Review

The Integrated Approach to Nitrogen in the Netherlands: A preliminary review from a societal, scientific, juridical and practical perspective

Mireille de Heer a,*, Frank Roozen b, Rob Maas a

a National Institute for Public Health and the Environment, RIVM, PO Box 1, 3720 BA Bilthoven, The Netherlands
b Ministry of Economic Affairs, PO Box 20401, 2500 EK The Hague, The Netherlands

A R T I C L E   I N F O

Article history:
Received 13 July 2016
Received in revised form 8 November 2016
Accepted 18 November 2016

Keywords:
Integrated Approach to Nitrogen
PAS
Natura 2000
Restoration measures
Room for deposition
AERIUS

A B S T R A C T

In north-western Europe, deposition of atmospheric nitrogen is one of the main obstacles to maintaining or restoring natural habitats to a favourable conservation status. The Integrated Approach to Nitrogen (PAS) of the Netherlands is a national plan that combines generic source measures to reduce nitrogen emission levels and ecological restoration measures in Natura 2000 areas, while creating room for economic development. The aim of the PAS is to ensure that conservation objectives can be achieved, while further economic development is facilitated around Natura 2000 areas within strict environmental limits. In this way, the PAS connects economy and ecology. This paper examines the PAS from a societal, scientific, juridical and practical perspective, based on a study of the literature, juridical cases and first experiences of the programme. Our review indicated that the PAS is a comprehensive approach to the nitrogen issue, aiming for a balance between the societal, scientific, juridical and practical perspective. However, the programme has not yet been in force long enough to observe actual results in the field.

© 2016 The Authors. Published by Elsevier GmbH. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

Contents

1. Introduction ............................................................................................................. 102
2. The Integrated Approach to Nitrogen ................................................................. 102
3. Available literature ................................................................................................... 104
3.1. Societal perspective ......................................................................................... 104
3.2. Scientific perspective ...................................................................................... 104
3.3. Juridical perspective ...................................................................................... 106
3.4. Practical perspective ...................................................................................... 106
4. Results and discussion .......................................................................................... 106
4.1. Societal support and feasibility ......................................................................... 106
4.1.1. Economic impact ....................................................................................... 106
4.1.2. Ecological impact ..................................................................................... 106
4.2. Scientific robustness ....................................................................................... 108
4.2.1. Ecological restoration strategies ............................................................... 108
4.2.2. Nitrogen data and modelling ..................................................................... 108
4.3. Juridical robustness ....................................................................................... 108
4.3.1. Enforceability of measures ................................................................. 109
4.3.2. Status of restoration measures ............................................................. 109

* Corresponding author.
E-mail address: mireille@deheer.co (M. de Heer).

http://dx.doi.org/10.1016/j.jnc.2016.11.006
1617-1381/© 2016 The Authors. Published by Elsevier GmbH. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).
1. Introduction

With the Birds and Habitats Directives, the EU Member States aim to halt the loss of biodiversity in the EU (European Commission, 2011; European Union 1992, 2009). Natura 2000, the European network of protected nature areas, is the main instrument to achieve this objective. For each Natura 2000 area, Member States have set specific goals for the conservation of species and habitats. Nitrogen emissions from agriculture, industry and traffic appear to be a major problem for achieving these goals (Fig. 1) (European Environment Agency, 2014, 2015; Hicks, Whitfield, Bealey, & Sutton, 2011; Sutton et al., 2011), especially in the Atlantic biogeographical region (Whitfield & McIntosh, 2014). Over the years, some north-western European countries have implemented policies and regulations to deal with the nitrogen problem (Whitfield & McIntosh, 2014).

The Netherlands has to address the excess deposition of nitrogen, as well (Ministry of Economic Affairs & Ministry of Infrastructure and the Environment, 2015a; Wereld Natuur Fonds, 2015). Nitrogen emissions in the Netherlands have about halved since the mid 1980s (CBS, PBL, Wageningen UR, 2014). Still, at many locations, deposition levels are way above the critical load for nitrogen (Wamelink et al., 2013). This is not only a problem for achieving nature goals, but it also has implications for economic developments around Natura 2000 areas. In accordance with the Birds and Habitats Directives, the Dutch Nature Conservation Act 1998 prohibits new activities or the expansion of existing economic activities with a negative impact on Natura 2000 areas. Thus, the issuing of permits for the development of farms, industries and roads that would involve additional nitrogen deposition became impeded (Ministry of Agriculture, Nature and Food Quality, 2010). Its negative impact on economic development also resulted in a bad reputation for EU nature regulations in Dutch society and a rather polarised relationship between ecological and economic stakeholders (Beunen, van Assche, & Duineveld, 2012; Buiks, Langers, Mattijssen, & Salverda, 2012).

To tackle the nitrogen issue, the Netherlands are now taking a new and very different approach. The national government and the twelve Dutch provinces, in consultation with economic partners and nature conservation organisations, have developed the Integrated Approach to Nitrogen (Programmatische Aanpak Stikstof, PAS) (Ministry of Economic Affairs & Ministry of Infrastructure and the Environment 2015a). The PAS is a national plan combining generic source measures to cut nitrogen emission levels and ecological restoration measures in the Natura 2000 areas, while creating room for economic development. The aim of the PAS is to ensure that conservation goals can be achieved, while economic development is facilitated around Natura 2000 areas within strict environmental limits. The concept of room for economic development can be compared to the concept of a safe operating space for humanity within planetary boundaries (Rockström et al., 2009) and the concept of environmental utilisation space or ‘ecospace’ (Opschoor, 1995).

After six years of development, the programme came into force on 1 July 2015. In order to be successful, the PAS has to be feasible and robust from both a societal, scientific, juridical and practical perspective. This paper, after an introduction on the approach, presents a review of the PAS from each of these perspectives, based on a study of the literature and juridical cases.

2. The Integrated Approach to Nitrogen

The conservation goal of the PAS is to avoid (further) deterioration of the conservation status of protected habitats in the short term (cf. Habitats Directive art. 6.2), and to contribute to achieving a favourable conservation status in the long term (cf. Habitats Directive art. 6.1). To achieve this goal, two types of measures are taken: generic source measures to reduce nitrogen emissions and ecological restoration measures in Natura 2000 areas.

The source measures include implementation of the existing Dutch and European policies on nitrogen. These policies mainly focus on the sectors of agriculture, industry and traffic and transport, targeting emissions of both ammonia (NH₃) and nitrogen oxides (NOₓ). Furthermore, especially for the PAS, an additional package with generic agricultural measures has been agreed with the agricultural sector (Ministry of Economic Affairs & Ministry of Infrastructure and the Environment 2015a; Ministry of Economic Affairs, LTO, Netherlands, NZO, Nevedi, NMV, NVP, NVV and CUMELA Netherlands, 2014). This package involves measures on animal housing (e.g. gas scrubbers), feed and management, and manure application techniques. These measures together should further reduce agricultural emissions, at least 10 kt/yr by 2030, compared to the situation of 2013 (-9%).

Ecological restoration within the framework of the PAS focuses on the 118 Natura 2000 areas in the Netherlands that contain nitrogen-sensitive habitats. These habitats are defined as habitats with a critical load of less than 2400 mol/ha/yr (van Dobben, Bobbink, Bal, & van Hinsberg, 2014). Restoration may involve measures to remove nitrogen from ecosystems, such as removing topsoil layers (sodding). It can also involve more generic measures to make ecosystems more resilient against the effects of nitrogen, such as hydrological measures. The PAS contains 69 restoration strategies, each containing a package of measures (Jansen, van Dobben, Nijssen, Bouwman, & Bal, 2014; Smits & Bal, 2014; Smits, Adams, Bal, & Beije, 2014). For the authorities concerned, implementation of the measures is a statutory requirement.

Under the PAS, part of the reduction in nitrogen deposition is made available for economic development. The political decision was made that this ‘room for deposition’ should allow for increases in emissions that are related to an annual economic growth of 2.5% (ECN & PBL, 2010; Verdonk & Wetzels, 2012). In addition, 50% of the emission reduction accomplished by the generic agricultural measures may be specifically used for development by the agricultural sector (Ministry of Economic Affairs, LTO Netherlands, NZO, Nevedi, NMV, NVP, NVV & CUMELA Netherlands, 2014).

---

1. The ‘room for deposition’ of the PAS is subdivided into four parts: a reservation for autonomous developments, a reservation for notifications, a reservation for priority projects and a free amount of room for deposition that project initiators can apply for (Ministry of Economic Affairs & Ministry of Infrastructure and the Environment, 2015a). The last two parts are called ‘room for development’. This paper does not distinguish between the four parts and uses the overall term ‘room for deposition’.
Fig. 1. Areas where critical loads for eutrophication for freshwater and terrestrial habitats are exceeded by nitrogen depositions caused by emissions in 2010. Source: European Environment Agency (2014), European Environment Agency (2015).

Fig. 2. Projected trend in nitrogen deposition after implementing the PAS. Source: AERIUS Monitor 14.2
Following the EU Habitats Directive and the Dutch Nature Conservation Act 1998, the calculated room for deposition can only be made available under the condition that this would not have negative impacts on conservation objectives in the Natura 2000 areas. This has to be appropriately assessed (Habitats Directive art. 6.3). For the PAS, this was done both on generic and site levels. The generic Appropriate Assessment shows that, under the PAS, nitrogen deposition will continue to decrease (see also Fig. 2) and that the PAS will have no negative effect on this decrease (Ministry of Economic Affairs & Ministry of Infrastructure and the Environment, 2015c). On site level, for each nitrogen-sensitive habitat type in each Natura 2000 area, ecologists have assessed whether the combination of the foreseen (decrease in) deposition and planned ecological restoration measures guarantees that the conservation objectives are not jeopardized. This means that there is at least no further degradation of habitat quality and that – if relevant – habitat quality or surface area can increase. The results from these so-called site analyses (‘gebiedsanalyses’) were positive for all of the 118 PAS areas (Ministry of Economic Affairs, 2015c). Altogether, this implied that the room for deposition can be made available by the competent authorities.

When applying for a permit, initiators of new or expanded economic activities can apply for room for deposition. In their application, they can refer to (the Appropriate Assessment of) the PAS. This is a major change compared to the situation before the PAS, when each individual initiator had to provide an Appropriate Assessment to show that his initiative would have no negative effect on Natura 2000 objectives. Another major change is the introduction of a limit values regulation (‘grenswaarderegeling’). If the deposition that is expected to result from a new or expanded economic activity will be lower than the limit value,\(^2\) a permit is not required and the initiator only needs to notify the competent authorities (Ministry of Economic Affairs, 2015a).

A monitoring system is an inseparable part of the PAS, to monitor its implementation and effects (Ministry of Economic Affairs, 2015b). Monitoring of the implementation concerns both source measures and ecological restoration measures. The monitoring of effects is focused on emissions and deposition of nitrogen as well as environmental conditions and nature quality in the Natura 2000 areas. If results indicate that the Natura 2000 objectives are in jeopardy, adjustments must be made. These may consist of additional or modified source measures or more or other ecological restoration measures. In addition, the available room for deposition can be reduced. This approach of ‘monitoring and adjusting’ guarantees that Natura 2000 objectives will not become threatened by the issuing of too much room for deposition.

The online calculation tool AERIUS (Ministry of Economic Affairs, 2013; RIVM, 2016a) supports the implementation and monitoring of the PAS (Fig. 3). First, the instrument is used for the development (and possible revision) of the PAS by calculating the available room for deposition for all Natura 2000 areas involved, on a level of 1 ha (Maltha, de Heer, & Wilmot, 2016). Second, when applying for a permit, initiators are legally obliged to use AERIUS (the product AERIUS Calculator) to calculate the nitrogen impact of their projects on Natura 2000 areas, i.e. the room for deposition needed (Ministry of Economic Affairs & Ministry of Infrastructure and the Environment, 2015f). Third, AERIUS facilitates the monitoring of the implementation and effects of the PAS, on both site and national levels.

At the core of AERIUS is the atmospheric transport model OPS, which calculates the dispersion and deposition of nitrogen (Sauter et al., 2015). This model is validated and calibrated on the basis of measurement data from the Dutch National Air Quality Monitoring Network and the Monitoring Ammonia in Nature (MAN) passive sampler network (Lolkema et al., 2015).

3. Available literature

For our paper, we examined 14 independent reviews of parts of the Integrated Approach to Nitrogen (PAS) that were conducted to support the development and implementation of this approach (Table 1). Each of the reviews was used to reflect on the PAS from the societal and/or scientific and/or juridical and/or practical perspective. In addition, some ten other sources were used (Table 2).

3.1. Societal perspective

The societal desirability and feasibility of the PAS were first of all assessed on the basis of the Environmental Impact Assessment (EIA) by the Ministry of Economic Affairs and the Ministry of Infrastructure and the Environment (2015b). The EIA looked at the societal desirability and feasibility of various ambition levels for the PAS by comparing the PAS with the autonomous situation (without PAS) and four alternative scenarios (Table 3). These alternatives differed in the size of the emission reductions they would generate by additional generic source measures, the room for deposition this would lead to, and the restoration measures they would entail.

In addition, we used three strategic impact assessments conducted by PBL Netherlands Environmental Assessment Agency and the Agricultural Economics Research Institute (LEI). PBL conducted an ex-ante evaluation of the expected effectiveness of the PAS (Folkert et al., 2014). The LEI conducted a cost-benefit analysis (Leneman et al., 2012) and an evaluation on the socio-economic consequences of the PAS (Leneman, Michels, van Veen, van der Wielen, Reinhard, & Polman, 2013).

Finally, for the review of the PAS from a societal perspective, we made use of the public consultation on the PAS (Ministry of Economic Affairs & Ministry of Infrastructure and the Environment, 2015e). In this consultation, the ministries received over 600 reactions from companies, sector organisations, NGOs and private citizens.

3.2. Scientific perspective

For the assessment of the scientific quality of the ecological restoration measures of the PAS, we used an international scientific
Table 1
Reviews conducted to support the development and implementation of the PAS and AERIUS, in chronological order, and the perspectives for which they were used in this paper.

| Review                                                  | References                                      | Perspective |
|---------------------------------------------------------|-------------------------------------------------|-------------|
| 1. Advice on the legal robustness                       | Council of State (2012)                         | X           |
| 2. Cost-benefit analysis                                | Leneman et al. (2012)                          | X           |
| 3. Evaluation of socio-economic consequences            | Leneman et al. (2013)                          | X           |
| 4. Scientific review of data and modelling              | Sutton (2013)                                  | X           |
| 5. Ex-ante evaluation of the effectiveness             | Folkert et al. (2014)                          | X           |
| 6. Review of ecological restoration strategies          | Review Committee 'Restoration strategies nitrogen-sensitive habitats Natura 2000' (2014) | X           |
| 7. Environmental Impact Assessment (EIA)                | Ministry of Economic Affairs & Ministry of Infrastructure and the Environment (2015b) | X           |
| 8. Review of fitness for purpose of AERIUS             | Duyzer et al. (2015)                           | X           |
| 9. Addition to the EIA                                  | Ministry of Economic Affairs & Ministry of Infrastructure and the Environment (2015d) | X           |
| 10. Review of the EIA                                   | Bleeker (2015)                                 | X           |
| 11. Review of AERIUS Monitor                           | Ministry of Economic Affairs & Ministry of Infrastructure and the Environment (2015e) | X           |
| 12. Public consultation on the PAS                      | Sutton et al. (2015)                           | X           |
| 13. Scientific review of data and modelling             | Fabrij and Dijk (2015)                          | X           |

X = major use; x = minor use.

* Netherlands Commission for Environmental Assessment.

Table 2
Additional sources on/relevant to the PAS, in chronological order, and the perspectives for which they were used in this paper.

| Subject                                                   | References                                      | Perspective |
|-----------------------------------------------------------|-------------------------------------------------|-------------|
| 1. Ecological restoration measures                        | Brouwer et al. (2009)                          | x           |
| 2. PAS and EU law                                         | Woldendorp and Schoukens (2015)                 | x           |
| 3. Court ruling on notifications                          | Council of State (2015)                        | x           |
| 4. Court ruling on ecol. restoration measures             | Council of State (2016)                        |             |
| 5. PAS in practice                                        | Boerema (2016)                                 |             |
| 6. Ecological restoration measures                        | de Keersmaeker (2016)                          |             |
| 7. Ecological restoration measures                        | Bobbink et al. (2016)                          |             |
| 8. Ecological restoration measures                        | van Diggelen et al. (2016)                     |             |
| 9. PAS and EU law                                         | Schoukens (2016)                               |             |

* Presentation at symposium.

Table 3
Overview of the alternatives in the Environmental Impact Assessment.

| Alternatives        | Variables                                                                 | Room for deposition | Restoration measures                                      |
|---------------------|---------------------------------------------------------------------------|---------------------|----------------------------------------------------------|
| PAS                 | Minimum of 10 kt emission reduction by generic agricultural measures       | 2.5% economic growth + 56% of the realised emission reduction by the agricultural sector | For each nitrogen-sensitive habitat type |
| Alternative 1       | Half of PAS                                                                | 2.5% economic growth + 100% of the realised emission reduction | Same as PAS |
| Alternative 2       | Same as PAS                                                                | 2.5% economic growth + 30% of the realised emission reduction | Same as PAS |
| Alternative 3       | 3 times PAS by extra emission reducing measures                            | Same as PAS         | None                                                     |
| Alternative 4       | Same as PAS + additional reduction of 3 kt by suspension of agricultural activities within 250 m from Natura 2000 areas | Same as PAS         | None                                                     |

review on the subject (Review Committee ‘Restoration strategies nitrogen-sensitive habitats Natura 2000’, 2014). In addition to this scientific review, we used an advice from the Dutch Council of State (2012) and the review of the Environmental Impact Assessment by the Netherlands Commission for Environmental Assessment (NCEA, 2015). Finally, we used three presentations on the ecological restoration strategies (Bobbink, Weijters, & Roelofs, 2016; de Keersmaeker, 2016; van Diggelen, van der Bij, Norda, & Aggenbach, 2016) and a study on restoration of fens and dune lakes by Brouwer et al. (2009).

Over the past decades, the measurement and modelling of ammonia in the Netherlands was thoroughly discussed among national and international experts. One of the starting points of the discussion was the explanation of the widening gap between the reported decline in ammonia emissions and the ammonia concentration measurements that showed no decline (van Pul, van Jaarsveld, Vellinga, van den Broek, & Smits, 2008). This ‘ammo-
nia gap' led to several reviews of the OPS-model (e.g. Sauter et al., 2015; Theobald et al., 2010), the measurements (e.g. Volten et al., 2012) and the methodology to estimate ammonia emissions (e.g. van Bruggen et al., 2014).

For the assessment of the scientific quality of the data and modelling of emissions, dispersion and deposition of nitrogen in relation to the PAS objectives, two international reviews were organised (Sutton, 2013; Sutton, Dragotsis, Geels, Gyldenkerne, & Misselbrook, 2015). In these reviews, the knowledge gathered in the studies to explain the ammonia gap (see previous paragraph) played an important role. The 2013 review focused on ammonia emission factors and deposition models. The 2015 review concerned the entire chain of data collection and emission calculations to deposition calculations. The key question was whether nitrogen deposition calculations on a regional level are a good scientific approach to determine actual deposition levels. In addition, from a review by ECN on AERIUS, we used findings on the quality of the calculations of the available room for deposition under the PAS (Bleecker, 2015).

3.3. Juridical perspective

We investigated the legal robustness of the PAS on the basis of the ex-ante evaluation by PBL (Folkert et al., 2014), the review of the Environmental Impact Assessment (NCEA, 2015) and the addition to this EIA (Ministry of Economic Affairs & Ministry of Infrastructure and the Environment, 2015d). In addition to the reviews, we used two court rulings by the Dutch Council of State, which gave a first indication of the juridical robustness of the PAS in practice (Council of State, 2015, 2016). Finally, we used two presentations on juridical aspects of the PAS (Boerema, 2016; Schoukens, 2016) and a paper discussing the chances of survival of the PAS in the light of the Habitats Directive (Woldendorp & Schoukens, 2015).

3.4. Practical perspective

The AERIUS calculation tool takes on a central role in the implementation of the PAS. We therefore evaluated the practical feasibility of the PAS on the basis of a review by the Netherlands Organisation for Applied Scientific Research (TNO) on the fitness for purpose of AERIUS Calculator beta 8 (Duyzer, Zandveld, & Lohman, 2015). In addition, we used results from a user acceptance test (UAT) of AERIUS Calculator beta 11.1 (Fabrij & Dijk, 2015). In the UAT, users followed 17 test scenarios. Part of the test was a Software Usability Measurement Inventory (SUMI) (University College Cork, 2016) to determine the user-friendliness of the tool. The UAT was performed by 77, partly (very) experienced, partly inexperienced AERIUS users.

4. Results and discussion

4.1. Societal support and feasibility

The Integrated Approach to Nitrogen is characterised by its focus on a decrease in deposition and the enhancement of nature quality through restoration measures, while legally justifying room for new economic activities that cause nitrogen deposition (i.e. room for deposition). According to the reviewers of the Environmental Impact Assessment, this coupling of room for economic development with the realisation of the objectives for Natura 2000 areas is likely to increase the public support for these objectives (NCEA, 2015).

4.1.1. Economic impact

An important factor determining the societal support for the PAS is its impact on the economy. The LEI calculated that the approach is economic on a national level, as the economic benefits over the first 6 years will outweigh the costs by between 100 and 200 million euros per year (Leneman et al., 2012). According to the LEI, the PAS is economically beneficial for agriculture, industry, traffic and transport, mainly due to the economic development options it offers, which, in turn, lead to new investments (Leneman et al., 2012) and jobs (Leneman et al., 2013). The costs of the PAS partly concern ecological restoration measures and monitoring, at the expense of the national and regional governments (Leneman et al., 2012). The remaining costs are the investments made by the economic sectors in the generic source measures.

Given the net benefits on the national level, the principle was included that the parties that invest to lower emissions, can at least partially benefit from this contribution to the generic reduction. This is a complicated puzzle. For the livestock sector, this has been solved by way of the special agreement according to which 50% of the emission reduction realised by this sector will be translated into room for deposition for the sector. The idea that such an approach helps to increase the support for the PAS is supported by the intention expressed by the Port of Rotterdam Authority to enter into a similar agreement for reducing nitrogen deposition from harbour activities (House of Representatives, 2015).

In addition to the direct economic benefits, the PAS also contributes to a lower administrative burden for businesses (Folkert et al., 2014). A major factor here is the limit values regulation, which reduces the annual administrative burden for businesses by around 1.9 million euros, depending on the number of permits that would normally be required (Ministry of Economic Affairs, 2015a). The PAS also simplifies the administrative task for project initiators, as they no longer individually have to provide an Appropriate Assessment for their permit applications, but – with respect to nitrogen – instead can refer to the (Appropriate Assessment of) the PAS (Folkert et al., 2014). Relatively, this benefit is largest for the agricultural sector, where nitrogen is an important aspect for the permit issuing. For example at large infrastructural or industrial projects, nitrogen often is a relatively smaller part of the total research for the permit(s).

4.1.2. Ecological impact

The societal support for the PAS, furthermore, depends on its expected impact on nature. The public consultation on the PAS showed there is concern about the PAS’ ambition level with respect to the decrease in deposition (Ministry of Economic Affairs & Ministry of Infrastructure and the Environment, 2015e). Various people were of the opinion that a favourable conservation status means that there should be no critical load exceedances for nitrogen, and that this should be the objective of the PAS. This point of view is based on the definition of a critical load, which is ‘the quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment are not expected to occur according to present knowledge’ (Nilsson & Grennfelt, 1988).

Looking at the four alternatives to the PAS in the Environmental Impact Assessment, achieving nitrogen levels below the critical load in all habitats and areas would be very difficult, even by the year 2030 (Fig. 4; Ministry of Economic Affairs & Ministry of Infrastructure and the Environment, 2015b). Therefore, setting the critical load as objective was considered not very realistic and politically not feasible. Early 2016, the Council of State ruled that ‘the exceedance of the critical deposition load can be no more than an indication that deterioration of a habitat is not unlikely’ (Council of State, 2016). This supports the idea that the critical load does not need to be the target.

Still, compared to the autonomous situation, a considerable reduction of nitrogen deposition is possible, as shown in the EIA by the PAS and alternatives 2 and 4 (the latter also including sus-
Fig. 4. Exceedances of the critical load in nitrogen-sensitive habitat types and habitats of protected species in the PAS areas, for 2014 and 2030, under an autonomous scenario, the PAS and four alternatives to the PAS. Bars indicate the percentage of the total area.
Source: Modified from the Environmental Impact Assessment (Ministry of Economic Affairs & Ministry of Infrastructure and the Environment, 2015b).

Fig. 5. Trend in average nitrogen deposition in PAS areas.
Source: Environmental Impact Assessment (Ministry of Economic Affairs & Ministry of Infrastructure and the Environment, 2015b)

Ecologists stress that restoration also has limitations and trade-offs, which makes them worry about the PAS-strategy so heavily relying on it. For example Bobbink et al. (2016), van Diggelen et al. (2016) and de Keersmaeker (2016) stated that for many habitat types, restoration measures do not completely counteract degradation by nitrogen deposition. Measures that counteract acidification do not reduce eutrophication or vice versa; there can be negative effects on fauna; in some cases restoration can eliminate historical eutrophication but is not durable under persistent exceedance of the critical loads. An example of the latter is shown in the evaluation of restoration measures on fens by Brouwer et al. (2009). Moreover, Bobbink et al. (2016) stated that present critical deposition levels are even too high. Given these limitations of restoration, it can be discussed whether the PAS should be more ambitious with respect to reducing deposition.

The period between de start of the PAS and the writing of this paper was too short to judge the effects of the PAS on achieving the conservation objectives. It will take a longer period of time for the effects of generic source measures on deposition and the impact of restoration measures to become visible in nature. At the same time, the competent authorities are already issuing permits for new emissions. It is this very point of ‘mortgaging the future’ that is causing various organisations to be sceptical about achieving nature objectives under the PAS (Ministry of Economic Affairs & Ministry of Infrastructure and the Environment, 2015e). Monitoring will show whether the PAS has its expected effect on nitrogen deposition and nature quality and whether or not the PAS will need adjusting. During the public consultation, the effectiveness...
of this system of monitoring and adjustment was questioned by environmental groups, while the economic sectors were afraid that negative findings might influence the available room for deposition.

4.2. Scientific robustness

4.2.1. Ecological restoration strategies

The restoration strategies of the PAS were drafted in a scientific process by about fifty expert ecologists, in consultation with a wider group of colleagues. The result was subjected to an international review. The review committee judged the report and the strategies as more than sufficient (Review Committee ‘Restoration strategies nitrogen-sensitive habitats Natura 2000’ 2014). According to the reviewers, the report can be used as a scientific basis for the implementation of ecological restoration strategies on site level. The reviewers also gave some recommendations; for example, to develop a guidance on possible conflicts between PAS restoration measures and other conservation measures in the context of the Habitats Directive. Such a conflict could for example occur when mowing is made impossible because of higher groundwater tables.

The Dutch Council of State (2012) in her advice judged that the work method applied — with restoration measures being drafted by expert ecologists and assessed by an international committee — guaranteed that restoration measures are based on state of the art knowledge. In view of the function of the PAS as Appropriate Assessment for the issuing of permits for nitrogen-emitting projects, the Council of State did point to the importance of guaranteeing a timely incorporation of new scientific insights in restoration strategies and in the PAS. To meet this requirement, the responsible ministries have committed to the development of a process for updating and upgrading the restoration strategies (Ministry of Economic Affairs & Ministry of Infrastructure and the Environment, 2015d).

The Netherlands Commission for Environmental Assessment, in her review of the Environmental Impact Assessment, discussed the uncertainties regarding the effectiveness of restoration strategies (NCEA, 2015). The commission stated that, for a substantial number of Natura 2000 areas, habitat types exist for which no measures with proven effectiveness are available. In their Addition to the Environmental Impact Assessment, the responsible ministries point to the fact that restoration measures are divided into three categories: proven, rule of thumb and hypothetical (Ministry of Economic Affairs & Ministry of Infrastructure and the Environment, 2015d). ‘The difference between them is in the degree of practical evidence, not in the scientific insights of the authors. According to both the authors of the restoration strategies and the international review committee all of the nationally approved measures are suitable to be implemented as restoration measures. However, measures that have not yet been sufficiently proven in practice should be subject to more monitoring and possibly also additional research.’ Furthermore, an independent review of the site analyses was announced, including an assessment of the effectiveness of the restoration measures applied. This review will be carried out after the PAS has been into effect for some years.

The NCEA (2015) also indicated that the long-term effectiveness of certain regularly applied measures appears to be only limited or debatable (see also Bobbink et al., 2016; Brouwer et al., 2009; de Keersmaeker, 2016; van Diggelen et al., 2016). This aspect has been recognised, and has been taken into account in the site analyses, for as much as was possible. Next, monitoring and the abovementioned review of the measures are crucial to follow the effectiveness of the measures in the field. When necessary, the PAS will be adjusted (Ministry of Economic Affairs & Ministry of Infrastructure and the Environment, 2015d).

4.2.2. Nitrogen data and modelling

The international review held in 2013 concluded that the ammonia emission factors used in the Netherlands with respect to the application of animal manure were scientifically well-founded (Sutton, 2013). The reviewers also concluded the scientific foundation for OPS, the Dutch deposition model and calculation core of AERUS, to be fit for its national purpose. In order to include international advances in atmospheric modelling of non-linear processes, the OPS model would need some adjustments, such as an incorporation of daily meteorological variations on ammonia emissions. In 2015, the second international review concluded that ‘the methods used in the Netherlands for emission inventory and modelling of atmospheric ammonia are generally sound’ (Sutton et al., 2015). And: ‘Dutch dispersion and deposition modelling can be considered to be well-suited to estimate regional spatial patterns’. However, the panel also concluded that Dutch dispersion and deposition modelling with OPS is currently inadequate for assessing long-term trends in ammonia concentrations. International progress in atmospheric chemical and physical modelling needs to be included in the model. This will be essential to assess to what extent reduction of sulphur and nitrogen oxide concentrations will increase the lifetime of ammonia in the air and to what extent climate change will increase ammonia emissions. Current efforts to address such model improvements need to be strengthened.

In its review, ECN addressed the issue of the spatial resolution of emission data in calculating the available room for deposition of the PAS, per hectare (Bleeke, 2015). ECN pointed to the fact that spatially refining the emission data may also increase uncertainties. An example is the introduction of provincial assumptions on the fraction of grazing cows. This is an important factor in determining emissions, but it is also known that there is much spatial and temporal variation which is not captured in the available empirical data.

4.3. Juridical robustness

Whether or not the PAS is juridically robust will become apparent from legal procedures against decisions that are made within the framework of the PAS. To date, the Council of State has not yet ruled on the systematics of the PAS as a whole. However, according to PBL Netherlands Environmental Assessment Agency (Folkert et al., 2014) and the Netherlands Commission for Environmental Assessment (NCEA, 2015), the approach of ‘monitoring and adjusting’ as followed under the PAS provides sufficient foundation for the attainability of the objectives set for the first time period, by guaranteeing that effective adjustments can be made whenever these objectives are threatened. Important here is that the adjustments are strictly enforced (Schoukens, 2016) and made as soon as the need arises, as the Court of Justice will accept no delay (Woldendorp & Schoukens, 2015). In the Addition to the Environmental Impact Analysis, it is stressed that, because the room for deposition is made available gradually over time, the risk of allowing economic developments that may later have to be reversed is avoided (Ministry of Economic Affairs & Ministry of Infrastructure and the Environment, 2015d). Also Woldendorp and Schoukens (2015) and Schoukens (2016) stress the importance of phased issuing of room for deposition, looking at the time lags and uncertainties in the effects of restoration. It enables timely and effective intervention when measures are not being implemented on time or prove to be insufficiently effective. If necessary, the issuing of permits may be halted for a shorter or longer period. All these factors are expected to contribute to the juridical robustness of the PAS as a whole.

Regarding art. 6.1 of the Habitats Directive, Woldendorp and Schoukens (2015) question whether the Dutch government has sufficiently demonstrated that there is no disproportionate delay in achieving the favourable conservation status. Schoukens (2016)
warns that excessive nitrogen deposition is one of the most important impediments to achieve the favourable conservation status and, in the end, will cause a deadlock scenario for economic developments. Here, it is relevant to bear in mind the goal of the PAS regarding art. 6.1: to contribute to achieving a favourable conservation status in the long term. The site analyses (Ministry of Economic Affairs, 2015c) state that a certain amount of room for deposition can be made available, without causing a disproportionate delay in achieving the favourable conservation status, compared to a situation without PAS (Ministry of Economic Affairs & Ministry of Infrastructure and the Environment, 2015e) (see also Fig. 4, showing a lower deposition under the PAS than under autonomous development).

4.3.1. Enforceability of measures

According to the ex-ante evaluation of the PAS by PBL, the legal enforceability and verification of the source measures of the PAS, or rather the lack of those, is a problem. For example, implementation of feed and management measures in the livestock sector, as agreed in the covenant with the sector, is not mandatory. This may result in lower effectiveness of the additional source measures than was taken into account in the PAS (Folkert et al., 2014). Although this may be true, in relation to achieving the objectives of the PAS it should also be noted that, in the agreement with the agricultural sector, the available room for deposition for livestock farming is related to the actually realised decrease in emissions. This is monitored within the framework of the PAS.

Enforceability of the implementation of the ecological restoration measures has been challenged in a legal case. A ruling by the Council of State on this subject currently is being awaited.

4.3.2. Status of restoration measures

Another juridical question regarding ecological restoration measures is whether they would have to be considered mitigation measures. If so, this would, among other things, imply that the measures would have to be taken in the same location and at the same time as the economic project or plan. This would be incompatible with the overall approach of the PAS, where there is no direct relationship between restoration measures and the individual projects and plans that require room for development. However, precisely because of the lack of such a direct relationship, the Council of State has judged that restoration measures are not considered to be mitigation (Council of State, 2016).

4.3.3. Notifications

Finally, from a juridical point of view, it is important to note that the Council of State has ruled that a confirmation of notification is not a decision as referred to in Dutch law (Council of State, 2015). This implies that notifications cannot be challenged in court and unforeseen reductions in the administrative burden can be cashed. The other side of this ruling is that, without the PAS, the juridical basis under the notifications will be lost (Boerema, 2016).

4.4. Practical feasibility

In its review of AERIUS Calculator, TNO considered the tool to be ‘fit for purpose’ (Duyzer et al., 2015). This means that all necessary functionalities were in place, in order to calculate the effects of projects and plans on deposition for the issuing of permits under the Nature Conservation Act. Sutton et al. (2015) congratulated the Netherlands on the development of the AERIUS tool to support future local decision-making.

The user acceptance test of AERIUS Calculator beta 11.1 showed no preventative issues (Fabrij & Dijk, 2015). In the ‘low impact’ category (‘nice to have’ user wishes) around 200 issues emerged. These were addressed in the first production version of Calculator (AERIUS Calculator 2014). In the SUMI test, AERIUS scored above the international market average (50) on all tested aspects: efficiency, affect (likeability), helpfulness, controllability and learnability. The overall score for user-friendliness was above average. The user-friendliness is also confirmed in the many positive reactions in interviews held among AERIUS users (RIVM, 2016a).

In interviews, both project initiators and competent authorities expressed the expectation that the permit issuing process would become easier with the PAS and AERIUS (RIVM, 2016a). In the past, there was often discussion between project initiators and competent authorities about data – for example, emission factors and habitat maps – and calculation methods to be used. Now, data and calculation methods are implemented in AERIUS. Moreover, calculation results can be directly used to underpin permit applications.

5. Epilogue

Our review indicates that the PAS can be considered a comprehensive approach to the nitrogen issue in the Netherlands, aiming for a balance between the societal, scientific, juridical and practical perspective. On 1 July 2015, the programme entered into force and first results can now be observed, in particular regarding the economic aspects. By 1 July 2016, 2741 notifications were made and 2536 permits were issued (1431 issued and 1105 definitively issued; RIVM, 2016b). By the same date, at 13 sites the room for deposition for notifications was depleted by 95%. This means that initiators need a permit for all new or expanded initiatives with a deposition on these sites (of more than 0.05 mol/ha/year). For 2 of these 13 sites, by 1 July 2016, also the free room for deposition for permits was nearly fully depleted. For all other sites, by that date, there was still free room for deposition for permits available. Altogether, the PAS appears to meet its objective of restarting the halted permit-issuing process, within the boundaries of the available room for deposition.

On the ecological side, for nearly all PAS areas, competent authorities have signed agreements with the site managers for the implementation of ecological restoration measures. It will take some years for the effects to become visible. The PAS needs to be in effect for a longer period of time to enable assessment of its impact on nature. Therefore, in this paper we cannot yet present any observations on this issue.

Boerema (2016), looking back at the first half year of the PAS, concluded that the PAS is complex, continuously changing and needs simplification. Important here is the update of the PAS on 15 December 2015, being the first of the annual updates of the PAS as announced in the programme (Ministry of Economic Affairs & Ministry of Infrastructure and the Environment, 2015a). The update mainly concerned scientific updates of emission factors and updates of priority projects (see footnote 1) (Ministry of Economic Affairs, 2015d). In turn, this resulted in changes in the room for deposition, including the reservation for notifications. Since the start of the PAS this reservation had become depleted for 20 sites; with the update there was room for deposition for notifications again at all sites, to then become depleted again for 13 sites by 1 July 2016. In the coming years there are likely to be more changes, especially in relation to the results of the restoration measures (Woldendorp & Schoukens, 2015). These changes, although unforeseen and explainable, can result in a picture of the PAS being unstable and unpredictable. Another issue related to changes in the PAS are the potential consequences for projects which are already underway in the permit issuing process (Vanweert, 2016). Excellent communication will be required to continuously explain what is happening.
The PAS strategy of inextricably linking ecology and economy is very suitable for the Dutch situation, where nature and economic activities are spatially close. In Flanders, the situation is comparable and a similar integrated approach to nitrogen is being developed (Agentenschap Natuur en Bos, 2016). In 2013, participants of an international workshop of the New Biogeographical Process for Natura 2000 considered the PAS and AERIUS to be promising approaches also for other north-western European countries (Whitfield & McIntosh, 2014).

We believe that using the PAS and AERIUS in other countries is indeed worth exploring, as long as it is also recognised that there are many differences in the nitrogen issue between countries. These differences concern the ecological and economic situation, the societal awareness and perception of the nitrogen issue, the availability of data and knowledge, the legal framework, and existing regulations and practices. This implies that the PAS cannot be copied exactly, but rather could be a source of inspiration and knowledge for other countries to develop their own strategies. For example, the knowledge and experience of the Netherlands with ecological restoration strategies might be of interest to other countries to use and build upon.

AERIUS tool is open-source software and could relatively easily be tailored to support policy processes on nitrogen in other countries. Carrying out pilot projects could be a good first step to explore the added value of the instrument for other EU Member States. Some initial benefits of such projects could be that they foster the collection and harmonisation of data and help raise awareness about the nitrogen issue. references

The authors would like to thank Bas Clabbers, Anoek de Groot, Diederk Metz, Angelique Nielen, Addo van Pul, Else Smeller and two anonymous reviewers for their valuable comments on the manuscript.

References

Agentschap Natuur en Bos, (2016). De programmatische aanpak van stikstofdeposities (PAS). Website [Accessed 18 March 2016].

Beuvenen, R., van Assche, K., & Duineveld, M. (2012). Performing failure in conservation policy: The implementation of European Union directives in the Netherlands. Land Use Policy, 31, 280–288.

Bleeker, A. (2015). Review uitwerking en implementatie beleidsuitgangspunten in AERIUS Monitor 2014-2 ECN report E-15-018. Petten: ECN.

Bobbink, R., Weijters, M., & Roelofs, J. (2016). N-depositie en biodiversiteit: Een gePASSeerd station? Presentation at the symposium on the PAS of the Flemish Environmental Law Association, 25–26 April.

Brouwer, E., van Kleef, H., van Dam, H., Leermans, J., Arts, G., & Belgers, D. (2009). Effectiviteit van herstelbeheer in vennen en duinoplissen op de middellange termijn. DIK report nr. 2009/dki 126–O. Directie Kennis en Innovatie, Ministerie van Landbouw, Natuur en Voedselkettings, Ede.

Buik, A., Langers, F., Mattissen, T., & Salverda, I. (2012). Draagvlak in de energetische samenleving: Van acceptatie naar betrokkenheid en legitimiteit. Alterra report 2362: Wageningen: Alterra.

CBS, PBL, Wageningen UR, (2014). Relatie ontwikkelingen emissies en luchtkwaliteit, 1990–2013. Compendium voor de Leeuwenhoek, indicator 0081, vs. 11, 16–07–2014. CBS, PBL & Wageningen UR.

Council of State. (2012). Voorlichting over de Programmatieke Aanpak Stikstof. The Hague: Council of State.

Council of State. (2015). Ruling 2015/05751/1/R2. The Hague: Council of State.

Council of State. (2016). Ruling 2014/06537/1/R2 and 2014/06589/1/R2. The Hague: Council of State.

de Keersmaeker, L. (2016). De stikstofcyclus verstoord: Een ecologische kijk op de N-problematiek. Presentation at the symposium on the PAS of the Flemish Environmental Law Association, 25–26 April.

duyzer, J., Zandveld, P., & Lohman, W. (2015). Doelmatigheidsonderzoek AERIUS Calculator (betalers/8 en Monitav) (versie 2014). TNO report 10211. Utrecht: TNO.

ECN & PBL. (2010). Reference projection energy and emissions 2010–2020. ECN report E-10-049. Petten: ECN.

European Commission. (2011). Our life insurance, our natural capital: An EU biodiversity strategy to 2020. COM(2011) 244 final. Brussels: European Commission.

European Environment Agency. (2014). Effects of air pollution on European ecosystems. Past and future exposure of European freshwater and terrestrial habitats to acidifying and eutrophying air pollutants. EEA Technical report 11/2014. Copenhagen: European Environment Agency.

European Environment Agency. (2015). The European environment: state and outlook 2015. synthesis report. Copenhagen: European Environment Agency.

European Union, (1992). Council directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. OJ L 206, 6/7/1992, p. 7–50.

European Union, (2009). Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds. OJ L 20, 26.1.2010, P. 7–25.

Fabrij, K. & Dijk, L. (2013). Testeindrapport GAT AERIUS Calculator (versie Beta 11.1). BIJ12/PAS-bureau, Utrecht.

Folkert, R., Arnouts, R., Backes, C., van Dam, J., van der Hoek, D. J., & van Schijndel, M. (2014). Beoordeling Programmatieke Aanpak Stikstof. De verwachte effecten voor natuur en vergunningverlening. Bilthoven: PBL.

Hicks, W. K., Whitfield, C. P., Bealey, W. J., & Sutton, M. A. (eds.). (2011). Nitrogen Deposition and Natura 2000: Science & Practice in determining environmental impacts. COSTTS29/Nine/ECC/ENV/WWP Workshop proceedings. COST. House of Representatives. (2011). Verslag van een algemeen overleg. Kamerstuk 32670 nr.99. The Hague: House of Representatives.

Jansen, A. J. M., van Dobben, H. F., Nijssen, M. E., Bouwman, J. H. & Bal, D. (eds.). (2012). Herstelstrategieën stikstofgevelede habitats. Ecologische onderbouwing van de Programmatieke Aanpak Stikstof (PAS). Deel III: Landschapsecologische inbedding. Unie van Bosgroepen, Alterra Wageningen UR, Stichting Bargerveen & Programmadirectie Natura 2000, Ministerie van Economische Zaken.

Leneman, H., Michels, R., van der Wielen, P., Oudendag, D., Helming, J., van Deursen, W., et al. (2012). Economisch perspectief van de PAS: baten en kosten van de Programmatieke Aanpak Stikstof in Natura 2000-gebieden. LEI-nota 12-070. Den Haag: LEI.

Leneman, H., Michels, R., van der Wielen, P., Reinhard, S., & Polman, N. (2013). Socialeconomisch perspectief van de PAS, socialeconomische effecten van de Programmatieke Aanpak Stikstof. LEI-nota 13-041. Den Haag: LEI.

Lolkema, D. E., Noordijk, H., Stolk, A. P., Hoogerbrugge, R., van Zanten, M. C., & van Pul, W. A. J. (2015). The Measuring Ammonia in Nature (MAN) network in the Netherlands. Biogeosciences, 12, 5133–5142.

Maltha, L., de Heer, M., & Wilmot, M. (2016). Calculating the room for deposition under the Dutch Integrated Approach to Nitrogen, using AERIUS. The Hague: Ministry of Economic Affairs.

Ministry of Agriculture, Nature and Food Quality. (2010). Hoofdlijnmetnotie Programmatieke Aanpak Stikstof. Kamerstuk 31700 XV 160. The Hague: House of Representatives.

Ministry of Economic Affairs & Ministry of Infrastructure and the Environment, (2015a). Programma Aanpak Stikstof 2015–2021 zoals gewijzigd na partijelijke herziening op 15 december 2015. The Hague.

Ministry of Economic Affairs & Ministry of Infrastructure and the Environment, (2015b). Plan-MER over het programma aanpak stikstof 2015–2021. Deel 1. The Hague.

Ministry of Economic Affairs & Ministry of Infrastructure and the Environment, (2015c). Passende beoordering over het programma aanpak stikstof 2015–2021. The Hague.

Ministry of Economic Affairs & Ministry of Infrastructure and the Environment, (2015d). Aanvulling op de Plan-MER over het programma aanpak stikstof 2015–2021. The Hague.

Ministry of Economic Affairs & Ministry of Infrastructure and the Environment, (2015e).Nota van Antwoord. Zienwijsen op het ontwerp Programma Aanpak Stikstof. The Hague.

Ministry of Economic Affairs & Ministry of Infrastructure and the Environment, (2015f).Regeling van de Staatssecretaris van Economische Zaken en de Minister van Infrastructuur en Milieu van 3 juni 2015, nummer 15/074288, houdende regels over de programmatische aanpak stikstof (Regeling programmatische aanpak stikstof), Staatscourant. 2015–16320.

Ministry of Economic Affairs, LTO, Netherlands, NZO, Nevedi, NMV, NVP, NVV, CUMELA Netherlands, (2014). Overeenkomst generieke maatregelen in verband met het programma aanpak stikstof.

Ministry of Economic Affairs, (2013). AERIUS, the calculation tool of the Dutch Integrated Approach to Nitrogen. The Hague: Ministry of Economic Affairs.

Ministry of Economic Affairs, (2015a). Besluit van 8 juni 2015, houdende geenwoorden voor toestemmingsovertuiging in het kader van de programmatische aanpak stikstof (Besluit geenwoorden programmatische aanpak stikstof), Staatsblad 2015–227.

Ministry of Economic Affairs, (2015b).Monitoring plan bij het programma aanpak stikstof 2015–2021. The Hague: Ministry of Economic Affairs.

Ministry of Economic Affairs, (2015c). Site analyses. The Hague: Ministry of Economic Affairs [Website. Accessed 26 February 2016].
Ministry of Economic Affairs. (2015d). Partijle herziening PAS op 15 december in werking. The Hague: Ministry of Economic Affairs.

NCEA. (2015). Programmatische Aanpak Stikstof (PAS). Toetsingsadvies over het milieueffectrapport en de aanvulling daarop. Report 2753-143. Utrecht: NCEA.

Nilsson, J., & Grennfelt, P. (1988). Critical loads for sulphur and nitrogen. Report from a workshop held at stokkloster, Sweden 19–24 March, 1988. NORD miljørapport 1988:15. Copenhagen: NORD.

Opschoor, J. B. (1995). Ecosystem and the fall and rise of throughput intensity. *Ecological Economics*, 15, 137–141.

RIVM. (2016a). AERIUS: Bilthoven: RIVM [Website. Accessed 26 February 2016].

RIVM. (2016b). *AERIUS Register*. Bilthoven: RIVM [Web application].

Review Committee ‘Restoration strategies nitrogen-sensitive habitats Natura 2000’ (2014). Herstelstrategieën stikstofgevoelige habitats in Natura 2000. Derde reviewronde.

Rocabro, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., Lambin, E. F., et al. (2009). A safe operating space for humanity. *Nature*, 461, 472–475.

Sauter, F., van Jaarsveld, H., van Zanten, M., van der Swaluw, E., Alen, J., & de Leeuw, F. (2015). The OP5 model description of OP5 4.4.4. Bilthoven: RIVM.

Schoukens, H. (2016). The integrated approach to nitrogen legal considerations in light of EU nature conservation law. Presentation at the symposium on the PAS of the Flemish Environmental Law Association, 25–26 April.

Smits, N. A. C. & Bal, B. (eds.). (2014). Herstelstrategieën stikstofgevoelige habitats. Ecologische onderbouwing van de Programmatische Aanpak Stikstof (PAS). Deel I: Algemene inleiding herstelstrategieën: beleid, kennis en maatregelen. Alterra Wageningen UR & Programmadirectie Natura 2000 van het Ministerie van Economische Zaken.

Smits, N. A. C., Adams, A. S., Bal, D., & Beije, H. M. (eds.). (2014). Herstelstrategieën stikstofgevoelige habitats. Ecologische onderbouwing van de Programmatische Aanpak Stikstof (PAS). Deel II: Herstelstrategieën voor stikstofgevoelige habitats. Alterra Wageningen UR & Programmadirectie Natura 2000 van het Ministerie van Economische Zaken.

Sutton, M., Howard, C., Erismann, J. W., Billen, G., Bleecker, A., Grennfelt, P., et al. (2011). *The European nitrogen assessment*. Cambridge: Cambridge University Press.

Sutton M. A., Dragosits U., Geels C., Glydenkarne S., Misselbrook T. H. (2015). Review on the scientific underpinning of calculation of ammonia emission and deposition in the Netherlands.

Sutton, M. (2013). *Summary for the Review on scientific underpinning of ammonia emissions factors and ammonia deposition models*. Midlothian: CBI Edinburgh. Theobald, R., Lefstrøm, P., Andersen, H. V., Pedersen, P., Walker, J., Vallejo, A., et al. (2010). An intercomparison of models used to simulate the atmospheric dispersion of agricultural ammonia emissions. In *HARMO-13 conference*.

University College Cork. (2016). SUMI. Cork: University College Cork [Webpage. Accessed 26 February 2016].

van Bruggen, C., Bannink, A., Groenestein, C.M., de Haan, B.J., Huismans, J.F.M., Luesink, H.H., van der Sluis, S.M., Vetelhof, G.L. & Vonk, J. (2014). Emissions into the atmosphere from agricultural activities in 2012. Calculations for ammonia, nitric oxide, nitrous oxide, methane and fine particulate matter using the NEMA model. WOT technical report 3. Wageningen: The Statutory Research Task Unit for Nature and the Environment.

van Diggelen, R., van der Buij, A., Norda, L., & Agenbach, C. (2016). Maatregelen in natuurterreinen: Een zaak van PAsjes en meten? Presentation at the symposium on the PAS of the Flemish Environmental Law Association, 25-26 April.

van Dobben, H. F., Bobbink, R., Bal, D., & van Hinsberg, A. (2014). Overview of critical loads for nitrogen deposition for Natura 2000 habitat types occurring in the Netherlands. *Alterra report 2488*. Wageningen: Alterra.

van Pul, W. A. J., van Jaarsveld, J. A., Vellinga, O. S., van den Broek, M., & Smits, M. C. J. (2008). The VELD experiment: An evaluation of the ammonia emissions and concentrations in an agricultural area. *Atmospheric Environment*, 42, 8086–8095.

Vanweert, F. L. H. (2016). PAS bij besluiten over plannen en projecten in Nederland. Presentation at the symposium on the PAS of the Flemish Environmental Law Association, 25-26 April.

Verdonk, M., & Wetzel, W. (2012). *Referentieraming energie en emissies: actualisatie 2012. Energie en emissies in de jaren 2012, 2020 en 2030*. The Hague: Plantbureau voor de Leefomgeving.

Volten, H., Bergwerff, J. B., Haaima, M., Lolkema, D. E., Berkhout, A. J. C., van der Hoff, C. R., et al. (2012). Two instruments based on differential optical absorption spectroscopy (DOAS) to measure accurate ammonia concentrations in the atmosphere. *Atmospheric Measurement Techniques*, 5, 413–427.

Wamelink, G. W. W., de Knecht, B., Poulwers, R., Schuiling, C., Wegman, R. M. A., Schmidt, A. M., et al. (2013). Considerable environmental bottlenecks for species listed in the Habitats and Birds Directives in the Netherlands. *Biological Conservation*, 165, 43–53.

Worlde Natuur Fonds. (2015). *Living planet report. natuur in Nederland*. Zeist: WWF Whitfield, C., & McIntosh, N. (2014). *Nitrogen deposition and the nature directives: impacts and responses*. Our shared experiences, report of the workshop held 2–4 December 2013, JNCC Peterborough. JNCC report 521. Peterborough: JNCC.

Woldendorp, H. & Schoukens, H., (2015). De Programmatische Aanpak Stikstof (PAS) in Nederland als inspiratiebron voor Vlaanderen: pas op de plaats van stap voor stap? Tijdschrift voor Omgevingsrecht & Omgevingsbeleid, 2015-3, 320–344.