N-VISIBLE

A Nitrogen Balance Framework

How to Use Nitrogen Balance to Estimate Nitrous Oxide and Nitrate Losses

Environmental Defense Fund scientists developed two environmental models[1] that calculate nitrous oxide emissions and nitrate leaching using aggregated nitrogen balance, or N balance, scores.[2] These breakthrough models provide a practical and cost-effective way to measure environmental outcomes from agriculture across watersheds and sourcing regions.

February 2021

[1] McLellan et. al (2018); Eagle et. al (2020).

[2] N balance measures how much N is not used by crops in a growing season and thus is vulnerable to being lost to the environment as nitrous oxide and nitrate. Visit edf.org/n-balance for additional information about how to calculate N balance.

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Applying the environmental models

This guide explains how to how to use these models to determine N losses to the environment and measure progress over time. We provide both imperial and metric versions of equations. Be sure to double-check all units and unit conversions.

As with most models, having more observations (in this case, N balance scores) provides more precise and accurate results. To have statistical confidence that a program or project has led to real environmental improvement — reduced nitrous oxide emissions and nitrate leaching — EDF recommends aggregating N balance scores from a minimum of 300 fields together and having three years of baseline data from the same 300 fields.[3] Emissions and leaching from subsequent years can then be compared to the three-year baseline to measure change.

The relationship[4] between N balance and nitrous oxide emissions, expressed in the nitrous oxide model, applies to aggregated groups of fields with most common soil types[5] and annual, non-legume[6] crops that are rainfed and receive commercial fertilizer and manure applications.

The relationship between N balance and nitrate leaching, expressed in the nitrate model, applies to rainfed, annual, non-legume crops receiving commercial fertilizer and grown in tile-drained fields.[7,8]

imperial units[9]

How to determine **nitrous oxide emissions**

Calculate the amount of **nitrous oxide lost to the environment** for each unique field using the following area-based equation.

$$N_2O = 1.25e^{0.0053\,\mathbf{N\ balance}}$$

where ***N_2O*** denotes emissions in units of lbs. N_2O-N/acre/year, and ***N balance*** is N balance in units of lbs. N/acre/year. Using this equation, fields with N balance scores of 25, 75 and 125 lbs. N/acre/year would have average N_2O emissions equal to 1.4, 1.9 and 2.4 lbs. N_2O-N/acre/year, respectively.

metric units[10]

How to determine **nitrous oxide emissions**

Calculate the amount of **nitrous oxide lost to the environment** for each unique field using the following area-based equation.

$$N_2O = 1.40e^{0.0047\,\mathbf{N\ balance}}$$

where ***N_2O*** denotes emissions in units of lbs. N_2O-N/acre/year, and ***N balance*** is N balance in units of kg N/hectare/year. Using this equation, fields with N balance scores of 25, 75 and 125 kg N/hectare/year would have average N_2O emissions equal to 1.6, 2.0 and 2.5 kg N_2O-N/hectare/year, respectively.

[3] In all cases, we recommend looking at N balance data in their context. For example, compare results from an individual year to see if they are consistent with previous years or if other factors like disease or weather caused an anomaly. In many cases, this consideration can be achieved by using a three-year moving average of N balance scores.

[4] McLellan et al. (2018) established the relationship between N balance and both nitrous oxide emissions and nitrate leaching losses from corn on silt loam soils in the Corn Belt. Eagle et. al. (2020) found that nitrous oxide emissions from corn on silt loam soils relate to N balance in much the same way as corn grown on other soils, and the same is true for other rainfed, non-legume crops receiving fertilizer and/or manure N and produced on most common soil types.

[5] The nitrous oxide model may not be suitable for very high clay soils and organic/peat/histosol soils.

[6] Models for estimating nitrous oxide emissions and nitrate leaching from soybean crops, which will allow for estimates of single-crop years and full corn-soybean rotations, are under development in collaboration with Iowa State University and are expected to be complete in late 2021.

[7] Research into extending the nitrate leaching losses model to include other cropping systems, including *Manure_N* and non-tile drained fields, is in progress with partners at the University of California — Davis.

[8] The nitrate equation has been adjusted from that presented in McLellan et al. (2018) to be area scaled and in imperial units (i.e., lbs. N/acre). The published version was in yield-scaled metric units (i.e., kg N per Mg grain).

[9] This equation can also be expressed in imperial units (lbs. N/acre) as $N_2O = \exp(0.224 + 0.0053 \times \text{N balance})$.

[10] This equation can also be expressed in metric units (kg N/hectare) as $N_2O = \exp(0.339 + 0.0047 \times \text{N balance})$.

imperial units[11]

How to determine **nitrate leaching**

Calculate the amount of **nitrate lost to the environment** for each unique field using the following area-based equation.

$$NO_3 = 10.43e^{0.0068\,\textbf{N balance}}$$

where **NO_3** denotes leaching losses in units of lbs. NO_3-N/acre/year, and **N balance** is N balance in lbs. N/acre/year. Using this equation, fields with N balance scores of 25, 75 and 125 lbs. N/acre/year would have average NO_3 leaching losses of 12, 17 and 24 lbs. NO_3-N/acre/year, respectively.

metric units[12]

How to determine **nitrate leaching**

Calculate the amount of **nitrate lost to the environment** for each unique field using the following area-based equation.

$$NO_3 = 11.69e^{0.0061\,\textbf{N balance}}$$

where **NO_3** is leaching losses in units of kg NO_3-N/hectare/year, and **N balance** is N balance in kg N/hectare/year. Using this equation, fields with N balance scores of 25, 75 and 125 kg N/hectare/year would have average NO_3 leaching losses of 14, 18 and 25 kg NO_3-N/hectare/year, respectively.

How to determine — and report on — environmental impacts at scale

The equations above estimate average nitrous oxide emissions and nitrate leaching for a field, and they improve in accuracy when large numbers of fields are aggregated. Because many environmental and management factors affect N cycling, the losses from each individual field can be quite variable. While direct measurements, if feasible, would find exact losses from an individual field to be higher or lower than the average, the high values balance out the low ones, and vice versa, when looking at the group as a whole.

Therefore, individual field-level nitrous oxide and nitrate values must be aggregated over at least 300 farm fields to ensure claims can be made with statistical confidence.

The relationship between N balance and nitrate leaching, expressed in the nitrate model, applies to rainfed, annual, non-legume crops receiving commercial fertilizer and grown in tile-drained fields.

Aggregate total annual N losses to the environment

For every year of available data, multiply each field's nitrous oxide emissions value by its acreage, where the result is expressed in total lbs. N_2O-N emissions/field/year. Total field-level nitrous oxide emissions can also be aggregated to the highest spatial scale of interest. For example, it is possible to calculate total nitrous oxide emissions for a whole farm (multiple fields), a group of supplying farms, or for an entire watershed, region, or other spatial scale of interest by adding together the total emissions (lbs. N_2O-N/year) for all participating fields.

Repeat this for nitrate leaching. For every year of available data, multiply each field's nitrate leaching losses value by its acreage, where the result is expressed in total lbs. NO_3-N leaching losses/field/year. Total field-level nitrate leaching losses can also be aggregated to the highest spatial scale of interest by adding total lbs. NO_3-N leaching losses/year for each participating field.

[11] This equation can also be expressed in imperial units (lbs. N/acre) as $NO_3 = \exp(2.34 + 0.0068\times \text{N balance})$.

[12] This equation can also be expressed in metric units (kg N/hectare) as $NO_3 = \exp(2.459 + 0.0061 \times \text{N balance})$.

Establish a baseline and evaluate improvements

Take the three-year average of calculated nitrous oxide emissions and nitrate leaching to establish a three-year baseline for each type of N losses. In subsequent years, measure improvement by subtracting total losses of nitrous oxide and nitrate from the respective baseline.

Report total annual changes in N losses and/or carbon dioxide equivalents

Companies can report annual sums for both nitrous oxide emissions and nitrate leaching without being duplicative because these values measure different ways that N is lost to the environment. Losses can be reported in either area-or yield-scaled units, but area-scaled is preferable as it more accurately reflects overall losses to the environment, which can be masked by improvements in yield efficiency if reporting yield-scaled values.

Many companies use carbon dioxide equivalent (CO_2e) as a standard unit of measure for greenhouse gas/carbon footprint reporting. Follow the steps below to calculate the carbon dioxide equivalent of direct nitrous oxide emissions — emissions that come directly off a field rather than indirect emissions that occur when nitrate leaches into waterbodies and denitrifies to become nitrous oxide.

1. Multiply total lbs. **N_20-N emissions** by 2.205 to convert to kg **N_20-N**, then divide by 1,000 to convert to metric tons (t N_20-N).[13]

2. Multiply t **N_2O-N** by 1.5711 to convert to t **N_20**/year (1 t **N_20-N** = 1.5711 t **N_20**).

3. Multiply t **N_2O**/year by 265 to convert to t **CO_2e**/year.[14] The result is total t **CO_2e**/year.

References

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[11] This equation can also be expressed in imperial units (lbs. N/acre) as NO_3 = exp(2.34 + 0.0068× N balance).

[12] This equation can also be expressed in metric units (kg N/hectare) as NO_3 = exp(2.459 + 0.0061 × N balance).

[13] 1 metric ton = 1000 kg = 1 Mg (megagram) = 1 x 10^6 g.

[14] 100-yr GWPs ~ $C0_2$:CH_4:N_20 = 1:28:265. (IPCC, 2014).