Manaaki Whenua
Landcare Research

Spatial nitrate leaching extent: an update for environmental reporting

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Spatial nitrate leaching extent: an update for environmental reporting

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1 Introduction and objectives

The Environmental Reporting Act 2015 aims to improve national environmental reporting in New Zealand. For this project, we are focusing on land-based activities putting pressure on water quality. In the Environment Aotearoa 2015 (Ministry for the Environment and Statistics New Zealand 2015) and the freshwater environment report 2017 (Ministry for the Environment & Stats NZ 2017), a map of nitrate leaching was produced based on nitrate leaching estimates using the OVERSEER® model version 5 and land use data for 2011. Trends of nitrogen leached from agricultural soils were also modelled between 1990 and 2012.

For this project, the Ministry for the Environment contracted Manaaki Whenua Landcare Research to:

- update the nitrate leaching map by adopting the same methodology using the latest available information on land use, land cover and statistics on animal numbers. The aim is to provide nationally representative and consistent information for state of environment reporting.
- create temporal trends in nitrate leaching by region and by livestock between 1990 and 2017.

2 Methods

2.1 Spatial extent

The map of nitrate-N leaching was produced by combining a map of animal numbers and estimates of nitrate leaching rates per animal type (Fig. 1).

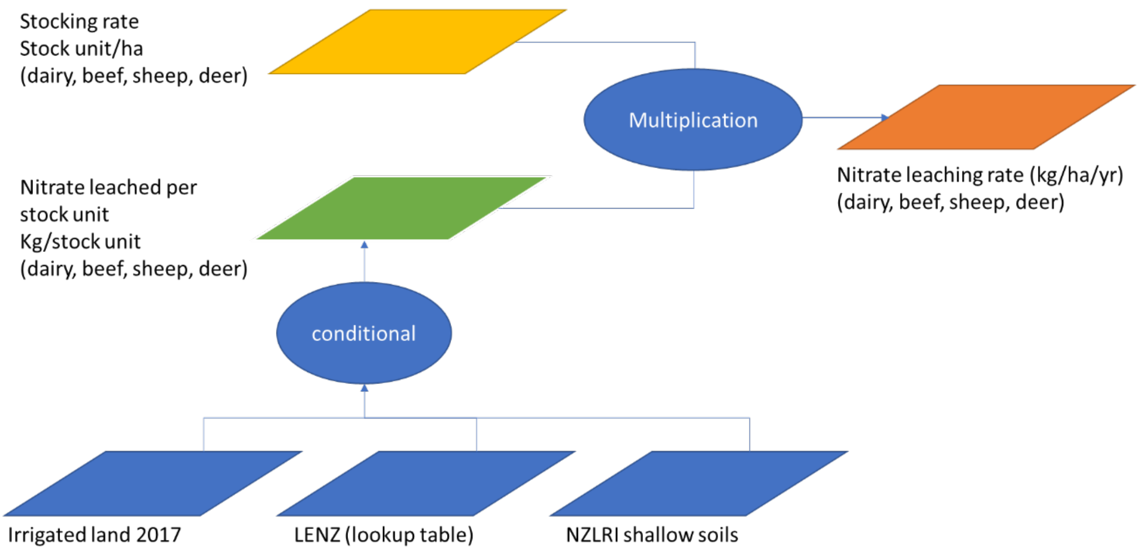

Figure 1. GIS workflow to create the map of estimated nitrate leached per animal type.

Animal numbers were estimated by distributing region-level totals (Statistics New Zealand, 2017a) according to land use and stock-carrying capacity (Landcare Research 1992). We utilized the latest available AgriBase™ (AsureQuality 2018) land use data from May 2018 and LCDB version 4.1 (Landcare Research 2015) land cover data from 2012 for our spatial modelling. In-house scripts and routines were implemented across the AgriBase™ to remove errors and defects. Stocking rate normalization to national stock numbers was based on the Agricultural Production Census 2017 at the regional authority level (Statistics New Zealand 2017a). The census data were mapped to 2017 regional boundaries (Statistics New Zealand 2017b).

Nitrate-N leaching rates per animal type were estimated for 100 unique soil and climate combinations in New Zealand (i.e. LENZ level II: Leathwick et al. 2003) using OVERSEER® (AgResearch 2011). We took into account two modifiers:

- Shallow soils that have twice as much nitrate leached than deep soils.
- Irrigated land that will have different nitrate leaching rates for dairy cows. To identify irrigated areas in our analysis, we rasterized the spatial data set prepared by Dark et al. (2017).

In the absence of a more robust method, nitrate leaching on horticultural and arable land was set to one and two times that estimated for sheep at stock-carrying capacity respectively (Lilburne et al. 2010).

To account for the change of the OVERSEER® version from 5 to 6, we multiplied the estimated nitrate-N leaching results with a correction factor. The models were run using in-house scripts implemented within the ERDAS Imagine GIS software suite. The results for the individual land-use types considered were added to derive the map of total nitrate-N leached at national scale.

2.2 Trends in nitrate leached from soils

The nitrate leaching maps were driven primarily by animal numbers, so regional trends of total nitrate-N leached between 1990 and 2017 were derived from regional statistics of farm animals (Statistics New Zealand 2017a). We updated the temporal trends of total nitrate-N leached for each region between 1990 and 2017, using the same method as Dymond et al. (2013). Regional summaries of the estimated total nitrate-N leached as well of the estimated nitrate-N leached for each individual animal type were derived by summarising the respective raster layer values at the pixel level within the boundaries of each regional authority. Regional boundaries were sourced from the 2017 Digital Boundaries High Def 12 Mile/REGC2017_HD_Full.shp" (downloaded from http://www3.stats.govt.nz/digitalboundaries/annual/ESRI_Shapefile_2017_Digital_Boundaries_High_Def_12_Mile.zip?_ga=2.69037201.1666251474.1550187085-2062439968.1549329717) (Statistics New Zealand, 2017b) then rasterized using GDAL_rasterize function. We used ArcGIS Zonal statistics to calculate regional statistics as a table.

We have assumed that leaching rates per animal are independent of stock density and that average farming practices have not changed significantly between 1990 and 2017.

OVERSEER® runs under different stocking densities showed that nitrate leaching per animal is indeed insensitive to stocking density.

3 Results

3.1 Spatial extent

Figure 2 shows the estimated spatial distribution of nitrate-N leached in New Zealand. There are many areas with leaching rates over 40 kg N.ha^{-1}.yr^{-1}, especially in the Waikato, Bay of Plenty, Taranaki, and along the eastern side of the southern Ruahine and northern Tararua ranges in the Manawatu–Wanganui region. Leaching rates were generally lower in the South Island than in the North Island, with the exception of areas in South Canterbury and Southland, which had many areas over 30 kg N.ha^{-1}.yr^{-1}.

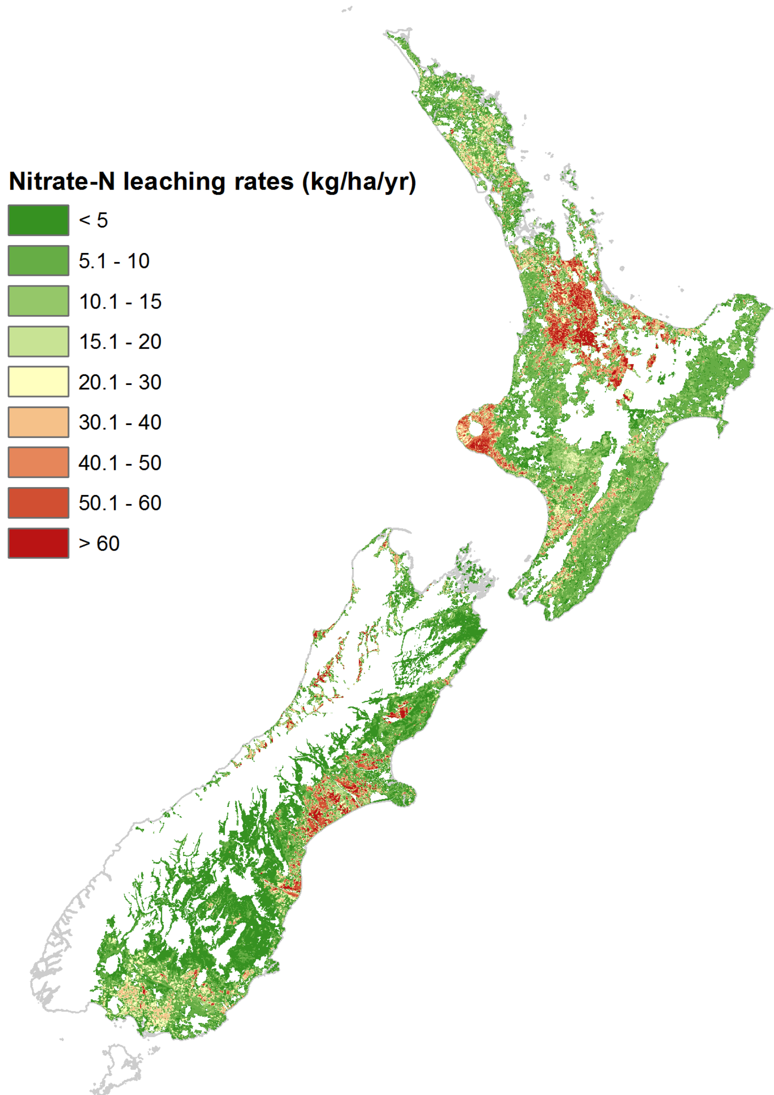

Figure 2. Spatial extent of nitrate-N leached in New Zealand (data sources ranging from 2012–2018).

The spatial extent of nitrate leaching was computed as five separate raster layers representing the total nitrate-N leached as well as nitrate-N leached per individual animal type, i.e. dairy, beef, sheep, and deer (see Appendix 1: list of files associated with this report).

3.2 Trend in nitrate leaching

Figure 3 shows total nitrate-N leached from livestock farming per year for each region between 1990 and 2017. The Waikato region exhibited by far the largest loss of N leached with more than 40 million kg N. yr^{-1} since 1990 but this loss has been reasonably stable since 2005. Canterbury also have large totals of nitrate-N leached at more than 30 million kg N. yr^{-1}in 2017. The graph shows a continued increase in nitrate-N leached in this region until 2013. However, in recent years, a slight reduction of the estimated nitrate-N leached can be observed in Canterbury. Manawatu–Wanganui has a relatively higher nitrate-N leached compared with the remaining regions, but this rate has remained relatively stable over the past 20 years. Southland also shows an increase of nitrate-N leached from 8 to 13 million kg N. yr^{-1}. Other notable trends are the halving of Auckland's total leaching losses (due to a halving of dairy and beef cattle numbers and a three-quarter reduction of sheep numbers) and the decrease of leaching losses in the Bay of Plenty, Gisborne, and Marlborough by about a quarter (Pay of Plenty) to a third (Gisborne, Marlborough) (due to a decrease in beef cattle and sheep numbers).

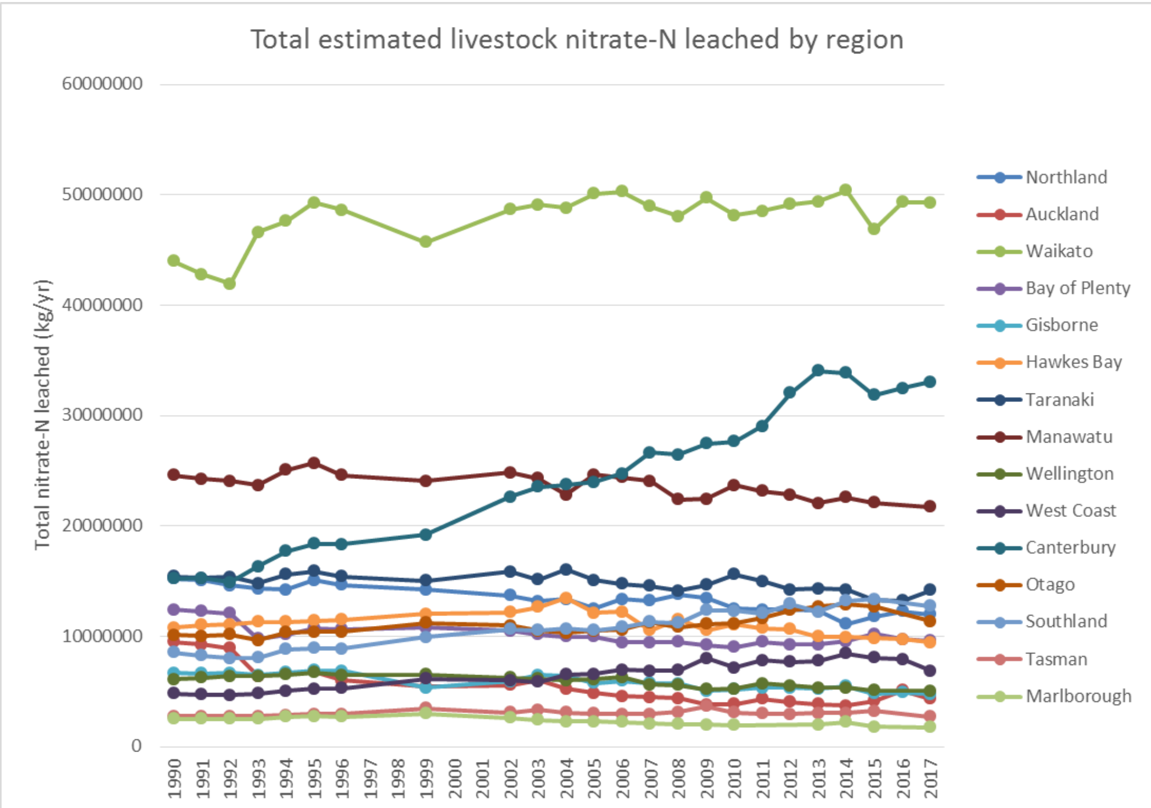

Figure 3. Total livestock nitrate-N leached by region (kg per year) from 1990 to 2017.

Dairy nitrate-N leached, in comparison, is more than 3 times higher than that of beef nitrate-N leached. Although the number of sheep is much higher than the number of beef cattle, the relative nitrate-N leached is at the same level (around 40 million kg per year in 2017). The trends per animal type reflect the trends in livestock numbers since 1990 with a sharp increase in nitrate-N leached in dairy and a decrease in sheep and beef nitrate-N leached (Fig. 4).

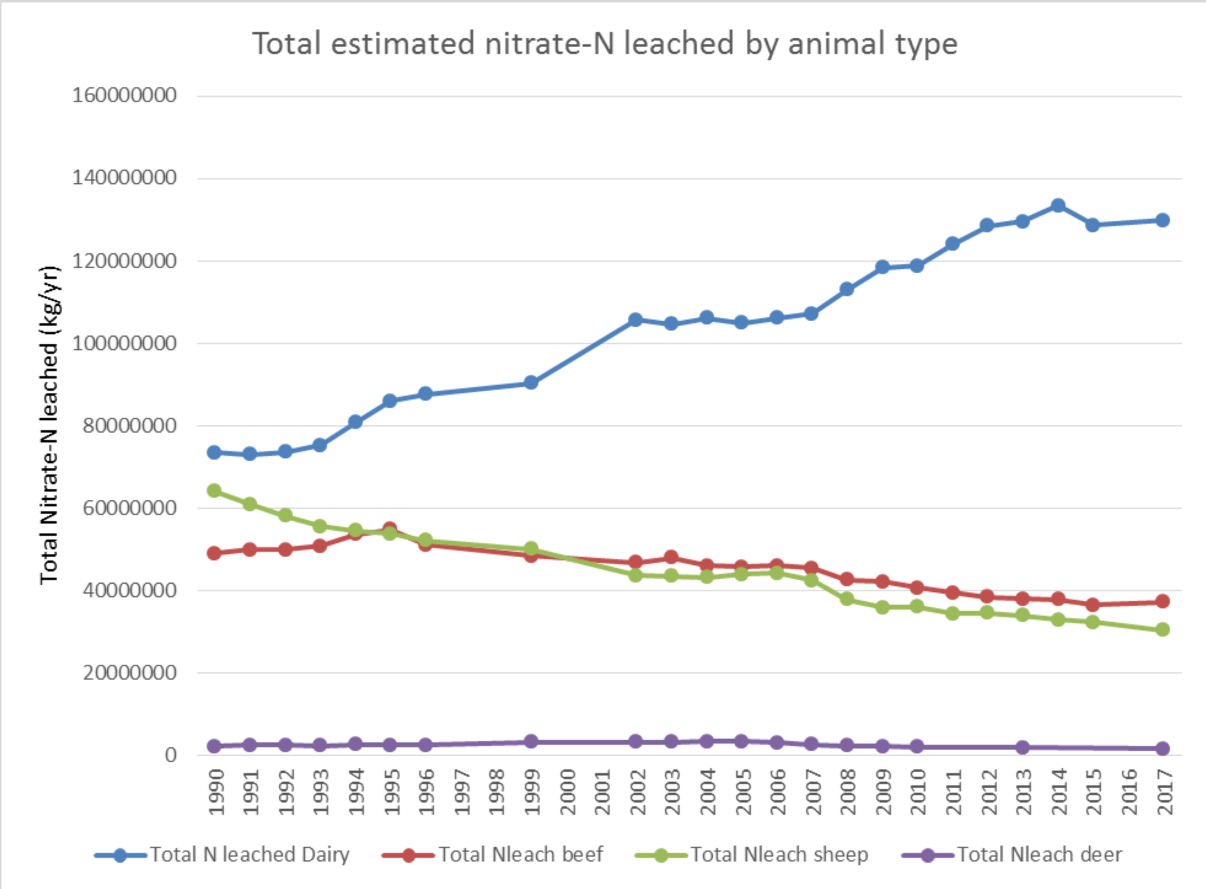

Figure 4. Total nitrate-N leached by animal type from 1990 to 2017.

4 Discussion and recommendations

4.1 Assumptions and Limitations

- We assumed that the relationship used to update to OVERSEER® version 6 was linear across livestock types and region.
- In the absence of data on management practice for all farms in New Zealand, the nutrient leaching maps assume average farmer practices, which we assume to include effective nutrient and dairy effluent management and avoidance of direct excreta connectivity to waterways. The Nitrate leaching per stock unit was calculated by assuming that stocking rates are an average for that particular type of land and land use. For this reason, the maps should not be used to infer leaching for any particular farm. They may be used to predict the general spatial

pattern in a district. To estimate individual farm losses it is necessary to run OVERSEER with the actual stocking rates and management practices applied.

- The animal numbers were distributed on the basis of potential carrying capacity (CCAV). However, this layer assumes no CCAV in tussock grasslands, and as such, no sheep and beef stocks and therefore no leaching have been assigned to these areas. Nitrate leached under tussock grassland is probably low as the stocking rate would be very low, but it should not be null. This also means that the distribution of stocks is spread to other parts of the regions, leading to a possible over-estimation of nitrate-N leached in those areas.

- The irrigation layer 2017 (Dark et al. 2017) was used to identify areas of dairy under irrigation. Based on the reported 'status' field in the dataset, we assumed that all included features in the layer are actually being irrigated.

- The land use map is a combination of LCDB4.1 and Agribase™ version 2018. As LCDB is dated from 2012, we are assuming that there is no change in vegetation cover between 2012 and 2018. Unfortunately, we had to use the latest available date of land cover that didn't match Agribase™.

Limitations of use include:

- The map should **not be used to infer leaching rates for individual farms** as average farming practices are assumed and actual stock numbers per farm were not available.
- The spatial extent of nitrate leaching should be considered as an update from EA 2015 and Our freshwater 2017, and **should not be used for comparing time differences** between this one and previous versions.

4.2 Uncertainty

The accuracy of the nutrient leaching maps can only be as good as the accuracy of the inherent uncertainty in the model, and in the input data. The OVERSEER® model has an accuracy of approximately 25-30% (Parliamentary for the Environment, 2018). The accuracy of the nitrate leaching map was estimated to be ± 25% (Dymond et al., 2013).

Regional values of nutrient leaching will have much less uncertainty because errors will tend to cancel out over large areas, leaving only systematic errors. The uncertainty of the temporal trend is therefore likely to be much smaller, relating to the uncertainty of animal numbers and differences in regional regulation or practices.

4.3 Recommendations

Compared with Environment Aotearoa 2015, the analysis of trends shows a similar pattern across the regions. It is important to note, however, that the Environment Aotearoa 2015 trend analysis is using a different methodology, based on emission factors from the Greenhouse Gas Inventory. These **two analyses are therefore not comparable** in their absolute numbers. From the Environment Aotearoa 2015 report: "estimates of nitrate leached from soil were based on modelled nitrogen excretion and retention for dairy cattle, beef cattle, sheep, and deer using animal population numbers derived from the Agricultural Production Survey. These were combined with default values for other livestock sources. It was assumed that 7 percent of the nitrogen applied nationally is lost from soil as leachate (Thomas et al. 2005). The time series uses calculations undertaken for New Zealand's Greenhouse Gas Inventory, as part of New Zealand's obligations under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. The inventory is a Tier 1 statistic under the New Zealand Official Statistics System."

Recommendations:

- One issue is that AgriBase™ is proprietary, which limits the possibility of releasing a land use map for environmental reporting. We recommend investigating other sources of land use information (including coreLogic). The work led by the LUCAS team could inform land use classes and avoid the limitations imposed by AgriBase™.
- The Environmental Reporting team from MfE needs to decide on the methodology to follow for the trend analysis EA2019, by either retaining the greenhouse gas methodology from EA 2015, or using the one in this report following a quality control process.
- Use the latest LCDB version when it becomes available.
- Improve data inputs where possible through actual animal numbers and farm management practices including mitigation options, while retaining national consistency.

5 References

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Appendix 1 – List of files attached for the Ministry for the Environment

- Nleaching2017.img: Raster layer at 100m. Each pixel represents the estimated nitrate-N leached in kg/ha/yr. This layer contains all nitrate leaching estimated from dairy, sheep, beef, deer, arable and horticultural land.
- Nleachingdairy2017.img and metadataNleachingdairy2017.doc: Raster layer at 100m and associated metadata. Each pixel represents the estimated nitrate-N leached in kg/ha/yr. This layer contains all nitrate leaching estimated from dairy cows.
- Nleachingdeer2017.img and metadataNleachingdeer2017.doc: Raster layer at 100m and associated metadata. Each pixel represents the estimated nitrate-N leached in kg/ha/yr. This layer contains all nitrate leaching estimated from deer.
- Nleachingbeef2017.img and metadataNleachingbeef2017.doc: Raster layer at 100m and associated metadata. Each pixel represents the estimated nitrate-N leached in kg/ha/yr. This layer contains all nitrate leaching estimated from beef.
- Nleachingsheep2017.img and metadataNleachingsheep2017.doc: Raster layer at 100m and associated metadata. Each pixel represents the estimated nitrate-N leached in kg/ha/yr. This layer contains all nitrate leaching estimated from sheep.
- Nleaching2017perregion.csv: total nitrate leaching for each livestock type by region for 2017.
- Temporaltrend1990-2017.csv: temporal trend results in nitrate leaching by region and by livestock type for the period 1990 to 2017.

Appendix 2 – Data dictionary for csv files

Nleaching2017perregion.csv

Variable name	Format	Unit	Variable definition
Total Nleaching	Float	Nitrate-N kg/year	This is the sum nitrate-N leached from spatial layer Nleaching2017.img
NleachingDAIRY	Float	Nitrate-N kg/year	This is the sum nitrate-N leached from spatial layer Nleaching2017.img
NleachingBEEF	Float	Nitrate-N kg/year	This is the sum nitrate-N leached from spatial layer Nleaching2017.img
NleachingSHEEP	Float	Nitrate-N kg/year	This is the sum nitrate-N leached from spatial layer Nleaching2017.img
NleachingDEER	Float	Nitrate-N kg/year	This is the sum nitrate-N leached from spatial layer Nleaching2017.img
Nleaching_livestock	Float	Nitrate-N kg/year	This is the sum nitrate-N leached from spatial layer Nleaching2017.img
Nleaching_other	Float	Nitrate-N kg/year	This is the difference between the sum of nitrate-N leached from livestock (sum of NleachingDAIRY, NleachingBEEF, NleachingSHEEP and NleachingDEER) and total Nleaching. This correspond to nitrate leached from arable and horticultural land

Temporaltrend1990-2017.csv

Variable name	Format	Unit	Variable definition
Region	string		Name of the regional authority
Livestock type	string		Livestock type: dairy cow, beef, sheep or deer
Date	integer		Year (1990 to 2017)
Nitrate-N leached kg/yr	float	Nitrate-N leached kg/yr	Nitrate N-leached for the specified year ("date"), regional authority ("Region") and livestock type ("Livestock type")