Chapter (not refereed)

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17 Critical Loads for Nitrogen to Avoid Eutrophication: Assessment of the Mass Balance Approach using the Aber Site, N.Wales.

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The nitrogen critical load to avoid eutrophication has been calculated for a 32 year old stand of Sitka spruce in N.Wales which has been intensively studied for 4 years. Default and measured values for the mass balance equation have been used to calculate a range of probable nitrogen critical load values which have then been compared to the range estimated from methods other than the mass balance approach.

The stand is planted on stagnopodzol soil and receives c. 16 kg N ha^{-1} yr^{-1} in throughfall + stemflow. Estimate of total inputs including dry deposition are c. 25kg N ha^{-1} yr^{-1} (D. Fowler, Pers. Comm.). There are indications that this site is nitrogen saturated as leaching losses are *ca.* 9 kg N ha^{-1} yr^{-1}. In addition, experimental addition of nitrate results in immediate and equivalent increases in nitrate leaching (Emmett *et al.*, 1995).

The mass balance equation used to calculate the nitrogen critical load CL(N) is the one defined in Grennfelt and Thˆrnelˆf (1992).

$$CL(N) = N_{up} + N_{de} + N_i + N_{l(crit)}$$

Nitrogen uptake (N_{up})

N_{up} was calculated using either (i) default values for nutrient to nitrogen ratios for bolewood, (ii) nutrient to nitrogen ratios recorded in the Aber stand (Table 1) or (iii) removal of N in present-day bolewood.

Table 1 *Nutrient to nitrogen ratios in Sitka spruce at Aber and default values.*

Ratio (%)	*Picea sitchensis*[1] (Bong(Carr.)	Default values[2]
Ca:N	0.80	1.2 - 1.5
Mg:N	0.30	0.2
K:N	0.95	0.7
P:N	0.13	0.08 - 0.1

[1] determined from five harvested trees at the Aber site.
[2] from Grennfelt and Thˆrnelˆf (1992).

For approaches (i) and (ii), weathering of nutrients was calculated using the PROFILE model to be 15, 124 and 31 eq ha^{-1} yr^{-1} for calcium, magnesium and potassium respectively. Atmospheric inputs of phosphorus were estimated from bulk precipitation. For base cations, inputs in bulk precipitation were multiplied by a scaling factor to account for aerosol and dust inputs. This scaling factor was calculated from the ratio of inputs of sodium in throughfall + stemflow to that in bulk precipitation. Resulting N_{up} values using the above three approaches were 2.10, 1.10 and 3.80 kg N ha^{-1} yr^{-1}. The low values of N_{up} using the nutrient to nitrogen ratio methods were a result of insufficient present-day inputs of phosphorus to ensure sustainable removal of biomass without depletion of the soil store. However, fertiliser application of phosphorus and potassium is frequently used in UK forestry and will ensure continued production. Assuming application of fertiliser will be carried out, N_{up} estimated from nitrogen removal in bolewood is lower than N_{up} calculated using calcium or magnesium to nitrogen ratios. As the minimum N_{up} calculated should be applied, approach (iii) should be used in CL(N) calculations at this site.

Denitrification (N_{de})

Denitrification at critical load was estimated using three approaches outlined by Grennfelt and Thˆrnelˆf (1992) (i) default values for aerated soils, (ii) Ineson and Sverdrup (1992) and (iii) de Vries *et al.* (1992). This resulted in estimates of 1, 2.4 and 5.2 kg N ha^{-1} yr^{-1} respectively. The moisture factor (f_m) in approach (ii) was set to 0.5 for moist soil. Using the de Vries *et al.* approach, f_{de} was set to 0.5 for sand with gleyic features. Studies in the field indicate that the lower end of this range (1-2 kgN ha^{-1} yr^{-1}) may be more applicable to the site.

Nitrogen immobilisation (N_i) and Nitrogen leaching (N_l)

The default range for N_i is 0 - 3 kg N ha^{-1} yr^{-1}. If N_i is estimated using the total N in soil store and years since last glaciation (11 500 yrs), a value of 2.1 kgN ha^{-1} yr^{-1} is computed.

Critical N leaching has been set to 4 kg N ha^{-1} yr^{-1} (default range 2 - 4 kg N ha^{-1} yr^{-1}) as this is similar to acid grassland leaching losses in the uplands of Wales.

Critical Load for Nitrogen (CL(N))

Comparison of CL(N) using the above values provides a range of values from 7.6 kg N ha^{-1} yr^{-1} using the mid-range default values to 12.3 kg N ha^{-1} yr^{-1} using nitrogen removal in bolewood for N_{up}, 2.1 kg N ha^{-1} yr^{-1} for N_i, 4 kg N ha^{-1} yr^{-1} for N_l and the Ineson and Sverdrup equation to calculate denitrification (2.4 kg N ha^{-1} yr^{-1}). The CL(N) to avoid eutrophication in managed acidic coniferous forest has been estimated by methods other than the steady state mass balance to be 15 - 20 kg N ha^{-1} yr^{-1} (Hettelingh *et al.*, 1992). These values are greater than those calculated here, however N_l in particular may be underestimated in the mass balance approach. Both ranges are below present-day inputs to Aber and thus are in agreement with the experimental data which indicates that this site is nitrogen saturated (Emmett *et al.*, 1995).

References

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