Work Package 1 Task 3:

Provision of input data sets for the testing and application of dynamic models

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Work building on previous contract

Forest surveys : Relations between foliar nutrition and nitrogen deposition

The best way to quantify tree nutrition at a large number of sites is to take foliar samples for chemical analysis. The largest survey of foliage chemistry undertaken in Great Britain in recent years was in 1995 when approximately 60 of the Level I forest condition monitoring plots, located throughout England, Scotland and Wales, were sampled under a European initiative (Stefan *et al*., 1997). To provide as much information as possible, the foliar nitrogen data from the conifer sites in this survey have been combined in Figure 4 with those from the Level II Intensive monitoring plots (Durrant, 2000) and other small surveys undertaken in recent years. Foliar concentrations of >1.8% in Scots pine were found by Aronsson (1980) to increase frost damage but the value of 1.7 % is more widely used to indicate nutrient imbalance in conifers (Gundersen, 1999). The results in Figure 1 show that approximately three quarters of the Scots pine plots had nitrogen concentrations in needles in excess of 1.7 %. Perhaps more significantly, there is a positive relationship (R^2 is 65.2 %, $p < 0.005$) between the estimated nitrogen deposition at the Scots pine plots (taken from the national 5 x 5 km data base for 1995-97) and foliar N concentrations. Thus nitrogen pollution does appear to be a strong contributory factor in causing increased foliar N concentrations at the Scots pine sites. Increases in estimated nitrogen deposition also appear to impact upon foliar N concentrations at the Norway spruce plots (R^2 is 42.6 %, $p < 0.05$), though the effect is less acute and, more crucially, the range of N contents is much lower. Only a quarter of all spruce plots (Sitka and Norway) were above the 1.7% threshold. There was no relationship between nitrogen deposition and foliar nitrogen concentrations in Sitka spruce which is in agreement with work done at Aber under the NITREX programme and at Deep Syke under this Umbrella.

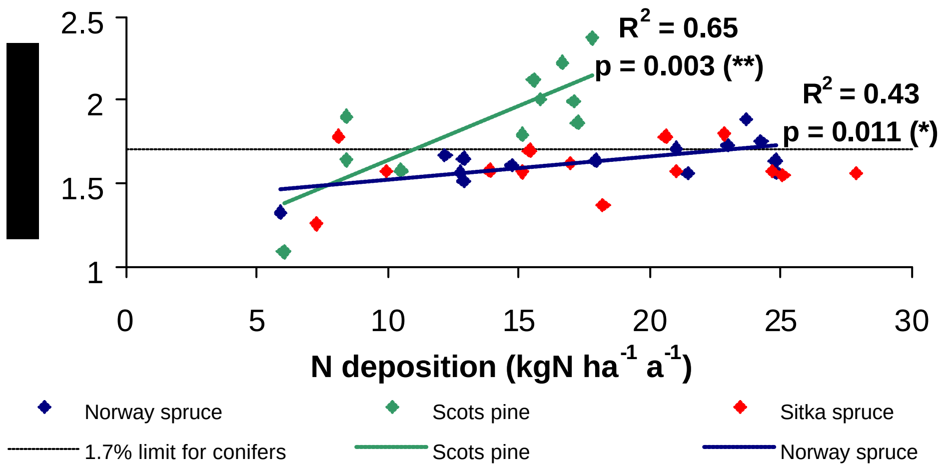


Figure 1. Relationships between nitrogen deposition and foliar nitrogen in three conifer species in GB

There is evidence that the high N concentrations in Scots pine needles are detrimental to forest health in some areas of Great Britain but not others. Figures 2 and 3, derived from forest condition data for the Level I plots during work undertaken during the last Umbrella contract, show both an increased occurrence of insect damage and a reduction in needle retention with increasing nitrogen deposition in Scots pine in Scotland. These relationships did not hold for either Norway or Sitka spruce (with the exception of a very weak decline in needle retention in Norway spruce). However, the relationships in both Figures are, inexplicably, only apparent in Scotland. If the English and Welsh sites are included in the plots both trends disappear and in England and Wales alone, needle retention improves with increasing nitrogen deposition (R^2 is 31.3 %, $p < 0.005$). It is possible that these different responses are due to site quality; broadly speaking the soils in England and Wales are more nutrient rich than those of Scotland. The possibility that nitrogen deposition in Figures 2 and 3 is acting as a surrogate for a temperature effect has been tested and rejected.

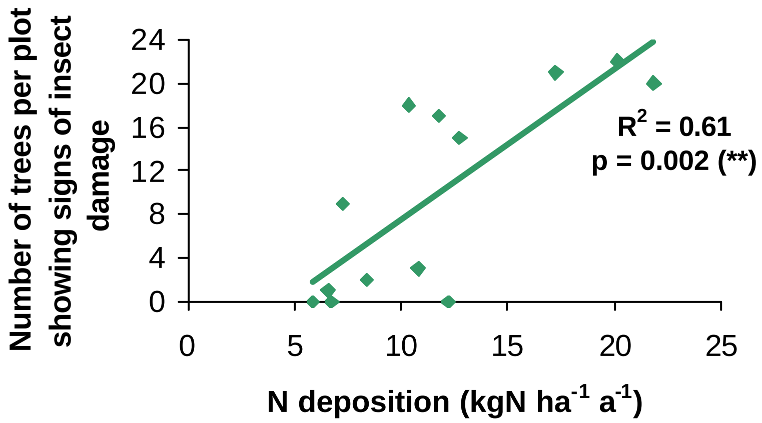


Figure 2. The relationship between nitrogen deposition and the occurrence of insect damage in Scots pine in Scotland in1999. (There are 24 trees assessed in each plot)

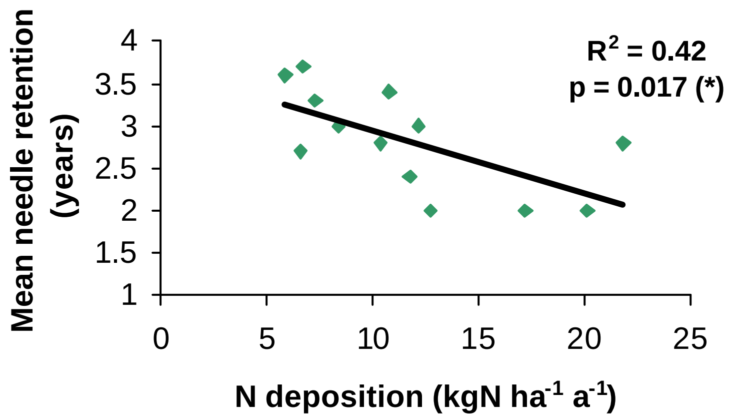


Figure 3. The relationship between nitrogen deposition and needle retention in Scots pine in Scotland in 1999

There is no evidence that nitrogen deposition is damaging the health of broadleaved plots. Both phosphorus concentrations (Figure 4) and N:P ratios increased in line with nitrogen deposition (there were no relationships between foliar P and nitrogen deposition levels in the conifers, in fact foliar P in Norway spruce fell slightly with increased N deposition). Unlike other countries, such as Switzerland where deposition levels have reached as high as 30-40 kgN ha^{-1} a^{-1} and detrimental effects on beech have been observed (Flückiger and Braun, 1998), it appears that nitrogen inputs are having a beneficial effect on broadleaves in England and Wales. It can be speculated that the additional nitrogen has improved root growth and the tree's ability to obtain phosphorus. Whatever the mechanism, there are no detrimental effects of nitrogen deposition on foliar chemistry and consequently no detrimental effects on the forest condition could be found when the oak data were investigated. This is perhaps not surprising as broadleaves naturally have higher nitrogen concentrations in their foliage than conifers and it is conceivable that the same level of nitrogen deposition would be beneficial to broadleaves and detrimental to conifers.

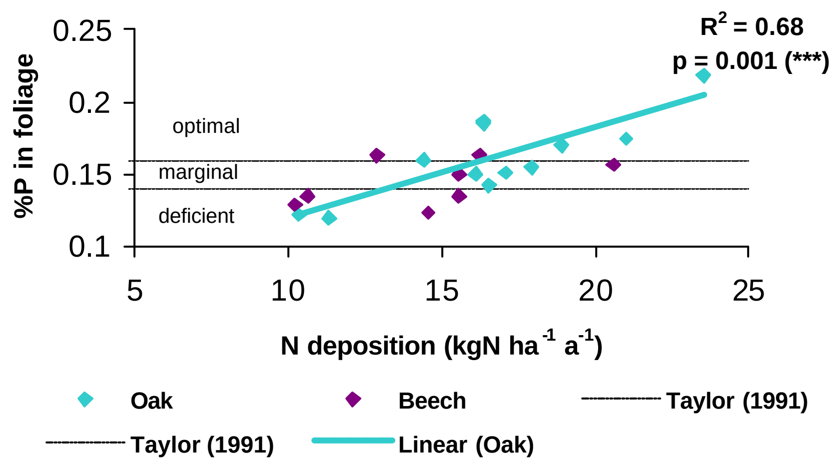


Figure 4. The relationship between nitrogen deposition and foliar phosphorus in oak and beech in England and Wales

In summary, the health of Scots pine in some areas of Scotland is likely to have been detrimentally affected by nitrogen pollution. There is no evidence of detrimental health effects caused by nitrogen pollution in any of the other species investigated except possibly Norway spruce.

Aronsson, A. 1980. Frost hardiness in Scots pine. II. Hardiness during winter and spring in young trees of different mineral status. Stud. For. Suec. 155, 1-27.

Durrant, D. 2000. Environmental monitoring in British forests. Forestry Commission Information Note, November 2000. Forestry Commission, Edinburgh.

Flückiger, W. and Braun, S. 1998. Nitrogen deposition in Swiss forests and its possible relevance to leaf nutrient status, parasite attacks and soil acidification. Environmental Pollution, 102, S1, 69-76.

Gundersen, P. 1999. Nitrogen status and impact of nitrogen input in forests – indicators and their possible use in critical load assessment. Conference on Critical Loads, Copenhagen 1999.

Stefan, K., Fürst, A., Hacker, R., and Bartels, U. 1997. Forest foliar condition in Europe; results of large-scale foliar chemistry surveys. EC-UN/ECE-FBVA, Brussels, Geneva, Vienna, 1997. ISBN 3-901347-05-4

Work on the Current contract

Work Package 1 : Critical loads and Dynamic Modelling

The overall aim of this Work Package is to develop dynamic models that will enable critical loads related scenario analysis on local and regional scales within the UK. Scenarios involving the evaluation of prospects for the recovery of damaged ecosystems are a particularly high priority.

Forest Research is contracted to contribute to Tasks 2 and 3 of this Work Package. These Tasks involve :

1. collating the input data sets with which to test dynamic models,
2. evaluating, and consequently developing, those models that are selected and
3. assisting in data provision for running regional applications towards the end of the contract.

MAGIC, SAFE and VSD are three models that will initially be tested. All three will be assessed for their predictive accuracy regarding both acidity and nitrogen. If the latter is not acceptable then other models, with origins more specifically related to nitrogen (such as PnET), will also be tested. It need not necessarily be the case that one single model will be suitable for all scenarios.

The tasks outlined above will be undertaken using the extensive data sets associated with the UK's Level II Forest Health Monitoring plots (Figure 5 and Table 1). The ability of the models to simulate the deep soil solution chemistry (representing the chemistry of the leachate) recorded at the plots will be tested. The models will be rated in terms of the following:

- Their ability to predict the relative order of long term average chemistry at three or more sites which are known to form a gradient for the output being tested. E.g. in Figure 6, can the models predict the order Llyn Brianne, Ladybower, Thetford for increasing average nitrate concentration?
- Their ability to predict absolute levels of the long term averages of the output being tested across a gradient of sites.
- Their ability to simulate seasonal (if appropriate) and long term time trends observed at individual plots

Figure 5. The locations of the plots for the intensive and continuous monitoring of forest ecosystems under EC regulation 1091/94

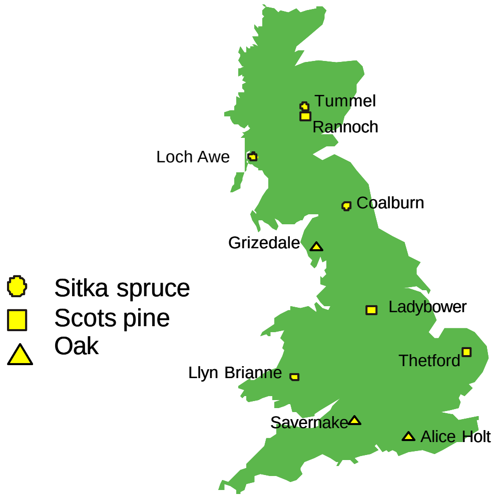
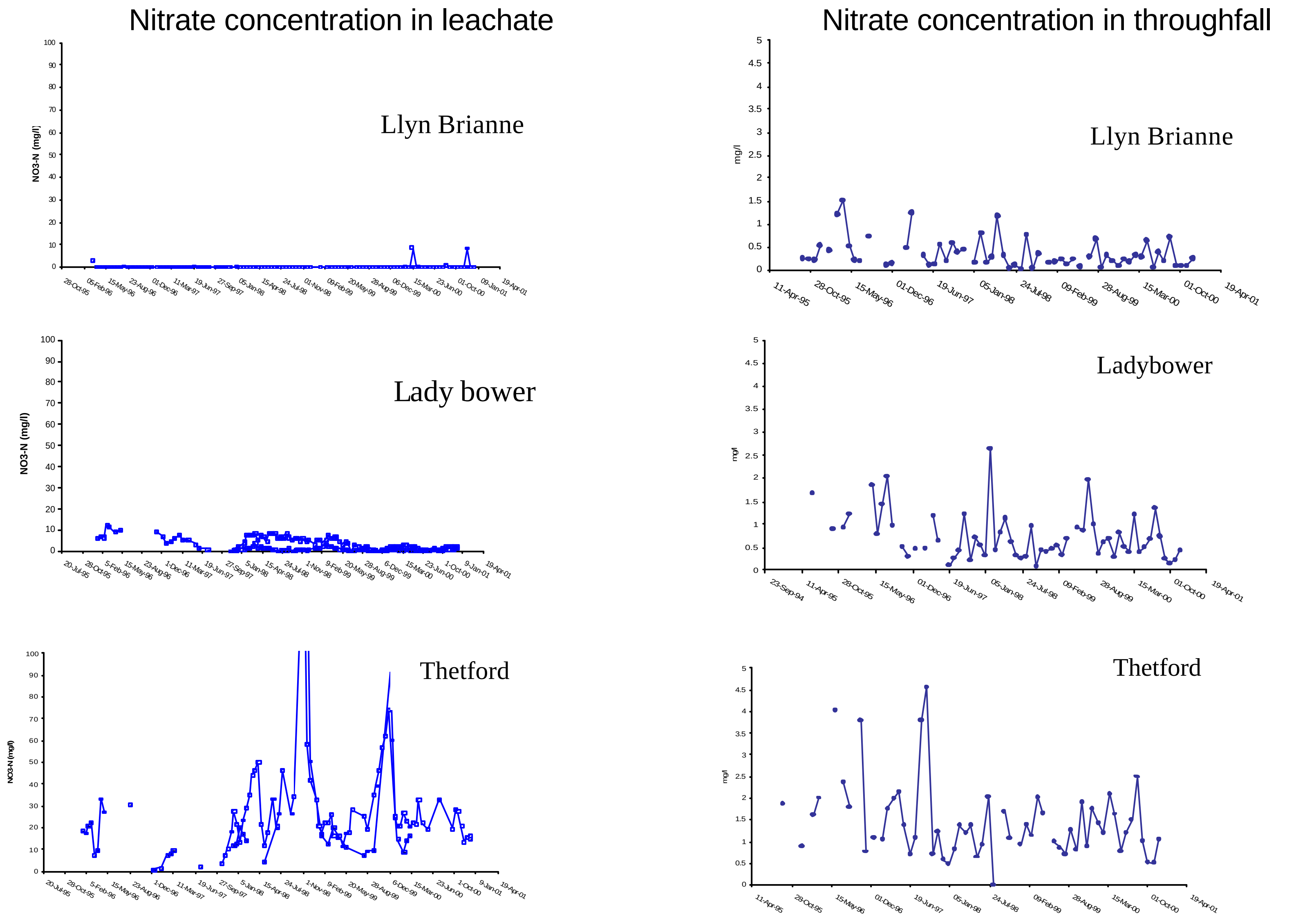


Table 1. Data requirements and availability for running dynamic models at the Forest Health Monitoring sites

	MODELS M (MAGIC) S (SAFE) V (VSD)	Alice Holt	Savernake	Lakes	Thetford	Ladybower	Rannoch	Coalburn	Llyn Brianne	Tummel	Loch Awe
Deposition											
Wet deposition	MSV	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Dry deposition	MSV	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Throughfall	S	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Historic sequences	MS		**6 years**								
Soil properties											
Soil depth	MSV	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
CEC	MSV	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Field moist bulk density	MSV	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Base saturation	MV	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Exchangeable Ca, Mg, Na, K	M	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Porosity	S										
Litter layer/O horizon C:N	MV	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Litter layer/O horizon C pool	MV	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
S adsorption half saturation	(M)										
S adsorption max capacity	(M)										
Soil moisture content	SV	ŏ			ŏ			ŏ			
Soil solution DOC	MS	Since April 02									
Soil solution major ions	M	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	
Soil solution pCO_2	MSV										
Soil solution pH	M										
Soil temperature	MSV	ŏ			ŏ			ŏ		ŏ	
(Apparent) $K_{GIBBSITE}$ **Al and H selectivity constants**	MSV V	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Particle size distribution	S	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Mineralogy	S	ŏ	ŏ	ŏ	ŏ	ŏ	%wt	%wt	ŏ	%wt	%wt
Base cation weathering rates	V	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Hydrology											
Precipitation	MS	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Evapotranspiration	MS	ŏ		ŏ	ŏ			ŏ			
Lateral flow by horizon	(M)										
Evapotranspiration by hzn.	S	ŏ		ŏ	ŏ			ŏ			
Percolation	V	ŏ		ŏ	ŏ			ŏ			
Vegetation											
Forest cover	MS	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Base cation uptake	MSV	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
NO_3 and NH_4 uptake	MSV	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Nitrification	M								ŏ		
Denitrification	MV								ŏ		
N imobilisation	V										
Compartment biomass	S	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Compartment Ca, Mg, N	S	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Deciduous canopy ratio	S	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Litterfall	S	ŏ		ŏ	ŏ		ŏ	ŏ		ŏ	
Mineralisation rate (litter)	S								ŏN		
Mineralisation rate (brash)	S										
Growth curves/sequences	SM										
Planting/harvesting info	SM	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ	ŏ
Compartment removal at harvest	S										

Figure 6.



Nitrate concentration in leachate
Nitrate concentration in throughfall
Llyn Brianne
NO3-N (mg/l)
mg/l
Lady bower
Ladybower
Thetford