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Environmental Monitoring in British Forests

INFORMATION NOTE

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SUMMARY

To gain a better understanding of the effects of air pollution and other environmental factors which affect UK forests, 10 long-term intensive monitoring plots covering three tree species have been established. The plots form part of a European-wide network ('Level II') established under European Union legislation. Data from these plots are being used to support other national environmental research programmes, and will provide information to support wider Forestry Commission objectives of protecting Britain's forests and woodlands and conserving their biodiversity.

INTRODUCTION

1. In the early 1980s, widespread forest decline became a matter of concern for foresters and scientists across Europe. Many countries established surveys to assess the condition of their forests. The Forestry Commission embarked on the first national survey of tree health in 1984 (Binns *et al.*, 1985). This survey has been repeated annually, and currently assesses a total of 8471 trees of five species in 355 plots (Redfern *et al.*, 2000). The results are reported in Information Notes issued by the Forestry Commission.

2. Under initiatives by the United Nations Economic Commission for Europe (UN/ECE), the various national surveys were incorporated into a large-scale pan-European survey of forest condition in 1987. This became known as the 'Level I' programme, with the major aim of monitoring crown condition changes over a long period of time in a large number of forest plots. There are now 15 EU and 19 non-EU country participants in the Level I programme. In total, the crown condition of almost 100 000 trees is assessed annually in around 5400 plots, representing almost 200 million hectares of forest in Europe.

3. The Level I network provides accurate information on the extent and spatial distribution of crown condition in Britain and Europe, and a database for analysis of changes over time. However, it cannot identify cause–effect relationships. It does not determine the extent to which air pollution and other stress factors are responsible for the health, or ill health, of forest systems. To achieve this, a second series of plots for intensive monitoring of forest growth and condition, and the environmental conditions which cause them, was initiated under European legislation in 1994. This is known as the 'Level II' programme (European Commission and ICP Forests of UN/ECE, 1996; Figure 1).

LEVEL II ORGANISATION

4. EU legislation for the Level II programme has required each country to nominate and finance a National Focal Centre responsible for the following tasks:

   - the establishment of a network of permanent intensive monitoring plots;
   - collection, validation and storage of national data;
   - data analysis and evaluation at the national level;
   - data submission to the European Commission;
   - participation in evaluation and interpretation of data at the European level.

   The UK National Focal Centre is based in Forest Research (an agency of the Forestry Commission) and is managed by the Environmental Research Branch.

5. Since 1995, 10 permanent intensive monitoring Level II plots have been installed in Britain in accordance with EU protocols (Figure 2). These represent three important forest species: Sitka spruce (*Picea sitchensis* (Bong.) Carr), Scots pine (*Pinus sylvestris* L.) and oak (*Quercus* spp.). Each plot is 0.3 ha in area and contains a permanent mensuration sample plot of 0.1 ha for growth studies. Monitoring is intended to take place for a minimum of 20 years. A plan of a typical Level II plot is shown in Figure 3.

Figure 1

Geographical distribution of the Level II plots in Europe

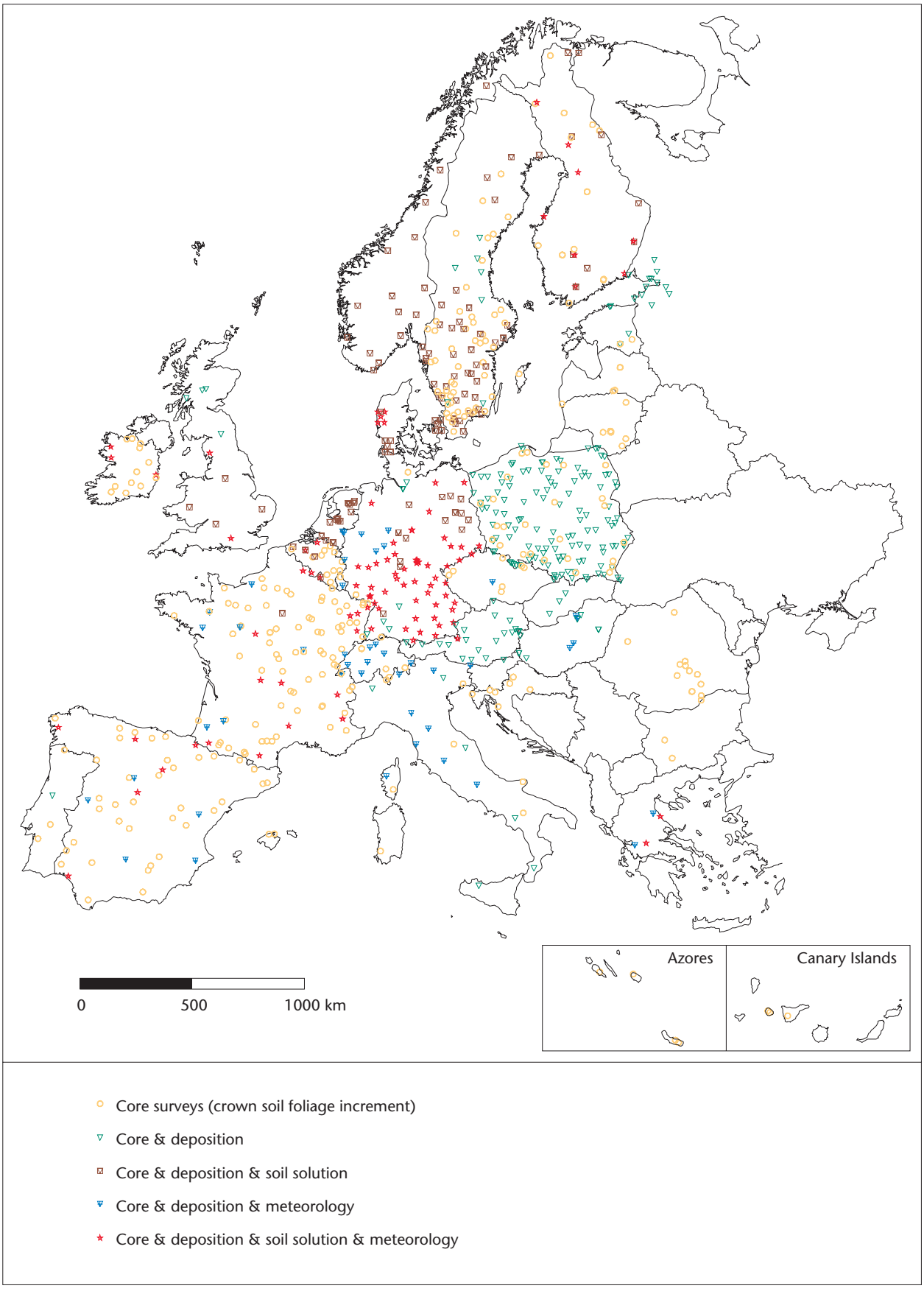

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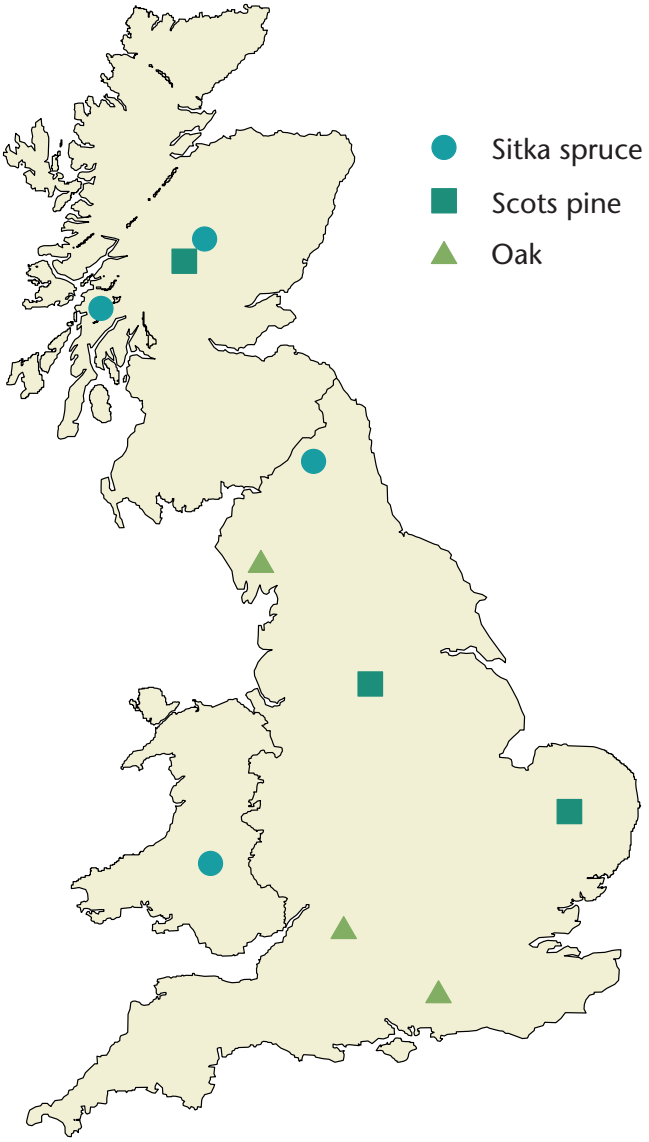
Figure 2

Location of the 10 Level II plots in Britain



6. The Level II network is supported by detailed measurements of a wide range of variables (Table 1) and is a valuable platform for atmospheric pollution research. The pan-European programme has been recently reviewed in depth. The aims of the programme have been broadened to reflect the growing co-operation with other European environmental interests and programmes, including biodiversity, sustainability, climate change and carbon sequestration. Environmental Research Branch is engaged in a range of central and supporting studies of forest ecosystem functioning using Level II data, examples of which are shown in Box 1.

Figure 3

Plan of a typical Level II plot (Grizedale) showing location of monitoring activities

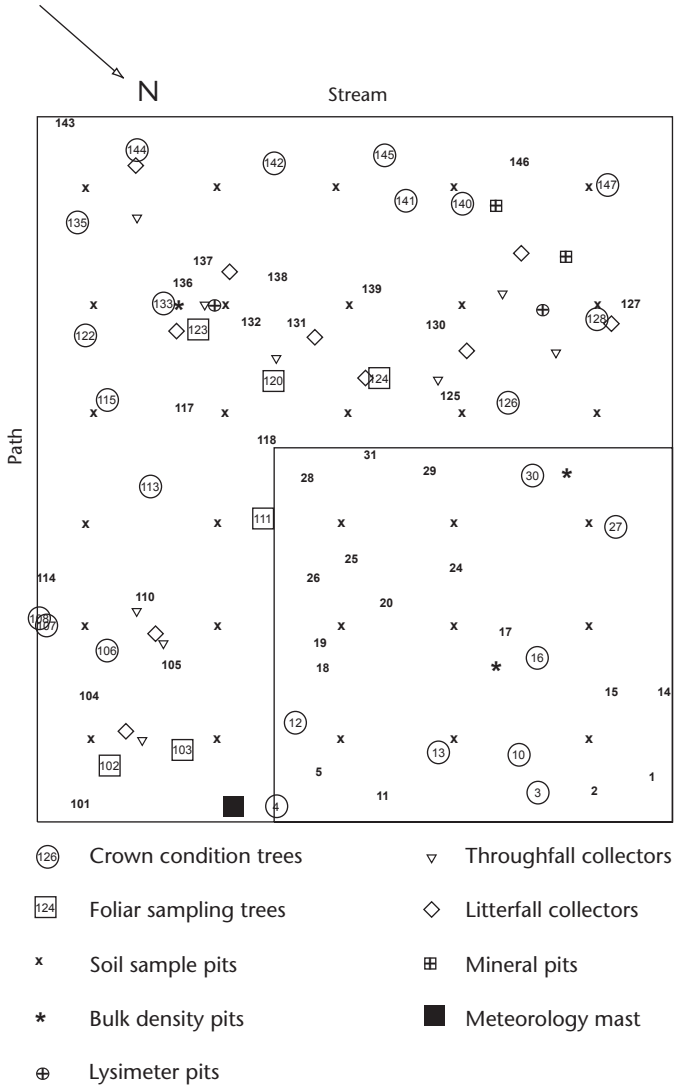


Figure 4 Litterfall collector

Table 1

Main assessments and frequency of measurements in Level II plots

	Number of plots	Starting year	Frequency of sampling
Foliar analysis	10	1995	Annual
Soil analysis	10	1995	10 years
Tree growth	10	1995	5 years
Crown condition	10	1995	Annual
Meteorology	4 4	1994 1995	Hourly (auto) Daily (manual)
Atmospheric deposition	10	1995	2 weeks
Phytopathological observation	10	1996	2 weeks
Ground vegetation	10	1998	3 years
Soil solution analysis	1 3 6	1996 1995 1997	2 weeks 2 weeks 2 weeks
Phenology	10	1998	2 weeks
Litterfall (oak plots) (Figure 4)	2	1998	2 weeks (autumn) 4 weeks (rest of year)

Box 1

Examples of studies involving the use of Level II data

Budget studies	Measurement of input and output of macronutrients, micronutrients and contaminants. Weathering studies on forest soils for the assessment of critical loads and long-term deposition impacts on forests.
Indicators	Identification of parameters that may be used as 'indicators' of sustainable forest management.
Soil/root research	Establishing links between soil acidity and tree root physiology.
Prediction studies	Physiological studies to validate process-based models that are used to predict effects of atmospheric pollution and climate on forest growth.
Protocols and measurement techniques	Development and validation of protocols and measurement techniques in conjunction with the EU and research institutes.
Long-term monitoring	Long-term monitoring studies of change in the forest ecosystem.

EARLY USES OF RESULTS

7. The main objective of the network is to look at change and the causes of change in forest ecosystems over a long time scale. However, some useful results have already been obtained from the data collected and these are outlined below.

Cause–effect relationships for pollutant inputs to UK woodland ecosystems

8. A 'critical load' is a threshold rate of atmospheric deposition beyond which significant damage to the forest ecosystem is considered to occur. Negotiations on European policy to control emissions were first based on critical loads in 1994 (the Second Sulphur Protocol, Oslo). Since then, the concept has been extended and a new Protocol encompassing both sulphur and nitrogen was signed in Gothenburg in 1999. Critical load values for Level II sites have been submitted by the UK National Focal Centre to the UN/ECE co-ordination centre (Hall *et al.*, 1997). In calculating a critical load, assumptions are made about a number of environmental processes, particularly the rate at which nutrients and acidity are deposited and then leached from the soil. Fortnightly collection and chemical analysis of throughfall and soil water is also providing data to test these assumptions (Kennedy, 1997; Kennedy *et al.*, 1998) and refine the methodology for predicting where damage may occur.

Validation of crown density measurements of Level I and Level II networks

9. Due to the density and close spacing of most forest stands in Britain, ride-edge trees within the forest boundary are used in the Level I network of plots for crown density assessments. However, some studies in Europe have shown that differences can occur in crown densities between forest-edge trees and those within the stand. They suggest that trees on the edge of plots may not be representative of the stand as a whole. In Britain, ride-edge trees are not exposed to weather, pollutant deposition and light in the same way as forest-edge trees, but some doubt was raised over the validity of UK crown density assessments. It was thus prudent to investigate the nature of any edge effect.

10. Using standard methods of crown condition assessment and analysis, a study on Scots pine and oak found that there were no significant differences in

crown condition scores between trees growing inside the stand and those growing on a ride or road within the forest boundary. There were no significant differences for any of the other parameters measured, indicating that the current UK practice is unlikely to affect the comparability of the results of the UK forest condition surveys with those of other countries in Europe (Durrant, 1997).

Rainfall and throughfall in Level II plots

11. The accuracy of rainfall measurement depends on a number of factors. The diameter, shape and height of the rainfall collector above the ground have the greatest influence (Neff, 1977; Rodda and Smith, 1985). Measurements of rainfall, canopy interception, throughfall and stemflow are required to calculate pollutant inputs in Level II plots. A rainfall and throughfall collector (Figure 5) was developed at Alice Holt Research Station to comply with European protocols for deposition measurements. To test the accuracy of the design, collectors were installed at Meteorological Station sites, and volumes of rainfall collected were compared with rainfall from a standard Meteorological Office pattern rain gauge. Good agreement was found between the new collector and the standard rain gauge on the sites tested.

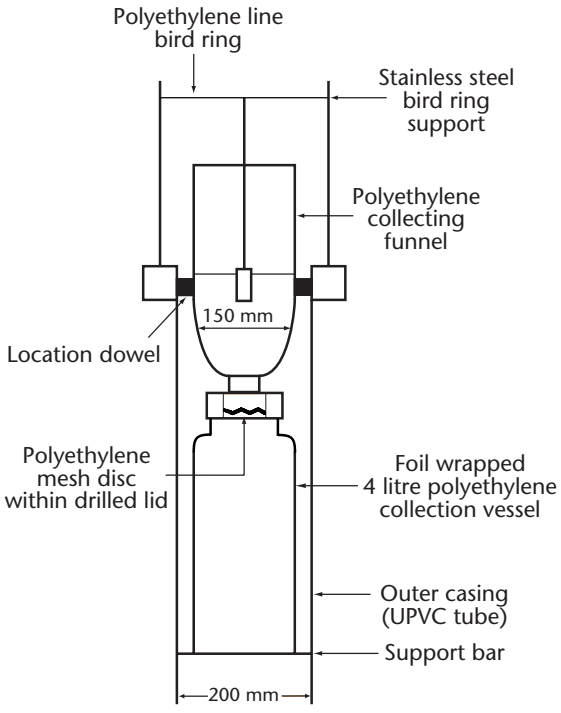


Figure 5

UK Level II rainfall and throughfall collector

12. An important consideration in the measurement of throughfall is to ensure that the results are representative of the plot area. The cost of water collection and analysis limits the number of collectors that can be used at each plot. It is therefore vital that throughfall collectors are installed in sufficient numbers within each plot, and are located so that they sample across the range of throughfall conditions. Consequently, a short project was undertaken to establish collector numbers and positions. At each site, ten collectors were installed under the canopy, with two rainfall collectors placed in an adjacent open area. Twenty additional collectors were installed for short periods and the results analysed statistically to determine the variation within each plot and to ensure that a representative sample was being collected.

Physiological modelling of cause–effect relationships

13. Crown condition provides an indication of the health of forest trees, but on its own it can only give a general indication of forest damage and is unable to separate the detrimental effects of air pollution from other causes of damage. Process based models of tree growth, such as the Forestry Commission individual tree growth model (Randle and Ludlow, 1998; Broadmeadow *et al.*, 1999) may provide a more precise indication of the factors affecting tree health by separating climatic variables from those that may be attributed to air pollution. A pilot project co-funded by the EU is being undertaken in two Level II oak plots in Alice Holt Forest, Hampshire and Grizedale Forest, Cumbria (Figure 6), where detailed measurements of tree growth and climatic variables are being made.

Figure 6

View of throughfall collectors in Grizedale Level II oak plot

CONCLUSIONS

14. The Level II monitoring programme is a vital resource to detect environmental change in UK forests and to provide the means of explaining changes in forest growth. Although a long-term monitoring project, it is already yielding valuable data, and there are opportunities for further ecological studies to be built upon the Level II framework. The plots have been established in working forests under normal forest management, so data also document change due to management practices and provide baseline figures for wider Forestry Commission objectives in conservation, sustainability and biodiversity.

ACKNOWLEDGEMENTS

The Level II project is a good example of interdisciplinary research involving several Branches in Forest Research, and co-operation and support from Forest Enterprise and private forestry. The author is grateful to all who have assisted in the work.

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ISSN 1460-3802
ISBN 0-85538-529-4

PPD/FCIN37/IH(ECD)/21-3K-NOV00