowance of fertilizer application depending on the soil status (e.g. frozen soil), the minimum distance to surface water and the prevention of fertilizer run off. Under the FO 17, the fertilizer application depending on soil status is specified and the minimum distance to surface water for fertilizer application is slightly increased (Table 2). Furthermore, the prevention of fertilizer runoff is generalized under the FO 17 and non-compliance is sanctioned as an administrative offense.

Data reporting and integration

Under the FO 17, federal states can prescribe that farmers submit their nutrient balance to the institutions being in charge of the FO enforcement. Based on a combination of national and federal law, manure flows between farms are already accounted in some federal states. Combining the information on exported and imported nutrients, nutrient balances and farm-specific data used for the direct payment calculation allows detecting possible violations easier than before. Moreover, federal states can decree that the nutrient need and application under the fertilizer planning is aggregated to single values for the whole farm which facilitates the enforcement.

2.7 *Regional differentiation of measures*

Under the Nitrates Directive, member states can choose to implement the national action programs either in identified so-called vulnerable zones or on the whole territory. In Germany, measures of the FO 07 and 17 are compulsory nationwide. However, the FO 17 includes a new element which allows and prescribes federal states to adopt measures in defined areas.

First, the FO 17 includes a bunch of additional measures for tackling emissions in pollution hotspots (Table 5). Relevant regions are defined depending on the NO_{3-} concentration and trend in groundwater bodies and the eutrophication of surface water, especially related to the P concentration. Concentration thresholds are related to the environmental targets of the Nitrates Directive and the Water Framework Directive. In these pollution hotspots, federal states have to apply at least three additional measures. They can choose which measures to apply and are allowed to prescribe more than three measures. It has to be noted that the measures are not compulsory for farms which prove to have an N surplus below 35 kg $ha^{-1}a^{-1}$ (section 2.3).

Table 5: Comparison of general measures and additional measures for pollution hotspots

Measure	General	Optional in pollution hot spots
Correction of fertilizer need in fertilizer planning	Not limited	Restricted to 10% of the originally estimated fertilizer need
Testing of nutrient content of manure and biogas digestate before application	Optional	Compulsory
Further restriction of P fertilizer application	Only in singular cases possible	In the defined area possible
Testing of N delivery from soil	Optional	Compulsory
Minimum distance to surface water for fertilizer application	4 meter 1 meter (if working widths equals spreading widths or if boundary spreading devices are used) 5 meter (steeply sloping ground)	5 meter 1 meter (if working widths equals spreading widths or if boundary spreading devices are used) 10 meter (steeply sloping ground)
Incorporation of manure on fallow land	As fast as possible, at least in four hours	As fast as possible, at least in one hour
Blocking periods for P fertilizer	Not included	15.11 to 31.1, prolongation of up to 4 weeks possible
Blocking periods for N fertilizer on grassland	1.11 to 31.1	15.10 to 31.11
Blocking period for solid manure	15.12 to 15.1	15.11 to 31.1, prolongation of up to 4 weeks possible
Blocking periods for N application to certain fruits and vegetables	1.12 to 31.1	1.11 to 31.1
Obligation to calculate nutrient balance[1]	Farms characterized by >15 ha, >750 kg organic N or import of manure or biogas digestate	Farms characterized by >10 ha, >500 kg organic N or import of manure or biogas digestate
N surplus limitation	50 kg N $ha^{-1}a^{-1}$	40 kg N $ha^{-1}a^{-1}$
Minimum storage capacity for liquid manure	6 months	7 months
Minimum storage capacity for solid manure	2 months	4 months

P – phosphate, N – nitrogen; [1]There are further exceptions for specialized farms which are not described here.

Second, the federal states are allowed to lower requirements outside of pollution hotspots. This includes lowering the minimum storage capacity for grassland based farms with high stocking density from nine to six months and excluding more farms from the obligation to calculate nutrient balances. The latter can be expanded to farms which have less than 30 ha, less animal manure production than 110 kg N $ha^{-1}a^{-1}$ and do not import manure or biogas digestate.

3 Studies on the impact of the revision

There is little research on the impact of the revised FO in Germany. This is partly caused by the fact that the FO 17 was just recently amended and detailed design of measures was unclear until the end of the revision process. Hence, existing research often focuses on isolated measures and does not completely reflect the changes under the FO 17.

An expert group evaluated the FO 07 on behalf of the Federal Ministry on Food and Agriculture and suggested possible improvements (Osterburg & Techen 2012). Numerous recommendations of the group are reflected in the revised FO. The report represents the most recent and comprehensive analysis of the FO 07 and its shortcomings. Moreover, it gives insides into possible impacts of revised measures. For the evaluation, the group mainly uses farm level control data reported from few federal states and data from the farm structure survey.

The latter allows calculating regional nutrient excretion and balances on community level by combining farm structure data with standard factors for animal excretion and plant removal. Osterburg & Techen (2012, pp. 212ff.) analyze the organic N threshold and the N and P surplus simultaneously as one threshold becomes binding first and leads to meeting the other thresholds likewise. The authors show that the P surplus restriction and the organic N application threshold become binding before the N surplus on the regional level. Thereby, the P surplus is most binding in North-West Germany whereas in the forage growing dominated regions (South Germany, Lower Saxony and North Rhine Westphalia) the organic N application threshold limits the application. The P surplus prevention on highly enriched soils increases the share of the total German manure production, which needs to be exported out of communities, from 1.5% to almost 4% (Osterburg & Techen 2012, p. 211). The results indicate the huge impact of the measures regarding P surpluses in the FO 17. Furthermore, they hint at which thresholds are most binding on farm level as the same relation of nutrient removal and input are present. However, the need to reduce surpluses will be higher on farm level than the analysis on community level suggests.

The evaluation of an unrepresentative sample of farm nutrient balances, coming from control organizations in six federal states, gives insides into reasons for nutrient balance surpluses at farm level and the impact of methodological changes under the FO 17 (Osterburg & Techen 2012, pp. 185ff.). Around 20% of the farms subject to research exceeded the N and P surplus restriction under the FO 07. Surpluses are found in farms with low and high amounts of organic nutrient input per ha. Hence, they are not only caused by high stocking densities and are also present on arable farms. Osterburg & Techen (2012, pp. 195f.) highlight, amongst others, the importance of management and the existing potential to increase N use efficiency. They found that grouped farms with similar structure, meaning mainly the same nutrient removal with the harvest and organic N input, have a standard deviation of mineral N fertilizer input of 40 kg N $ha^{-1}a^{-1}$. The implementation of the compulsory fertilizer planning in the FO 17 aims at closing the existing efficiency gaps.

Generally, nutrient surpluses are highest in livestock fattening farms and lowest in forage growing farms (Osterburg & Techen 2012, pp. 187ff.). The latter is mainly caused by the overestimation of the nutrient removal with on farm grown forage. Under the FO 17, nutrient removal via forage production is estimated based on the feed need of the present animal stock. This will lead to an increase of the N surplus of farms which have overestimated their forage yield before. In the examined data, 25% instead of 10% forage growing farms in the sample exceed the threshold of 60 kg N $ha^{-1}a^{-1}$ when following the new balance approach. However, the data does not allow any conclusions with regard to the enforcement of the surplus as it mainly comes from past years when higher surpluses were still allowed. Furthermore, it represents only annual values but thresholds have to be met in a sliding multi-year average. Osterburg & Techen (2012, p. 187) conclude that farms which exceed the threshold for the N balance can adapt by reducing external N fertilizer inputs. Farms exceeding the P surplus usually have little options to reduce mineral P fertilizing. Possible adaption strategies are P-reduced feeding and the increase of P removal by straw export.

The prolongation of blocking periods under the FO 17 shifts manure application to spring. Osterburg & Techen (2012, pp. 169ff.) estimate that in 2010 around 30% of the total excreted manure was applied between April and October, mainly after the harvest of the main crop. They conclude that around 20% to 25% of the manure is affected by stricter blocking periods on arable land under the FO 17. Assuming an increase of N efficiency due to higher N use in spring, these measures lead to a decrease of N surplus from 3 to 4 kg N $ha^{-1}a^{-1}$ on a regional scale. The prolongation of the blocking period is strongly connected to the minimum storage capacity. Farms, which exceed 3 LU ha^{-1}, need to increase their storage capacity from livestock excretion from 6 to 9 months. In 2007, around 45% of the LU in Germany are kept in farms which had already capacities for more than 6 months. The authors conclude that by now a large share of farms holds already higher storage capacities than required by law in the past (Osterburg & Techen 2012, p. 174). As more recent data was not available and the presence of storage capacity could not be linked to the LU density, it is not possible to estimate the share of current compliance precisely.

The introduction of low NH_3 emissions application is characterized by the fading out of broadcast spreading. Osterburg & Techen (2012, pp. 177f.) use data from 2010 to show that around 50% of the total manure is applied to grassland or covered land by broadcast spreader. On grassland, around 90% of the manure was applied with broadcast spreader. Hence, the restrictions under the FO 17 will especially affect grassland based livestock production. With regard to the incorporation of manure on fallow land, data show that in 2010 around 25% of all farms incorporate manure faster than one hour and around 40% between one and four hours (Osterburg & Techen 2012, p. 180).

In several federal states, reports on regional nutrient balances and manure transport are published frequently (e.g. LWK NRW 2014; LWK Nds. 2017). In comparison to the regional nutrient balances calculated by Osterburg & Techen (2012), they take already existing manure flows within and between communities into account. The reports focus on characterizing the status quo under the FO 07. The recent report from Lower Saxony, however, also includes projections on future regional nutrient excess after the implementation of the FO 17 (LWK Nds. 2016, pp. 23ff.). Results show that seven instead of four counties (NUTS 3) exceed the allowed P surplus when it is lowered from 20 to 10 kg P ha^{-1} a^{-1}. This increases the area need for manure application outside of surplus counties to 120,000 ha. The inclusion of all organic N fertilizer in the organic N application limit leads to the exceeding of the threshold in seven instead of one county. The calculation does not fully reflect the upcoming changes as the reduction of P surplus on highly enriched soils, possible reduction of allowed surpluses in polluted areas and methodological changes of the nutrient balance calculation are missing. However, the results indicate the large impact of the changes in the FO 07 regarding P surpluses and illustrate the upcoming need for farmers to adapt.

There is no literature on the detailed reduction of different emissions realized by the revised FO. To fulfill the directive EU 2001/42/EG on the assessment of the effects of certain plans and programs on the environment, the impact was evaluated qualitatively in the context of a strategic environmental assessment, using mainly results from Osterburg & Techen (2012). The German Government's Climate Action Programme 2020 budgets a contribution of agriculture to the overall reduction efforts. Thereby, the biggest part, 3.3 Mio t CO_2 equivalents, should be realized by the revision of the FO (BMUB 2014, pp. 59ff.). With regard to NH_3 emissions, older estimations assume a reduction of around 45 Gg NH_3 due to the implementation low emission manure application techniques. As total NH_3 emissions are estimated at 540 Gg a^{-1} in 2015, this represents a relevant reduction

(UBA 2014, pp. 94ff.). A report published by the German Working Group of the Federal States on Water Issues assumes a reduction of the N input to groundwater and surface water bodies of 30% in pollution hotspots and 10% area-wide (LAWA 2014, pp. 24f.). However, due to methodological limitations and incomplete reflection of the FO 17, these figures are highly insecure.

4 Conclusion

In Germany, the FO is the core legislation to limit nutrient emission from agriculture to the environment. It implements the EU Nitrates Directive and contributes to achieving environmental targets laid down in several other regulations. The discussion paper at hand summarizes the most important changes under the current revision of the FO and the existing research. The FO 17 comprises stricter regulations than the FO 07, causing most probably efforts of farms to comply and a considerable reduction of the pressure on the environment. Generally, there is little research on the revision available.

Existing literature hints at an increasing need to lower nutrient surpluses at the farm and regional level, especially with regard to P. This will, among other, lead to an increased manure transport and, most likely, to a boost of manure processing techniques. The transport of manure includes the risk of increasing emissions in the manure importing regions. This regional pollution swapping has been rarely discussed in the revision process and research on its prevention is needed, especially with regard to regional differentiation of measures. However, manure transport is just one adoption strategy of farmers to comply with stricter surplus restrictions. In comparison to static calculations, as applied in the existing research, economic optimization approaches can help to include farmers’ behavior when facing stricter regulations and identify possible cost-efficient compliance strategy.

Generally, more research on the environmental impact of the revised FO is needed. A precise reduction of the abated emissions is of special importance to quantify the contribution to existing environmental targets and to identify further needs for reduction. This is, for instance, crucial with regard to the Water

Framework Directive which objectives are missed widely in Germany (SRU 2015). The FO serves as a basic measure to reach the targets of the directive. Further reduction is realized mainly by voluntary agri-environmental measures which should be designed complementary to the FO.

The impact of the revision is highly depending on the enforcement of the regulations. Existing research usually assumes that the measures are fully applied. However, empirical results hint a lack of enforcement in the past. The revised FO comprises several elements which allow a better enforcement of regulations, as for instance higher penalties or better data access for enforcing institutions. The detailed implementation and enforcement of the FO are depending on the federal states and remain to be seen in the future. The same holds true for existing vagueness of the directive which institutions on the federal level have to specify. Besides uncertainty with regard to the enforcement and detailed implementation, the design and impact of the farm gate balance methodology, as well as the derogation, are still uncertain.

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