# Netherlands

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**Introduction**
Nitrogen deposition in the Netherland is recognized for being a large threat to protected habitats and species. Various policy measures are taken to reduce this threat. On the one hand, there is the international policy to reduce emissions on an international level, as stated in the LRTAP Convention. On the other hand, there is a Dutch Integrated Approach to Nitrogen (PAS; Ministry of Economic Affairs & Ministry of Infrastructure and the Environment, 2015) which was set-up to reduce emissions on national, sub-regional and local levels, and take restoration measures in sensitive Natura 2000 areas.

Both type of policies make use of information on critical loads for nitrogen (Van Dobben et al., 2006; Van Dobben et al., 2014). In the Call for Data 2015□2017, CCE asked for data and updates on critical loads of acidification (SMB model), eutrophication (CLnutN from SMB or CLempN), and critical loads of Nitrogen and Sulphur, for protecting plant species diversity. This report describes the methods used to generate this information about the Dutch ecosystems.

**General methodology**
In the Netherlands, there is a long history of using dynamic soil-vegetation models in environmental assessments (Kros et al., 1998). The backbone of this modelling has long been the SMART2-MOVE model. Within this modelling framework, the SMART2 model has been used to simulate abiotic soil conditions under certain deposition scenarios, while MOVE was used to assess how changes in soil conditions could influence plant species occurrences. These same models have been used to derive critical loads for Dutch plant associations (Van Dobben et al., 2006), nature targets types (Van Hinsberg and Kros, 2001) and the habitat types included in the European Habitats Directive (Van Dobben et al., 2014). For recent calls for data, PROPS-NL has been used instead of MOVE and VSD+ (Bonten et al., 2009) instead of SMART2 (see CCE, 2011; CCE, 2014; CCE, 2015).

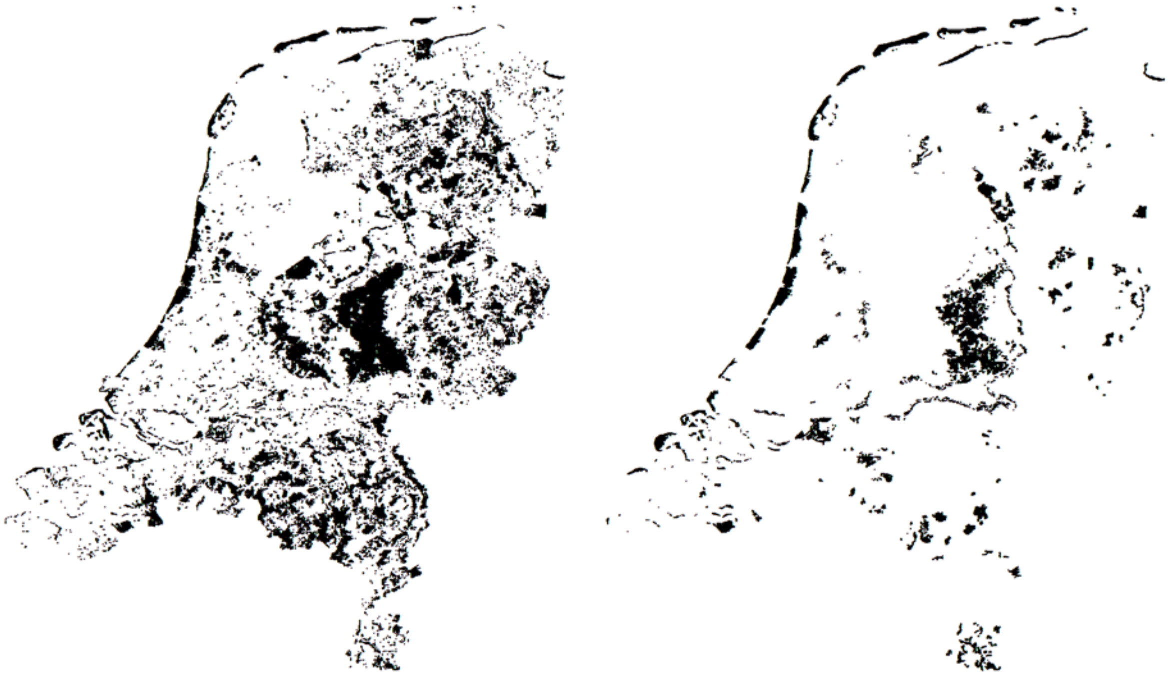

*Figure NL-1. 250x250m grids in the Critical Load database with terrestrial Dutch nature target types in the National Ecological Network (left) and terrestrial habitat types in the Natura 2000 areas (right).*

**Mapping critical loads for nature policy targets**

In the Dutch critical load database, critical loads were calculated for both Natura 2000 areas and other terrestrial natural areas in the National Ecological Network (NEN; Figure NL-1, left). In earlier studies, the critical loads in both areas were based on maps of the Dutch nature target types. Now, within the Natura 2000 areas, CLbio and CLnutN were mapped for protected habitat types (Figure NL-1, right). This map of habitat types was provided by the Ministry of Economic Affairs.

In order to derive a consistent set of input parameters for VSD+, information on habitat type (i.e. species list and suitable pH and nitrogen availability) had to be linked with information on corresponding soil types and vegetation types. Within each 250x250-metre grid, we determined the dominant habitat type and the most likely type of vegetation that would occur in that habitat (i.e. deciduous forest, dark coniferous forest, light coniferous forest, heathland and grassland). The same was done for the seven soil types for which VSD+ has been parametrized. This linkage was not only based on vegetation and soil types present within the grids, but also on information about the type of vegetation and soil that could occur within a particular habitat type (http://www.synbiosys.alterra.nl/natura2000).

Information on parametrization of vegetation and soil types in VSD+ was similar to earlier calls for data, except for the amount of litterfall and the N content in litterfall. In previous calculations of critical loads, these inputs were assigned to combinations of nature target types and soil types. In the calculations for habitat types, we now derived this information based on plant associations, following the same procedure as reported in the CCE report of 2014. We calculated the values per plant association by taking the average value of all nature target types in which that associations could occur. Then we calculated the average of all plant associations within a habitat type. The calculated amounts and contents of litterfall was checked with information from the SUMO model (Wamelink et al., 2009) and adjusted where needed. Any N content below 1% was set to 1%.

Ranges of suitable pH and nitrogen availability were derived for each nature target and habitat type. This was done by calculating conditions suitable for 80% of the desired species that could occur under optimal abiotic conditions (f = 0.8). The desired species were obtained from the lists of typical species of habitat types and target species for Dutch nature targets (Bal et al., 2001). These species can be considered as the species that are present when biological quality of habitats and targets is high (see CCE, 2015). Invasive or undesired species (i.e. the species that are more abundant in less-developed forms of the given plant associations) were not included, because modelling these species produced unrealistic results (Kros et al., 2016).

**Critical load function**

Critical loads for nitrogen based on a critical N availability were calculated according to:

$$CL(N) = N_{avail,crit} - N_{upt} - N_{lf} - N_{fix} - N_{seep} \quad \text{(NL-1)}$$

With $N_{avail,crit}$ = critical N availability, $N_{upt}$ = N uptake, $N_{lf}$ = total litterfall of N (above and below soil surface), $N_{fix}$ = N fixation (set to zero), $N_{seep}$ = N flux via upward seepage.

Since we used nitrogen availability as the criterion to compute N critical loads related to both eutrophication and biodiversity, both CLeutN and CLNmax were computed with eq. NL-1. However, for each 250x250m grid, we compared the calculated CLeutN with the empirical critical range (see CCE, 2011). When CLeutN was within this range, the calculated value was used, otherwise we took the empirical value given by Van Dobben et al. (2012). For CLNmax we always used the value computed with eq. NL-1. For the acidification critical loads, a critical pH was used as the criterion which means that CLmaxN is based on pH and thus differs from CLNmax which is based on N availability. Critical loads for sulphur are always based on a critical pH, so CLSmax and CLmaxS are identical.

From the calculated CLNmax we calculated CLSmin by finding the Sdep at CLNmax (see also Figure NL-2) according to:

$$CLSmin = CLSmax(pH) - (CLNmax - CLNmin) * slope \quad \text{(NL-2)}$$

In which the 'slope' was calculated as:

$$slope = f_{ni} * (2 - f_{de}) - 1 \quad \text{(NL-3)}$$

where $f_{ni}$ is the nitrification fraction and $f_{de}$ is the denitrification fraction.

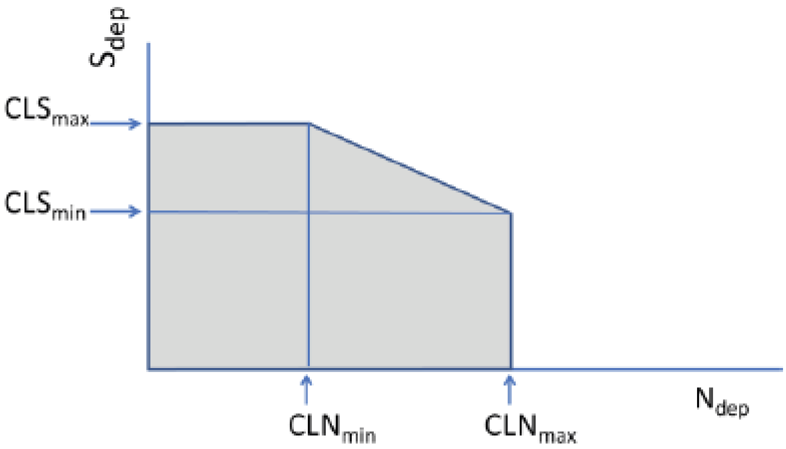


*Figure NL-2.The biodiversity critical load function.*

**Results and discussion**

Cumulative frequencies (Figure NL-3) show that CLeutN has a smaller range than CLNmax, which is caused by forcing the values of CLeutN to be within the empirical range. Tables NL-1 to NL-3 summarise the results per vegetation type. Table NL-1 depicts the results for all grid cells, whereas Table NL-2 shows the results for the cells within Natura 2000 areas with habitat types, and Table NL-3 shows the results for the cells outside Natura 2000 with nature target types. Results show that the largest differences between CLeutN and CLNmax can be found in locations with deciduous forests. High CL(N) values are calculated in these forests with relatively low N input from litterfall. This often causes critical loads that exceed the empirical ranges. For CLeutN, these high values were corrected so that they meet the empirical ranges (see Van Dobben et al. (2014) for habitat types or Bal et al. (2007) for nature target types) causing CLeutN to be lower than CLNmax.

We were not always able to calculate the full critical load functions (see Tables NL-1 to NL-3). Reasons for this vary between sites and types of parameters. For example, for various sites, CLNmin could not be calculated, because used N input by litterfall and/or seepage already exceeded the desired N availability leaving no room for any additional deposition of N. CLSmax could not be calculated when the critical pH cannot be obtained without acid deposition, and CLSmin cannot not be calculated in cases where CLSmax or CLNmax or CLminN were absent (cf eq. NL-2).

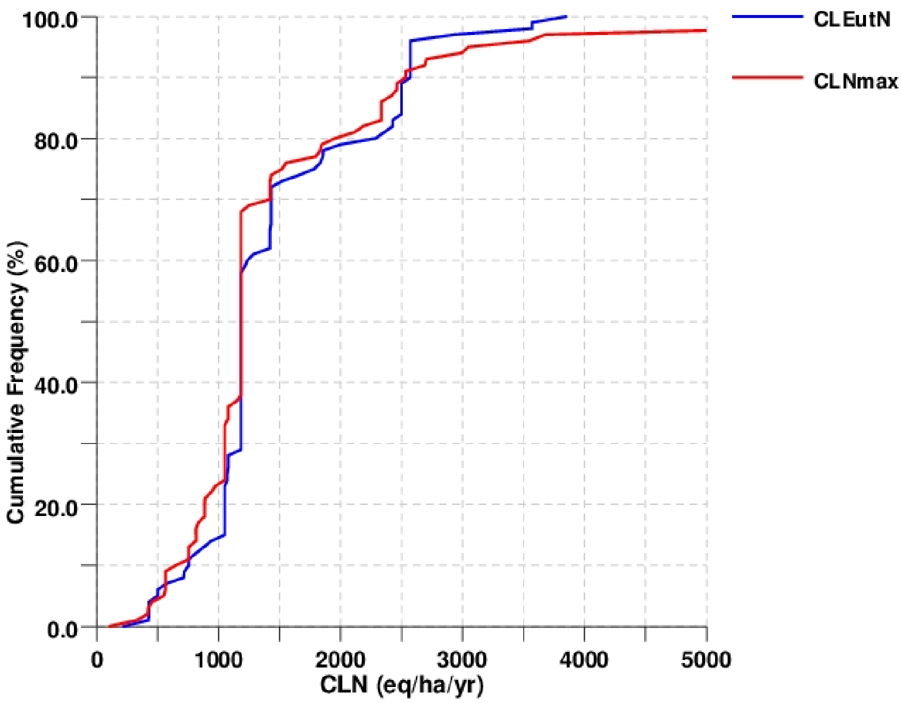


*Figure NL-3. Cumulative frequency distributions of CLeutN and CLNmax, based on the N-availability criterion.*

**Discussion on choice for dominant habitat types**

For the habitat type calculations, the original habitat type map was gridded to a map with 250 x 250 $m^2$ grid cells. For each grid cell, the dominant habitat type within a grid cell was assigned to that particular grid cell. By assigning a habitat type to a 250x250-$m^2$ cell, the habitat map increased in size from about 88000 ha to more than 141,000 ha. Moreover, the relative contribution of the various habitat types did not change because of this procedure, as the regression line between the relative contribution of each habitat type within the original map and the derived map was close to the y=x line (y=1.071x – 0.001; $r^2$=76%). However, the area of, for example, dry heath increased by 12%.

By focusing on the dominant habitat type, we could calculate critical load values that have the highest relevance for the grid cell. Moreover, the focus on dominant habitat improved the link with soil and vegetation maps. By focusing on the critical load for the dominant habitat type, significant negative effects of deposition levels equal to the critical load for the dominant habitat on other more sensitive habitats in the grid cell cannot be ruled out, which is not in accordance with the Habitat Directive. This problem can be resolved by calculating critical loads for the most sensitive habitat type in each 250x250 grid cell. However, such an approach would need more precise soil and vegetation data and more site-specific model parameterization. Given the shortcomings of our procedure, it is clear that the current maps on CLeutN should not be used on a local scale.

**Discussion on calculated critical load values**

Results show that calculated critical loads for nitrogen for habitat types are often outside the empirical critical load ranges for the EUNIS type to which the habitats belong. For example, calculated CLNmax for bogs, fens, open sand and various forest types are higher than the empirical critical loads. This is a shortcoming in the modelling, as the empirical critical loads often are based on information on species loss or vegetation changes which also should be the basis of the modelling. A similar problem was identified when using critical loads calculated with the SMART model (Dobben et al., 2014). As empirical values are broadly accepted, and the model results are considered as a further specification, Dobben et al. (2014) used modelled critical loads only when ranges overlapped. In that process, model output was critically screened in view of the shortcomings and uncertainties that exist when modelling certain habitat types. For the submitted CLeutN a similar check with CLempN was made. However, for the CLNmax, this check has not yet been performed as delivering this unchecked raw data enables a better comparison with data from other countries. In addition, shortcomings in VSD+ modelling or parametrization can easier be identified.

Results show that the model is very sensitive to N input by litter production ($N_{lf}$). In various cases, no possible CL(N) could be calculated, because input by litter was already higher than the maximum N availability (CLeutN < 0). In such cases, $N_{lf}$ is probably overestimated. At the same time, for forests, litter production might be underestimated, since calculated critical loads are often higher than empirical critical loads. This might partly be due to not including the nutrient cycle of the ground vegetation. Another important source of uncertainty might be the ratio between above-ground and below-ground litter production.

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*Table NL-1. CLNmin, CLSmax, CLeutN and CLNmax for all grid cells (mol/ha). The standard deviation is provided between brackets. Number of results per category is also given.*

| Vegetation | | CLNmin | | CLSmax | | CLeutN | | CLNmax | |
|---|---|---|---|---|---|---|---|---|---|
| | Count | Value (stdev) | Count | Value (stdev) | Count | Value (stdev) | Count | Value (stdev) | Count |
| Deciduous forest | 24460 | 507 (124) | 23229 | 6070 (20510) | 19791 | 1749 (704) | 24436 | 2313 (1749) | 23997 |
| Grassland | 25935 | 471 (82) | 24319 | 16594 (31387) | 7419 | 1590 (875) | 25907 | 1192 (1029) | 22266 |
| Heathland | 12231 | 44 (3) | 11284 | 1802 (7421) | 12136 | 968 (218) | 12160 | 923 (378) | 11959 |
| Pine forest | 20975 | 265 (27) | 20576 | 1746 (8410) | 20912 | 1261 (381) | 20973 | 1229 (295) | 20894 |
| Spruce forest | 3557 | 385 (52) | 3470 | 1960 (8134) | 3489 | 1388 (602) | 3557 | 1295 (394) | 3536 |
| TOTAL | 87158 | 368 (179) | 82878 | 4839 (17448) | 63747 | 1460 (704) | 87033 | 1493 (1228) | 82652 |

*Table NL-2. CLNmin, CLSmax,CLeutN and CLNmax for grids within Natura 2000 areas with habitat types (mol/ha). The standard deviation is provided between brackets. Number of results per category is also given.*

| Vegetation | | CLNmin | | CLSmax | | CLeutN | | CLNmax | |
|---|---|---|---|---|---|---|---|---|---|
| | Count | Value (stdev) | Count | Value (stdev) | Count | Value (stdev) | Count | Value (stdev) | Count |
| Deciduous forest | 8643 | 524 (123) | 8483 | 1866 (5876) | 6613 | 1647 (434) | 8643 | 2991 (1128) | 8516 |
| Grassland | 4804 | 488 (52) | 4679 | 10480 (19021) | 427 | 1499 (460) | 4804 | 2128 (1371) | 3597 |
| Heathland | 9201 | 44 (3) | 8550 | 1374 (4228) | 9106 | 1014 (149) | 9200 | 956 (393) | 9076 |
| Pine forest | 147 | 206 (74) | 127 | 4469 (7726) | 132 | 1482 (489) | 147 | 2489 (1949) | 137 |
| Spruce forest | 2 | 387 (0) | 2 | 251 (0) | 2 | 1857 (0) | 2 | 5953 (0) | 2 |
| TOTAL | 22797 | 327 (242) | 21841 | 1837 (6009) | 16280 | 1359 (458) | 22796 | 1977 (1333) | 21328 |

*Table NL-3. CLNmin, CLSmax, CLeutN and CLNmax for grids outside Natura 2000 areas with nature target types (mol/ha). The standard deviation is provided between brackets. Number of results per category is also given.*

| Vegetation | | CLNmin | | CLSmax | | CLeutN | | CLNmax | |
|---|---|---|---|---|---|---|---|---|---|
| | Count | Value (stdev) | Count | Value (stdev) | Count | Value (stdev) | Count | Value (stdev) | Count |
| Deciduous forest | 15817 | 497 (124) | 14746 | 8180 (24518) | 13178 | 1805 (809) | 15793 | 1940 (1910) | 15481 |
| Grassland | 21131 | 466 (88) | 19640 | 16973 (31954) | 6990 | 1611 (943) | 21103 | 1012 (836) | 18669 |
| Heathland | 3030 | 44 (3) | 2734 | 3087 (12834) | 3030 | 825 (315) | 2960 | 819 (307) | 2883 |
| Pine forest | 20828 | 266 (26) | 20449 | 1728 (8411) | 20780 | 1259 (380) | 20826 | 1221 (228) | 20757 |
| Spruce forest | 3555 | 385 (52) | 3468 | 1961 (8136) | 3487 | 1388 (602) | 3555 | 1293 (378) | 3534 |
| TOTAL | 64361 | 383 (147) | 61037 | 5868 (19808) | 47465 | 1496 (769) | 64237 | 1324 (1143) | 61324 |