Bachelor's thesis

Reducing agricultural N emissions in the Netherlands:

Technical possibilities, practical complications and the projected effect of Dutch regulations on biodiversity

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Abstract

Anthropogenic N emissions are currently one of the biggest drivers of biodiversity loss in the Netherlands. This has led to the implementation of multiple Dutch regulations to mitigate N emissions since 1987, of which the programmatic approach nitrogen (PAN) is the most recent. After a period of rapid decline, Dutch N emissions have stagnated since 2005. The objective of this research is to find to what extent the further reduction of agricultural N emissions is limited by technical and practical constraints and to what degree Dutch policies such as the PAN can mitigate the effects of excessive N deposition on biodiversity. I find that, while there is some technical potential to improve nitrogen management on Dutch farms, the realisation of reductions in agricultural N emissions is often complicated by practical obstacles, such as resistance in farmers to comply with regulations. Farmers will likely need to be more involved in the process of policy making to reduce this resistance and to be fully invested in the idea of nature conservation. Additionally, the proper use of on-site restoration measures will be of critical value to comply with the Habitats directive if the Dutch N emission objectives are not drastically lowered in the foreseeable future.

Introduction

Anthropocene reactive Nitrogen (N) emissions are estimated to have more than tripled total terrestrial N emissions compared to pre-industrial times (Fowler et al., 2013; Vitousek et al., 2013). These N emissions, both in the Netherlands and globally, mostly come from agricultural practises, the combustion of fossil fuels and other industrial processes (Canfield et al., 2010; Erisman et al., 2003; Rijksoverheid, 2014).

Even though N Is an essential plant nutrient, too much N deposition can result in a of high soil acidity, which leads to a high abundance of soil NH_4^+ and Al^{3+}. Because many plant species cannot live under these circumstances, this almost always leads to a loss in biodiversity (Bobbink et al., 1998; De Vries, 2008). Additionally, long-term, excessive N deposition can lead to dominance of relatively fast-growing nitrophilic species at the expense of characteristic species, which often leads to a lower plant species richness (Bobbink et al., 1998; Bobbink et al., 2014). Consequently, anthropogenic N emissions are often regarded as one of the biggest threats to terrestrial biodiversity (Bobbink et al., 2010; Schoukens, 2017; Steffen et al., 2015). Agricultural N emission is an especially big threat to biodiversity in the Netherlands, as it makes up 42 % of the total N deposition in the Netherlands (RIVM, 2017a)

The threat of excessive N emission has been recognised by both Dutch and European governments and have led to the installation of multiple policy tools to limit and reduce N emissions through agricultural practises since 1987 (Aarts, 2000; Schröder & Neeteson, 2008). These include the Nitrates Directive (ND) to reduce nitrate emissions (EC, 1991), the National Emission Ceilings Directive (NECD) to reduce ammonia emissions (EC, 1999) on European level and The Dutch Mineral Accounting system (MINAS) to reduce N emissions on a national level. Additionally, regulations were put in place to reduce biodiversity loss on a local scale and conserve nature sites of high conservational value. These include the birds directive to protect all European wild birds and their habitats (PbEU, 2009) and the Habitats directive, which requires European countries to maintain or restore natural habitats to a favorable conservation status (PbEG, 1992). The Dutch nature Conservation act of 1998 was the Dutch implementation of these directives (Ministry of Agriculture, Nature and Food quality, 2010). In order to mitigate the effects of N deposition on Natura 2000 sites, prohibited the development of farms, industries, roads and other activities that would lead to an increase in N deposition on these areas (de Heer et al., 2017).

The regulations to mitigate N emissions have proven to be rather successful, as agricultural ammonia emissions in the Netherlands decreased from 331 million kg NH_3 in 1990 to 136 million kg NH_3 in 2005 (Rijksoverheid, 2018). However, only a very slight decrease was seen in agricultural N emissions between 2005 and 2010 and no significant decrease has been observed since then (Rijksoverheid, 2018). Still, over 62 % of the ecosystems in the EU and over 70 % of the Natura 2000 sites in the Netherlands were subject to excessive amounts of N deposition in 2012 and 2014 respectively (Porsch et al., 2012; Schoukens, 2017), indicating that N emission levels are still too high and more measures to reduce N emissions are necessary to comply with the habitats directive. The management options to reduce N emissions from livestock farming have biological and technical limitations (Powell et al., 2010; Sommer & Hutchings, 1995), however, and especially the mitigation of N emissions from manure application has already come a long way since the 1990s (RIVM, 2016). As such, it is unclear how much further Dutch agricultural N emissions can be reduced without significantly lowering the agricultural output of livestock farming (Schoukens, 2017).

Besides the technical limitations, conservation measures are not always easy to implement from a practical standpoint, as they are often met with a lot of resistance from farmers (Runhaar et al., 2016). Farmers are often afraid of implementing different management strategies to reduce N emissions from their farm, as they are afraid that this will lead to financial setbacks (Claus et al., 2017; Runhaar et al., 2016). Another issue is that EU conservation regulations, and specifically the Dutch conservation act, have had a bad reputation amongst the Dutch farmers, due to its negative impacts on economic development (Beunen et al., 2012). This has led the Dutch farmers to have a lack of confidence in Dutch conservation regulations and to not be fully engaged in reaching environmental goals (Bouma, 2016; de Lauwere et al., 2016; Runhaar et al., 2016). Consequently, this lack of engagement may influence to what extent farmers carry out regulations enforced by the Dutch government, thereby jeopardising the ability reach the full technical potential of N mitigation measures.

In an attempt to combine conservation measures and ecological development, the Dutch government came up with the programmatic approach nitrogen (PAN), that was launched in 2015 (Rijksoverheid, 2017). The PAN is an integrated approach that aims to achieve the objectives of the habitats directive, while also providing room for economic development around Natura 2000 sites with strict environmental boundaries (de Heer et al., 2017). An important part of the PAN is to make room for economic development that requires N emission (farmers, roads, industry etc.) by reducing agricultural N emissions, even when this reduction is based on projections and has not yet been realised (Rijksoverheid, 2017). Besides the aim to reduce N depositions, it relies heavily on temporary, on-site restoration measures to remove excessive N from Natura 2000 sites and restore these habitats to a favorable conservation status (Rijksoverheid, 2017).

This seemingly mild approach to reducing N emissions, despite the possible threats that prolonged N emissions pose to biodiversity (Bobbink et al., 2010; Schoukens, 2017; Steffen et al., 2015), has raised concerns on how much the PAN can actually accomplish in terms of nature conservation, and whether it focuses too much on economic development (Ministerie van Economische Zaken & Ministerie van Infrastructuur en Milieu, 2015). Additionally, its heavy reliance on-site restoration measures has been questioned, as they do little to remove N from ecosystems in the long run, are subject to limitations and can sometimes have adverse side-effects on biodiversity (de Heer et al., 2017; Jones et al., 2017; Soons et al., 2017).

In this paper, I will be aiming to review the complications that come with the objective to solve the continuing threats that anthropogenic N emissions pose to biodiversity in the Netherlands. To help accomplish this, I will start by giving a brief overview of the PAN, as it is currently the most important policy tool to tackle the nitrogen issue in the Netherlands (de Heer et al., 2017). In the light of the objectives set out by the PAN, I will then discuss the technical potential of mitigating N emissions through changes in agricultural management. Here the focus will predominantly lie on in the dairy sector, as it is responsible for over half of the Dutch ammonia emissions (Thomassen et al., 2008). This will be followed up by an assessment of the practical complications and limitations that come with governmental regulations to reduce N deposition, such as the PAN. I will end by evaluating the effect that reducing N deposition to the levels set out by the PAN will have on the nature conservation goals of the habitats directive, and whether its heavy reliance on on-site restoration measures is justified.

2 Explanation programmatic approach nitrogen (PAN)

Two sets of measures are taken in the PAN: generic source measures and ecological restoration measures. The ecological restoration measures apply to a portion of the Natura 2000 areas that are labeled as nitrogen-sensitive, meaning a critical load of less than 2400 mol/ha/yr (van Dobben et al., 2013). They are a set of measures that apply to an area's specific needs in terms of straight up removing N from or making the areas more resilient to deposition of N (Rijksoverheid, 2017). They include measures such as restoration of water management, increasing the groundwater level and the removal of nitrogen-rich material by mowing, grazing or periodic incineration.

The generic source measures of the PAN aim to mitigate N emissions through a set of policies on N emissions in Dutch agriculture. These policies put emission ceilings in place on a multitude of agricultural practises, including feed and management, manure application and animal housing (Besluit emissiearme huisvesting, 2017). Its objective is to reduce agricultural ammonia emissions in 2030 by 9 % (10 kilotons) compared to the situation in 2013 (de Heer et al., 2017). For every abated unit of N deposition, the programme allows room for economic development through so-called 'room for deposition' and 'room for development'. The 'room for deposition' is the total sum of N deposition that the programme frees up for economic development. The room for development is the portion of the room for deposition that is used for developments that directly harm Natura 2000 sites or other N-sensitive habitats. Examples include building or enlarging a farm near a Natura 2000 site, building new roads near a Natura 2000 site or building new industry that emits N near a Natura 2000 site (Ministry of Economic Affairs & Ministry of Infrastructure and the Environment, 2015). For every unit of N that the programme reduces, 0.5 units become available directly for agriculture (De heer et al. 2017). The other part of the room for deposition is for 'autonomous developments', which allows for increases in N emissions that would be expected under an annual economic growth of 2.5 % (Verdonk & Wetzels, 2012).

Another important part of the PAN, is that, in order not to let farmers and other stakeholders wait, permits to emit more N can be issued based on projections of N emissions calculated by the AERIUS-model (a model that calculates the actual and future emission of N and the deposition on Natura 2000 sites based on economic activities such as farms, industry and traffic), before the projected reduction in N emissions is realised (Folkert et al., 2014).

3 Technichal possibilities of reducing N emissions in Livestock farming in the Netherlands

Through the generic source measures, the PAN aims to reduce ammonia emissions by 5.7 kilotons in 2020 and 10 kilotons in 2030 compared to 2013 (Rijksoverheid, 2017). According to a review of the PAN, however, the technical potential of the measures that are set out to realize this reduction is overestimated. They calculate the actual potential of these measures to be around 5 kilotons by 2020 (12 % less than expected), and estimate further mitigation of N emissions to be costly (Folkert et al., 2014). To review the potential of reducing emissions in the Netherlands, I will give a brief overview of the technical possibilities to realize the PAN's emission objectives and possible further reductions.

3.1 Current situation

The Netherlands currently has the highest N surplus (N output minus N input) per hectare of agricultural land in the EU (EEA, 2017). This is mainly because they have a high animal density per occupied unit of farmland, which is typically subject to a high N surplus (Leip et al., 2011). Over 39 % of the total Dutch N emissions by animal husbandry and over 50 % of the Dutch total NH_3 emission comes directly from dairy cows (Thomassen et al., 2008). Pigs, other cattle (produced for meat) and chicken amount for roughly 24 %, 18 % and 14 % of the Dutch N emissions by animal husbandry respectively (Hou et al., 2016). Dutch pigs, other cattle and chicken have around average N excretion (N input minus N output) levels for European standards, whereas Dutch dairy cows have the highest per cow emission of N in the EU (Hou et al., 2016). This does not directly translate to a high milk output per cow, as 9 EU countries on average produced more milk per cow per year than the Netherlands in 2017 (Eurostat, 2017). Similar outcomes are found in the N excretion data of European pigs, where the Netherlands ranks below neighbouring countries such as Denmark and Germany in terms of N excretion per produced kg of pig meat (Pierer et al., 2016). These results suggest that there are theoretical possibilities of improving management to decrease N excretion on both Dutch dairy and Dutch pig farms.

The differences found in N excretion per produce, however, could also be the consequence of poor measurements and different methods of obtaining data in different countries (Leip et al., 2011). Moreover, differences in N surplus between countries can stem from differences in site-specific conditions, such as weather patterns and soil type (Oenema et al., 2012; Oenema, 2013), and do not always indicate poor management.

3.2 Management options

The PAN aims to decrease the ammonia emissions from farms by 10 kilotons in 2030 (Rijksoverheid, 2017) through the generic source measures mentioned in chapter 2. Reducing agricultural N emissions in line with the set policies can be achieved through a range of management options. Some that are commonly used include: improving the efficiency of animal housing, improving the balance of protein or amino acids in animal feed to better fit the protein needs of animals (Rotz, 2004), lowering the N input by reducing the use of chemical fertilizers and by more efficiently utilizing home-produced organic manure, and exporting manure of farm (Oenema et al., 2011). Other management options that are not covered by the PAN's policies, but could further decrease agricultural N emissions, include the reduction of grazing intensity to decrease the N that is lost to the environment through leaching (Demanet et al., 2011) and reducing the relative number of young animals (they on average excrete more N than adult animals) (Oenema, 2013).

3.3 Nutrient use efficiency (NUE)

Using N surpluses to tell how efficient a farm can be managed can be inaccurate, because it only looks at N balance per farm. As such, a small farm will almost always have a lower N surplus than a big farm, simply because its production is lower. When looking at N surplus per hectare, this problem still occurs, since farms with low animal densities will almost always be favoured over farms with low animal densities, regardless of how efficiently they are managing their nutrients. Nutrient use efficiency (NUE) is a measurement for how efficient a farm is operating. NUE is defined by the N output (harvested products, such as milk and dairy for dairy cattle, meat for pigs, manure etc.) divided by the sum of N input: NUE = N output / N input (EUNEP, 2015), and is often used to determine environmental losses (de Klein et al., 2016). In this paper, farm NUE, which calculates the ratio between the total amount of N input and N output on a farm, will be used to estimate how efficient farms are operating as a whole.

3.4 Practical application of management options

Nitrogen use efficiency in livestock farming is constrained by the biological efficiency with which animals can transform feed N into milk and meat and by the efficiency with which crops and pastures can convert applied manure N and fertilizer N into edible products (Powell et al., 2010). Still, there are likely management options that could improve NUE and decrease N excretions on Dutch dairy farms, as shown by reports that display significant differences in NUE on Dutch dairy farms (Daatselaar et al., 2015; Oenema, 2013).

It is important to consider that different soil types and different farming intensity result in different NUE, and this should therefore be accounted for when comparing NUE on different farms (Ondersteijn, 2002). Significant differences in NUE, ranging up to a two-fold increase, are still found, however, when only farms with the same soil type and the same level of milk production ha^{-1} are taken into account (Daatselaar et al., 2015), showing that a change in management on some farms could significantly reduce their N excretion. Similar results were found in an experiment with commercial pilot dairy farms in the Netherlands, where farmers were intensively monitored and coached to manage N budgets efficiently. They made use of a variety of the management options described in chapter 3.2. This led to an average increase in NUE from 34 % to 38 % between 2003 and 2011 (Oenema, 2013). In the same time the, average Dutch dairy farm increased its NUE from 23 % to 30 % (Oenema, 2013). These results are still promising, as there is still a 8 % gap in NUE between the average Dutch dairy farm and farms that were intensively coached. This is not a gap that could be accounted for by only a difference in soil type (Ondersteijn, 2002), and could mean that a significant increase in NUE (and possible mitigation of nitrogen excretion) could be reached by coaching the average farm more intensively. However, as previously mentioned, NUE is limited by cows' ability to convert feed N into milk and meat and by the ability of crops and pastures to convert applied manure and fertilizer N into edible products (Powell et al., 2010). The smaller absolute increase in NUE on pilot farms than on the average Dutch farm in this period, despite the pilot farms receiving intensive coaching, could indicate that the possibilities of improved N management are reaching its biological limits.

3.4.1 Internal nutrient cycle (INC) farming

To reduce nitrogen emissions on dairy farms, some Dutch farms aim to improve the internal nutrient cycle (INC). This practice aims to mitigate Nitrogen losses to the local and national environment by re-utilising on farm N as efficiently as possible (Dolman et al., 2014; de Vries et al, 2014). As such, farms that make use of this practise are less reliable on external N inputs. Consequently, they mitigate N excretions both directly (lower use of purchased feeds and fertilizer) and indirectly (production and transport)(Dolman et al., 2014). N Emissions on INC farms were on average 5 to 10 % lower than on regular Dutch farms (de Vries et al., 2014). The farms were very similar in terms of productivity per farm and per hectare, while also showing similar soil conditions. As such, external factors were negligible and difference in nitrogen emissions could be attributed to higher NUE (de Vries et al., 2014). The higher NUE was accompanied by an improved economic performance and did not significantly alter societal performance (measured as other benefits to society, such as nature conservation or bird protection). This further shows that improving the NUE and reducing agricultural N emissions are not necessarily subject to societal or economic trade-offs (Dolman et al., 2014; de Vries et al., 2014).

3.4.2 Organic farming

Another possible way of reducing N excretions is to switch from conventional to organic farming. Organic dairy farming entails the prohibition of synthetic fertilizer and pesticides for crops and requires most of the food to consist of organically produced roughage (Thomassen et al., 2008). This usually results in a relatively low N input (Flaten et al., 2018). Three independent studies comparing organic to conventional to organic dairy farming found that N surplus per hectare was twice as high on conventional farms compared to organic farms in the Netherlands, Norway and Sweden (Einarsson et al., 2018; Flaten et al, 2018; Thomassen et al., 2008). N emissions per produced kg of milk were also significantly lower on organic farms than on conventional farms. On the study conducted in the Netherlands, the input/output (animals + milk + roughage + manure) ratio on conventional farms was over 1.5 times as high as on organic farms. Even when only accounting for milk and meat, the organic dairy farms produced 5 % more output per N input than conventional farms (Thomassen et al., 2008). Given that in 2017 only around 2 % of the Dutch cows were managed organically (CBS, 2018b), there is substantial potential to mitigate N emissions. However, organic farming usually uses up more land (Thomassen et al., 2008) and land is a very scarce and costly resource in the Netherlands (Aarts, 2000). This also results in higher prices on organic products (Padel & Foster, 2005), but making the switch to organic farming requires an investment that not all farmers are willing to make. As such, totally making the switch to organic livestock farming in the Netherlands would probably be an unrealistic goal. Still, organic farming is a growing industry in the Netherlands (CBS, 2018b), as it can also offer some benefits, such as a more stable price of produce (CBS, 2018a).

3.5 Costs of reducing N emissions

Even though measures to reduce N emissions and improve NUE are usually seen as costly (Folkert et al., 2014), simple measures such as balancing rations properly and manure N crediting (checking the amount of N in manure) before application can improve both NUE and farm profits (Powell et al., 2010). The notion that improving NUE does not have to be costly is also displayed in a study that focused primarily on altering the diets of pig and dairy cattle. By improving the quality of pig food to better suit their protein needs during different growth phase, it is estimated that a net gain of around 15-20 euros per abated kg N can be realised. On dairy farms, they estimate that by cutting grassland more frequently than currently happens on the average farm, the average quality of the food will go up, which compensates for the extra costs that are involved with the higher cutting frequency. This is estimated to result in a decreased N excretion per kg milk and a net gain of around 21 euros per abated kg N (Pierer et al., 2016).

The notion that a high NUE and an economically viable way of operating a farm do not have to be mutually exclusive, is further shown by an experimental mixed crop-livestock farm in the Netherlands. Over 15 years ago, this experimental farm already combined high economic output with a high NUE, even for today’s standards (Lantinga et al., 2013). They also performed a scenario analysis to further optimise the experimental farm and showed that the farm could theoretically reduce N emissions by an additional 30% (Lantinga et al., 2013), showing that the possibilities of reducing agricultural nitrogen emissions to below the PAN’s objectives should be theoretically attainable.

4 Practical applicability of regulations to reduce N emissions in the Netherlands

Despite some critique on the technical potential of the generic source measures included in the PAN (Folkert et al., 2014), both the Dutch government and the EEA remain optimistic that these measures can, in theory, achieve the PAN and NEC ammonia emission objectives (EEA, 2018; RIVM, 2016). The PAN relies heavily on the willingness of farmers to cooperate, however, and collaborations between nature conservation and Dutch farmers in the past sometimes showed unwillingness by farmers to fully implement the necessary measures for nature conservation, particularly when it is not in the farmer's best (short-term) interest (RIVM, 2016; Runhaar et al., 2016). This could provide problems with the realisation of the emission objectives, especially since a portion of the measures that farmers are to take are voluntary (RIVM, 2016). Therefore, I will attempt to provide an overview of the difficulties in the practical applicability of the PAN and other Dutch measures to reduce N emission.

4.1 A farmer's perspective

It is hard to quantify the willingness of farmers to work with the PAN and other regulations to reduce N emissions from their lands, but it is likely that the confidence they have in the governmental regulations will be of influence (Runhaar et al., 2016). In 2016, a survey on Dutch farmers showed that they had little confidence in the Dutch "manure law", which regulates the use and transport of manure in the Netherlands (RVO, 2018). The survey showed that the farmers thought the law was too confusing and they were afraid that it was going to cost them money through lower yields and a reduced soil fertility (de Lauwere et al., 2016). Additionally, some regulations in the PAN can be relatively easy to evade, as some are voluntary (cannot currently be enforced by law) and others can be time consuming and costly to monitor, making the likelihood to get caught quite small (Folkert et al., 2014). Currently, estimates of losing out on N emission reduction relative to PAN's prognosis, due to farmers not carrying out regulations properly, range from 0-5 % for the building of more efficient housing to 10-20 % for the application of manure regulations, air scrubbers and food- and management regulations (Folkert et al., 2014).

4.2 Permits

As previously mentioned, the PAN enables governmental permits that allow more N emissions to be handed out based on projections calculated by the AERIUS-model. As such, permits for N emissions can be handed out before evaluating the effects of previous measures. These permits could be part of the reason that a slight increase was seen in the Dutch ammonia emissions between 2015 and 2016 (RIVM, 2017b). According to some, these permits are essential to get the farmers on board of the PAN and to reduce N emissions in the Netherlands (Folkert et al., 2014). On the other hand, the permits have been met with skepticism, concerning to what extent conservation objectives can be achieved with these permits in play (de Heer et al., 2017). Some propose that the PAN's objectives to mitigate N deposition rely too heavily on the positive effects of future restoration measures, and cannot be justified in the light of precautionary principle that underlies the habitats directive (Schoukens, 2017).

4.3 European Court ruling

In line with the abovementioned (4.2) critiques, the ability to hand out permits to emit more N based on projections, has been ruled improper by the European court in November 2018. The European Court ruled that there should be more certainty as to how successful the future PAN regulations will be, before giving out the permits for N deposition room (ECR, 2018). It also ruled that permits that allow grazing of livestock and applying manure should be under stricter supervision, and more research should go into whether these permits will affect surrounding nature significantly (ECR, 2018). Even though this does not mean that the Dutch government can no longer hand out any permits, it does lead to a significant reduction in the availability of room for development (Schouten, 2018). The room for development was a way of incentivising farmers to comply with the regulations, since they can mitigate the financial losses that sometimes come with reducing N emissions (Folkert et al., 2014). As such, the reduction of room for development could further decrease the willingness of farmers to comply with the regulations of the PAN.

4.4 Fraud

Fraud by farmers can lead to discrepancies between the PAN's emission projections and the actual N emission levels. This applies mostly to Dutch "manure law" (van Grinsven et al., 2017), which states that only a certain amount of N in manure can be applied per farm (RVO, 2018). These limits were thought to be exceeded relatively often, both knowingly and unknowingly (for example because the composition of manure can be hard to predict) (de Lauwere et al., 2016). In the case that the manure production of a farm is too high, the excess manure has to be transported elsewhere, for example to farms that have not yet reached their manure quota (de Lauwere et al., 2016). When moving manure off farm to dispose it elsewhere, travel documents have to be made stating the amount of nitrogen and phosphate that is being moved in the truck (NVWA, 2017). Additionally, farmers have to send about half a kilogram of the manure they are "transporting" to a laboratory to get it tested for nitrogen and phosphate content. However, travel documents can be falsified relatively easily, to create the idea that manure is transported off farm, while it is actually being dumped on farm illegally (Velthof et al, 2017). Moreover, the nitrogen and phosphate content of the manure sample that is sent to the lab can be increased, by injecting additional nitrogen or phosphate into the manure (Dohmen & Rosenberg, 2017). The higher the N content of the sample, the more manure N has been transported off farm in the eyes of the state. As such, these practices can lead the government to believe that a lot of manure N is transported of farm, when in reality it is dumped on farm illegally.

The average cost for a pig or poultry farmer to dispose their manure is between 15 and 25 euros per ton (Van Grinsven et al., 2016), which equates to around 1000 euros per truckload (Dohmen & Rosenberg, 2017). This can make it very attractive for farmers to get rid of their excess manure illegally (by dumping it on their own land and creating fictitious disposal), especially given that the fine for falsifying these travel documents is only 300 euros and checks are relatively scarce (Dohmen & Rosenberg, 2017). Estimates in early 2017 were that between 30 and 40 % of the excess manure in the Netherlands was disposed illegally (van Grinsven et al., 2017). The portion of farmers that committed manure fraud was especially large in East-Brabant and Noord-Limburg, an area that comprises around 1/5th of the total Dutch manure production, where 64 % of the farmers were committing manure fraud (Dohmen & Rosenberg, 2017). It is hard to tell how big of an effect this manure fraud might have on the N emissions objectives of the PAN, but an estimate was made that a 50 % decrease in the export of manure would lead to an additional N deposition of around 2 kilo tons per year by 2020 (Folkert et al., 2014). This would equate to an increase of 1.2-1.6 kilo tons per year (over 20 % of the predicted loss in N emission by 2020), according to the estimates that 30 to 40 % of the Dutch manure was not exported properly (van Grinsven et al., 2017). The consequences of this could be especially detrimental when it leads to large amounts of additional N emissions in areas close to Natura 2000 sites or other sites that the PAN aims to conserve (Velthof et al. 2017).

4.5 Uncertainties in traffic NO_x emissions

Recent measurements show that traffic NO_x emissions, as agreed to in the Dutch "national cooperation programme air quality", were exceeded (NSL) (Folkert et al., 2014; Rutledge-Jonker et al., 2017). This could be an additional complication to the N deposition objectives of the PAN. Even though the EU has announced new regulations to compensate for this discrepancy, adjustments to the emission ceilings have not always had the desired effect in the past (Velders et al., 2011). Recent research that the magnitude of these exceedances may be a lot larger than was initially thought, as NO_x emissions were found to be up to 4 times higher than predicted in Central Europe (Karl et al., 2017). Even though these results are preliminary, they might indicate an additional source of N deposition that was not (to this extent) accounted for in the PAN (Folkert et al., 2014).

5 Biodiversity goals PAN

As previously mentioned, the PAN's ability to realise the predicted reduction in N emission is sometimes questioned, and concerns have been addressed that it focuses too heavily on economic development, rather than on nature conservation (de Heer et al., 2017; Schoukens et al., 2017). However, there are large uncertainties concerning the effectiveness of some of the PAN's generic source measures, and some of them could prove to reduce more N emissions than was initially projected in the PAN (Folkert et al., 2014). Additionally, on-site restoration measures could compensate for additional N deposition in some areas (Folkert et al., 2014). As such, the nature conservation goals as set out by the PAN are still definitely in reach (Folkert et al., 2014). In this chapter I will be reviewing the effectiveness of some of the on-site and generic source measures set out by the PAN to restore nitrogen-sensitive habitats in the short run (2021) and to ultimately (2032) improve biodiversity and create a sustainable environment for nitrogen-sensitive habitats.

5.1 Critical loads

Not all Natura 2000 sites are treated equally in the PAN, as there are large differences in how different habitat types react to N deposition (Emmett et al., 2011). Whether a specific habitat type will be affected by current N deposition levels is determined by its critical load. The critical load is the deposition level below which harmful effects on biodiversity, ecosystem function or structure do not occur according to present knowledge (Nilsson, 1988). The PAN's on-site restoration measures only apply to Dutch habitats that are currently exposed to N levels above their critical load, and generic source measures are stricter around ecosystems with low critical loads (Rijksoverheid, 2017).

Not everyone agrees with the accuracy of critical loads, however, and recent research shows that a decline in vegetation biodiversity already occurs at nitrogen deposition levels assumed to be lower than the critical loads (Payne et al., 2013; Wilkins et al., 2017), which could mean that the critical loads in the PAN are too high. Similar results were found in studies performed in the Netherlands, as decrease in vegetation richness was found in Dutch acidic grey dunes in the at N deposition levels below critical loads (Kooijman et al., 2017). Additionally, N deposition levels in Dune areas might be underestimated in the PAN, due to high amounts of N deposition from the sea. This increase in N deposition is especially high on the Wadden Islands, due to a lack of chemical P-fixation in this area (Kooijman et al., 2017). These findings could mean that the current levels of N deposition are hurting certain habitats more than was initially assumed, and a re-evaluation of the critical loads might be needed to realise the PAN's conservation goals.

5.2 Effects of a decrease in N deposition on biodiversity

It is well established that long-term excessive N deposition has a negative effect on plant biodiversity in most terrestrial ecosystems (Bobbink et al., 1998; Jones et al., 2017), but the extent to which this is reversible is unclear (Isbell et al., 2013). Some researches do show an increase in biodiversity following a decreased nitrogen input, but these often include large differences in nitrogen input (Strengbom et al., 2001; Tilman & Isbell, 2015), and may not be applicable to the current situation, where only a relatively minor decrease in N deposition is predicted (Rijksoverheid, 2017). When an increase in biodiversity is observed after a smaller decrease in N deposition, this decrease is usually accompanied by on-site restoration measures, such as mowing (Storkey et al., 2015; Wamelink et al., 2009). In grasslands, soil N concentrations seem to respond relatively rapidly to N deposition levels, and take about 4 years to recover from prolonged periods of excessive nitrogen deposition (O'sullivan et al., 2011; Stevens et al., 2012), but other variables, such as vegetation species composition may be slower to recover (Stevens, 2016). The notion that the effects of N deposition may not be instantaneous, but rather that N accumulates over time is often put forward (Emmett et al., 2007; Isbell et al., 2013; Phoenix et al., 2012; Power et al., 2006; Rowe et al., 2017.) Some propose that, in soil-based systems, N can remain substantially active for a couple of decades after N deposition has occurred (Power et al., 2006; Rowe et al., 2017). Consequently, ecosystems might take a long time to recover from N deposition. Alternatively, it is argued that some ecosystems may not be able to recover from prolonged exceedance of the critical loads at all, and that regime shifts can occur, where ecosystems enter an alternative, low-biodiversity state (Isbell et al., 2013; Stevens, 2012). This can happen for example when certain species are unable to recolonise when they are lost from the seed bank (Stevens, 2016) or when less-competitive species are unable to compete with nitrophilous, more competitive species (Stevens 2012). Ecosystems in this alternative state will require on-site restoration measures to provide a sudden change in N rather than a slight decrease in atmospheric nitrogen deposition (Stevens, 2016).

5.3 PAN's N emission mitigation objectives and its effects on Dutch biodiversity

The aims of the PAN are to decrease the N deposition levels on vulnerable sites from 1.360 mole N/ha/yr in 2014 to 1.315 mole N/ha/yr in 2020 (Velders et al., 2014) and to reduce ammonia emissions by 6.4 kilotons in 2021 and 10 kilotons in 2030 (Rijksoverheid, 2017). Currently, over 70 % of the nature sites that the PAN aims to preserve are subject to N deposition levels above their critical load (Schoukens, 2014). The aim for 2021 will most likely not reduce this number by a lot, seeing as the critical loads are exceeded by more than 45 mole N/ha/yr for the majority of these habitats (Folkert et al., 2014). Even though no specific objectives are set for reducing the N deposition levels on vulnerable sites by 2030, the Dutch emission objectives are relatively uniform until 2030 (Smeets et al., 2017), implying that a big reduction in N deposition levels on vulnerable sites by 2030 is unlikely.

Based on models that assume that the effects of N remain substantial until 30 years after deposition, it is estimated that the current projections of N deposition in the UK will result in an average increase in biodiversity of about 3 % by 2030 in 5 wide-spread semi-natural habitat types that are sensitive to N deposition (Payne et al., 2017). Contrary to these estimates, another modelling study in the UK found a modest decrease in biodiversity in acid grasslands, deciduous woodlands and heaths and bogs by 2030 under the current N deposition projections (Stevens et al., 2016). The latter estimates were made under the assumption that recovery from N deposition is not possible (Stevens et al., 2016). Given that recovery from excessive N deposition, albeit slow, is observed in some experimental studies (Power et al., 2006; Strengbom et al., 2001; Tilman & Isbell, 2015) it is unlikely that recovery is entirely impossible. Stilll, the assumption that the effects of N deposition become insignificant 30 years after they happened, might be too optimistic (Stevens et al., 2016).

Despite the fact that these modelling studies were not done based on Dutch data, the UK is bound by NEC and the habitats directive too (PbEG, 1992; EC, 1999), indicating that similar results can be expected in the Netherlands (Payne et al., 2017). As such, these results are an indication that the decrease in N deposition that the PAN sets out to achieve will most likely do little to increase biodiversity and restore the Natura 2000 sites to a favorable conservation status by 2030.

5.4 On-site restoration measures and hydrological management

PAN's objective to at least maintain (and possibly improve) the biodiversity in nitrogen sensitive Natura 2000 sites by 2021, relies heavily on hydrological management and temporary on-site restoration measures (Rijksoverheid, 2017). Hydrological measures include improving the water quality or elevating the ground water level, by building weirs for example. It has the potential to mitigate the effects of long periods of N deposition and to make ecosystems more resilient to N deposition in the long-term (Folkert et al., 2014; Jones et al., 2017). It might, however, be hard to get local governance to actively pursue the hydrological measures that the PAN prescribes, as they sometimes have to be performed on agricultural soils and can lead to resistance from farmers and other locals (Folkert et al., 2014). Additionally, experiments with raising the ground water level in different habitat types have not always been successful in increasing the species richness and can lead to unforeseen consequences (Stevens et al., 2013). Hydrological measures can cause damage to non-target species and a loss of seed-bank in most of the Netherlands' ecosystems, and could cause a major change in soil processes in dunes and heathlands (Jones et al., 2017), which can alter the composition of plant communities (van der Putten et al., 2013).

The PAN aims to realise over 50 % of its objective to maintain the quality of nitrogen sensitive ecosystems through the use of temporary on-site restoration measures such as mowing, cutting, grazing and burning (Rijksoverheid, 2017). These measures have the potential to remove aboveground vegetation biomass and soil N from long periods of atmospheric N deposition very quickly (Härdtle et al., 2006; Jones et al., 2017; Stevens et al., 2013), and, consequently, can be crucial in restoring soil and plant communities in the short-term (Stevens, 2016). Moreover, on-site restoration measures, such as low-intensive grazing can improve habitat suitability (the ability of a habitat to support a viable population over an ecological time-scale (Kellner et al., 1991)), for plant species of conservation interest (Jones et al., 2017). However, these measures are not always enough to remove more N than comes in from deposition, especially when performed under low intensity (Stevens et al., 2013). As such, on-site restoration measures would likely have to be rather intensive (e.g. high intensity burns in heathlands or heavy cutting with removal in grasslands) to have the desired effect (Jones et al., 2017). Yet, a high intensity of some on-site restoration measures, such as grazing or burning, can have adverse impacts on habitat suitability (Jones et al., 2017). Additionally, they often come with consequences that contradict the objective of the measures, such as a loss of non-target species, damage to fragile species and a loss of seedbank (Jones et al., 2017). On-site restoration measures can also drastically reduce phosphate and other nutrients in the soil, which can lead to consequences in soil-plant interactions and can ultimately cause a loss in biodiversity (Soons et al., 2017). These unforeseen consequences, coupled with the fact that on-site restoration measures are only temporary and will have to go on for a long time under the predicted rates of N deposition, have spewed some concerns on the effectiveness of on-site restoration measures and the PAN's reliance on it (de Heer et al., 2017; van der Bij et al., 2017). As such, N deposition needs to be substantially reduced to decrease the long-term reliance on possibly risky on-site restoration measures.

7 Discussion

To tackle the continuing threat that excessive N deposition poses to biodiversity in the Netherlands, a significant reduction in agricultural N emissions will most likely have to be achieved. Still, agricultural N emissions have more or less stabilized since 2005 (RIVM, 2017a), which has raised questions on how much more farmers can do to reduce emissions without jeopardizing their production (Schoukens, 2017). Studies that compare Dutch dairy farms with similar soil type and production intensity still find significant differences in NUE, however (Daatselaar et al., 2015; Dolman et al., 2014; de Vries et al., 2014), suggesting that a further decrease in N emissions does not have to go at the cost of productivity.

It can be difficult to quantify how much N emissions can actually be reduced when farms are utilising N as efficiently as possible, but dairy farms that are currently using relatively efficient methods of N-cycling show that a 5-10% decrease in N emissions from Dutch dairy farms could be attainable (Dolman et al; de Vries et al., 2014). Additionally, a modelling estimate shows that N emissions of dairy farms can be further decreased by about 30%, if all management techniques are optimised (Lantinga et al., 2013).

Another concern that farmers often express, is that reducing N emissions is too costly (Folkert et al., 2014; de Lauwere et al., 2016). This is part of the reason that Dutch farmers often do not comply with Dutch regulations, especially when they are voluntary (Folkert et al., 2014). Even though concerns for economic setbacks can sometimes be justified (Folkert et al., 2014), research suggests that significant improvements in NUE can be made without negatively effecting a farmer's profit (Dolman et al., 2014). Additionally, sometimes measures to improve a farm's NUE can even result in an increase in profit (Pierer et al., 2016).

Still, the communication between governmental institutes and farmers is often lacking, and this lack of information sharing tends to result in confusion and distrust amongst farmers, which can negatively impact the willingness of farmers to work with the government to reduce N emissions (Claus et al., 2017; de Lauwere et al., 2016). For some N emission mitigation measures in the PAN, the technical potential may be missed by 10-20%, due to farmers not complying with the regulations (Folkert et al., 2014). Additionally, farmers are committing manure fraud on a large scale, which may further reduce the realized potential of N mitigation objectives of the PAN by about 20% until 2020 (Folkert et al., 2014; van Grinsven et al., 2017).

The distrust and confusion amongst farmers may grow even further as a result of the European Court ruling, which states that the permits to emit more N can no longer be handed out based on projections of N emission reduction (ECR, 2018). These permits are a way of allowing farmers room for economic growth in exchange for cooperating with nature conservation objectives. Due to the fact that these permits will now most likely be handed out a lot less frequently, farmers may feel less incentivised to put the necessary measures in place to reduce N emission from their farms. This unwillingness of farmers to cooperate with the measurements of the PAN may lead to increased resistance against the PAN amongst policy makers that agreed with the PAN only because it offers room for economic growth. This might then lead these policy makers to decrease the amount of money they want to make available for nature conservation, resulting in increased resistance amongst conservationists (Folkert et al., 2014).

To avoid this cascade effect, it can be of detrimental value to increase the communication between farmers and policy makers. More communication can make farmers feel better about the regulations, and farmers tend to make decisions based on how they feel rather than on rational explanations (Oenema, 2016). As such, more communication between farmers and policy makers can increase the willingness of the farmers to comply with Dutch regulations. Additionally, it is suggested that farmers should be more involved in the decision-making of how to approach conservation issues, as the motivation and engagement of farmers can be of critical value in achieving future environmental goals (Bouma, 2016, de Snoo et al., 2013).

Examples of farms that operate with frequent knowledge exchange between farmers and conservationists often already show relatively high levels of NUE compared to average Dutch farms (Oenema, 2013; de Vries et al., 2015). This suggests that higher levels of engagement in farmers could help to achieve environmental goals. Currently, the Dutch Ministry of Economic Affairs is developing a 'nature-inclusive' way of farming, that brings together farmers, policy-makers, and other stakeholders to discuss shared meanings and objectives aimed at achieving an agricultural transformation that minimises ecological impacts and can help with nature conservation (Runhaar, 2017). Even though this programme's primary aim is not the reduction of N emissions, it shows that the Dutch government recognises the problem of a lack of engagement in farmers when it comes to nature conservation, and that it is willing to design new programmes that get all actors on the same page to develop a way of farming with more room for conservation measures.

Still, even under the assumption that the PAN lives up to its full technical potential and farmers all comply with its regulations, the positive effects of the reduction in N emissions on Dutch biodiversity will probably be small (Payne et al., 2017), and its effect might not even be enough to halt biodiversity loss in some habitat types (Stevens et al., 2016). These estimates are under the assumption that current critical loads are accurate, but some suggest that they are still too high for certain habitat types (Payne et al., 2013; Wilkins et al., 2017). If critical loads assumed in the PAN are indeed too high, the current projections for N depositions will do even less to restore Dutch biodiversity. As such, the aim to comply with the habitats directive will have to rely on on-site restoration measures and hydrological management very heavily if N emissions are not drastically lowered.

Hydrological management can reduce N levels from ecosystems and make them more resilient to further N deposition (Folkert et al., 2014; Jonest et al., 2017), while temporary, on-site restoration measures can be utilised to quickly get rid of a lot of excess N from an ecosystem (Härdtle et al., 2006; Jones et al., 2017; Stevens et al., 2013). Both of these measures often come with undesired consequences, however. Hydrological measures can cause damage to non-target species and a loss of seed-bank in most semi-natural ecosystems and can significantly change composition of plant communities in dunes and heathlands, due to an alteration in soil processes (Jones et al., 2017; van der Putten et al., 2013). Additionally, hydrological management can be hard to implement due to resistance from local governments and farmers (Folkert et al., 2014). Temporary, on-site restoration measures often have to be performed at a high intensity to be effective and reduce more N from a system than can come in through deposition (Stevens et al., 2013). Yet a high intensity of these measures can decrease habitat suitability, while they can also induce a loss of non-target species, damage to fragile species, a loss of seedbank and a reduction in other nutrients (Jones et al., 2017; Soons et al., 2017).

Due to the uncertainty of the extent of the abovementioned effects, a long-term reliance on on-site restoration measures will probably be unfavourable, and it is important to further reduce N deposition to sustainably restore Natura 2000 sites to a favorable conservation status (Jones et al., 2017; Stevens et al., 2013).

Whether the effects of N deposition are cumulative does not affect this claim, as it only affects whether ecosystems have the ability to recover from N deposition without the help of on-site restoration measures. Even under the worst-case scenario, where N deposition is entirely cumulative, ecosystems would still benefit from lower levels of N deposition, as it could mitigate the biodiversity loss that is assumed in some habitats under current projections (Stevens et al., 2016). Additionally, a mitigation of N depositions would at the very least be the most sustainable measure of sustaining biodiversity, as it reduces the need for repeated on-site restoration measures, which are often accompanied by adverse side-effects on biodiversity.

Even though there is technical potential to further reduce agricultural N emissions, it is unlikely that actual N deposition levels will be substantially lower than the PAN's objectives by 2030, given the practical complications that come with reducing agricultural N emissions and given that N deposition from non-agricultural sources, such as traffic, may be higher than was projected in the PAN (Folkert et al; 2014 Karl et al., 2017). Accordingly, if a drastic change to Dutch N emission levels, such as a massive reduction in Dutch livestock, does not occur, the realisation of the objective to comply with the habitats directive may be even more heavily dependent on potentially risky on-site restoration measures than was presumed.

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