Gisburn Revisited: Lessons from a Long-term Trial of Effects of Afforestation

H A I Madgwick
Rotorua, New Zealand

Abstract

The historical background, establishment and subsequent development of an experiment to determine effects of four tree species on soils are described. Some lessons learned are outlined. It is concluded that an obsession with the question of tree species as soil degraders or improvers needs to be replaced by an emphasis on ecosystem function and on procedures to maintain long-term productivity.

Key words: *experimental design, tree-soil relationships*

Historical background

While the effects of trees on soil has long been a contentious issue there have been few well designed and replicated experiments to study the question. The earliest reference to the subject in New Zealand I have found is a two-page paper by Cockayne (1914). Sixty years later little progress had been made in this country (Will and Ballard 1976).

The Nature Conservancy was established by the British Government in 1949 to undertake research and conservation. One subject of interest was the effect of extensive afforestation, often with introduced species. As a consequence Dr J D Ovington was employed to undertake the necessary research. His first approach was to examine a number of unreplicated species trials on a range of sites. Topics included effects on soil (Ovington 1953, 1954a, 1956, Ovington and Madgwick 1957), understorey vegetation (Ovington 1955), microclimate (Ovington 1954b, Ovington and Madgwick 1955) and nutrient cycling (Madgwick and Ovington 1959). Difficulty in interpreting soil data led to biomass studies in an attempt to obtain a clearer picture of the nutrient demands of afforestation (eg Ovington 1957).

In a parallel development, Rennie (1955) used published data to estimate nutrient demands of forests on nutrient poor soils. The climax was Ovington's establishment in 1955 of a properly designed experiment to examine effects of four species in pure stands and 50:50 mixtures. The upland site, near Gisburn, Yorkshire had previously been used for sheep farming. Choice of site was partly influenced by the fact that the area was a water catchment and the local water engineer was concerned about effects of afforestation on water supply.

THE EXPERIMENT

The experiment involved four tree species: two conifers, *Pinus sylvestris* L. and *Picea abies* (L.) Karst., and two hardwoods, *Quercus petraea* (Mattuschka) Liebl. and *Alnus glutinosa* (L.) Gaertn. These were planted both as pure stands and mixtures. In plots with 50:50 mixtures trees were planted in a checkerboard pattern with each subplot containing six by three trees. The choice of this planting pattern was made in an effort to forestall problems of retaining mixtures as stands developed. Statistical design was a randomised block with three replications. Each plot was 0.2 ha with trees planted at 1.5 m spacing. Each block contained two unplanted plots, one of which was maintained for the existing land use of sheep grazing. At establishment soils and vegetation were sampled for chemical analysis and sheep weights recorded. While this assessment was carried out by the Nature Conservancy, the experiment was a joint responsibility with the Forestry Commission.

SUBSEQUENT DEVELOPMENT

Personnel changes

Three years after the experiment was established Dr Ovington went to North America on sabbatical leave. Soon afterwards a new research leader was appointed and the team which had set up the experiment had dispersed. When Dr Ovington returned to Britain he was posted to a new research station near Cambridge and the Gisburn experiment remained outside his jurisdiction. In 1965 Dr Ovington left Britain to take up the position of professor in Canberra. Mr A H F Brown actively pursued research on the site with reduced resources. He has now retired and his position remains unfilled.

Changes in research emphasis

Some time after the experiment had been established it was decided that the sheep grazed plots were too small and sheltered to be truly representative of the original land use. Because of this, several subsequent studies concentrated on comparisons among forested plots. Soil heterogeneity in one block caused problems. This heterogeneity and the magnitude of the task in sampling all plots meant that several investigations involved only one or two of the original replicate blocks.

Windthrow became a serious problem in several plots and the site was clear felled in 1988. Conifers have been re-established by planting and hardwoods by coppicing maintaining the original experimental design. It would appear that the current policy is one of maintenance as opposed to active research.

Research results

Research results can be divided into three categories dealing with physical, chemical and biological effects of afforestation (table 1). Summarising results so drastically means they have been oversimplified. Brown (1992) gives a more detailed overview of results. A full bibliography covering the experiment is included with the references.

It may be concluded that effects of trees on soil chemistry were small, at least as assessed by analytical techniques developed in agriculture. However, unpublished work on growth of plants in soil collected from the various plots suggests that effects of trees on soils have been greater than suggested by conventional soil testing (A H F Brown, personal communication). Large differences between species have occurred in a number of soil biological characters. In the organic layer, conditions under alder now approach a mull, while under oak there is a mor (Brown 1992). Understorey vegetation and soil fauna both vary widely depending on the overstorey species. Mixtures often have had effects which were not the average of conditions under the respective pair of pure stands (Brown 1982, 1992).

Table 1: Summary of research findings

Subject	Age (years)	Order of species	Reference
Physical factors			
Depth of litter layers	32		Moffat and Boswell 1990
L		O>G>P>A=S	
F		P>S>O>G>A	
H		P>A>S>G>O	
Soil temperature	23		Howson and Brown 1979
Surface		U>O>A>P>S	
5 cm		O>P>S>U>A	
Light intensity	25	A>O>P>S	Brown 1982
Chemical factors			
Soil pH of Ah horizon	32	G>O>A=S>P	Moffat and Boswell 1990
Loss of ignition of Ah	32	A>P>O>G>S	Moffat and Boswell 1990
Throughfall chemistry	31	P=S>A=O	Brown and Iles 1991
Drainage chemistry	31	A>O,P>S	Brown and Iles 1991
Forest floor effects		A>O,P,S	
Soil effects			
Organic matter 'quality'	29	A>P>S>O>U	Brown 1992
Biological factors			
Agaric sporophores	20		Brown 1978
Mycorrhizal		P>O>>A>S	
Decomposers		S>>P>>O>A	
Understorey vegetation	25	Complex	Brown 1982
Soil fauna			Brown 1992
Lumbricid worms	26	A>P>S>O	
Enchytraeid worms	28	P>S>A>O	
Competition	26	–	Brown 1992
	33	–	Yanai 1992
Decomposition			
Cotton strip assay	23	Complex	Brown 1988, Brown and Howson 1988, French 1988, Howson 1991

Note: A, alder; G, grazed; O, oak; P, pine; S, spruce; and U unplanted. 'Order of species' is a ranking based on magnitude of species effects. 'Complex' indicates that effects were not easily summarised. For 'Competition', ordering of species by effects is inappropriate

Discussion

The history of the Gisburn experiment illustrates a number of points which are pertinent to the theme of this meeting.

THE NULL HYPOTHESIS

We have come a long way from the time when the question was asked, is this species a soil degrader or improver? Consider the range of sites on which *Pinus radiata* is grown–from young sand dunes to old fertilised, improved pastures. Such a range precludes a simple answer–even if we understood what was meant by the terms 'improver' and 'degrader'. Perhaps a better question is, can growth of a particular species be maintained in the long term without loss of productivity and given changes in genetic make-up of planting stock and in silvicultural practices? Others will want to know how plantations might affect values such as runoff amount and quality or populations of native plants and animals. I suggest that it is necessary to sharply define the null hypothesis one wishes to test. The null hypothesis will go a long way to providing answers to design criteria such as the number of sites to be selected, plot size and silvicultural treatment. Using Gisburn as an example, a comparison between trees and sheep was invalidated because the presence of trees affected the grazed plots. Grazed plots were of insufficient size.

CHANGES IN RESEARCH OBJECTIVES

Also emphasised from the experience of Gisburn is that research objectives as they were originally envisaged may be superseded. Publications, especially in the open press, have tended to concentrate on effects of mixtures. Sound basic design has allowed the experiment to be used in ways not originally planned.

CHOICE OF SPECIES

Preliminary research on species trials had indicated a wide range of effects especially among conifers. At Gisburn political constraints limited the choice of species. *A. glutinosa* had not been included in the species trials examined but is native to Britain. Oak, Norway spruce and Scots pine had exhibited only a small fraction of the range of conditions to be found under the 17 species examined in different species trials. Certainly two conifers could have been chosen which would have demonstrated a much wider range of influence on the site. When choosing species we should ask whether we wish to determine effects of specific species or whether we are interested in the range of effects which may be obtained by conversion from a previous land use to forestry.

EXPERIMENTAL DESIGN

The decision to use four species in both pure stands and mixtures at Gisburn resulted in 12 treatments per block. The consequent workload stretched fieldwork resources and overwhelmed the capacity of the analytical section so that many samples remain which have not been analysed chemically. In retrospect it has been suggested that a minimum of four, and preferably five, replicates would have been preferable (A H F Brown, personal communication). Five replicates would have necessitated omitting either one species or all species mixtures if the total number of plots was held approximately constant.

SITE SELECTION

Gisburn represented upland marginal grazing lands which are being converted to forestry, though the species chosen did not reflect those used in current forest practice on such sites. Preliminary work was undertaken to select a uniform site. However, difficulties arose later because one block proved to be on heterogeneous soils. Block by species interactions became important (Moffat and Boswell 1990).

RESOURCE ALLOCATION

Perhaps the most serious problem raised by the Gisburn experiment concerns resource allocation. Major factors include changing attitudes of politicians, research administrators and scientists. Restructuring of the Nature Conservancy and changes in both personnel and fashions in research occurred over the life of the experiment. Loss of Dr Ovington's involvement in the experiment meant loss of the major driving force. He had built up a dedicated research team which had demonstrated its ability to handle the workload imposed by the Gisburn experiment in initial sampling, albeit aided by an exceptional British summer. Members of his team either left or were relocated within the Nature Conservancy. It was hardly likely that another researcher taking over control of the experiment would assume the same degree of commitment. It is a credit to the dedication of Mr Brown that so much was achieved in spite of the reduced resources available to him.

In a wider context major changes in attitudes to research funding over the past 40 years must also be considered. An emphasis on contract research and short-term funding would make embarking on a project such as the Gisburn experiment a hazardous enterprise. I wonder whether current thinking about research directed to the public good extends to understanding long-term effects of trees on soil.

In conclusion I believe we should reassess the worth of being obsessed with the question, is a given tree species a soil improver or degrader? It may be claimed that we have moved beyond this question already. However, it remains a frequent concern in the lay press, especially where afforestation with conifers is concerned. Titles of recent research publications indicate a strong bias towards focusing on effects as opposed to mechanisms. I submit our aim should be to understand functioning of forest ecosystems. Given the key parameters of a species, we need to be able to predict ecosystem development and to be able to determine how to maintain site productivity. In any event, effects of silvicultural operations are likely to be more important than tree species *per se* (Madgwick 1994). In retrospect the main advantage of the Gisburn experiment has been as a focus for research. Much more has been accomplished there than was envisaged when work began in the early 1950s.

Acknowledgments

I wish to thank Mr A H F Brown for considerable help without which this paper would have contained less information and more errors of memory. He graciously allowed me sole authorship. As a retired scientist he is no longer under pressure to publish, while I am left free to make personal comments for which I bear full responsibility. It has been Hugh's dedication to the Gisburn experiment which has enabled Dr Ovington's original vision to bear fruit. Thanks are also extended to Dr Juliet C Brown of the Institute of Terrestrial Ecology for her assistance in providing copies of publications and for enabling me to renew contacts with Hugh Brown.

References

Brown, A H F. 1978. The Gisburn experiment: effects of different tree species on the activity of soil microbes. In *Annual Report of the Natural Environment Research Council 1977* pp 41–42.

Brown, A H F. 1982. The effects of tree species, planted pure and in mixtures, on vegetation and soil at Gisburn. In *Annual Report of the Natural Environment Research Council 1981* pp 74–75.

Brown, A H F. 1988. Discrimination between the effects on soils of 4 tree species in pure and mixed stands using cotton strip assay. In *Cotton Strip Assay: An index of decomposition in soils* (eds A F Harrison, P M Latter and D W H Walton) pp 80–85. ITE Symposium No. 24, Institute of Terrestrial Ecology, Grange-over-Sands, England.

Brown, A H F. 1992. Functioning of mixed-species stands at Gisburn, NW England. In *The Ecology of Mixed-Species Stands of Trees* (eds M G R Cannell, D C Malcolm, P A Robertson) pp 125–150. Special Publication No. 11 of the British Ecological Society, Blackwell Scientific Publications, Oxford.

Brown, A H F and Harrison, A F. 1983. Effects of tree mixtures on earthworm populations and nitrogen and phosphorus status in Norway spruce (*Picea abies*) stands. In *New Trends in Soil Biology* (eds P Lebrun, H M André, A de Medts, C Grégoire-Wilbo and G Wauthy) pp 101–108. Proceedings of the VIII International Colloquium of Soil Zoology, Dieu-Brichart, Ottignies-Louvain-la-Neuve.

Brown, A H F and Howson, G. 1988. Changes in tensile strength loss of cotton strips with season and soil depth under 4 tree species. In *Cotton Strip Assay: An index of decomposition in soils* (eds A F Harrison, P M Latter and D W H Walton) pp 86–89. ITE Symposium No. 24, Institute of Terrestrial Ecology, Grange-over-Sands, England.

Brown, A H F and Iles, M A. 1991. Water chemistry profiles under four tree species at Gisburn, NW England. *Forestry* ***64***, 169–187.

Chapman, K. 1986. Interactions between tree species: decomposition and nutrient release from litters. PhD Thesis, Lancaster University.

Christensen, B T. 1982. The effect of afforestation on carbon and nitrogen in the soil at Gisburn: a pilot study. Merlewood Research and Development Paper No. 89. Institute of Terrestrial Ecology, Grange-over-Sands, England.

Christensen, B T. 1982. The effect of afforestation on carbon and nitrogen in the soil at Gisburn: a simple model study. Merlewood Research and Development Paper No. 90. Institute of Terrestrial Ecology, Grange-over-Sands, England.

Cockayne, A H. 1914. *Pinus radiata* plantations. Effect on soil fertility. *New Zealand Journal of Agriculture* ***8***, 409–410.

French, D D. 1988. Seasonal patterns in cotton strip decomposition in soils. In *Cotton Strip Assay: An index of decomposition in soils* (eds A F Harrison, P M Latter and D W H Walton) pp 46–49. ITE Symposium No. 24, Institute of Terrestrial Ecology, Grange-over-Sands, England.

Harrison, A F, Dighton, J and Brown, A H F. 1982. Application of the P-deficiency biomass to trees. In *Annual Report of the Natural Environment Research Council 1981* pp 84–85.

Howson, G. 1991. The cotton strip assay: field applications and global comparisons. In *Advances in Soil Organic Matter Research: The impact on agriculture and the environment* (ed W S Wilson) pp 217–228. The Royal Society of Chemistry, London.

Howson, G and Brown, A H F. 1980. Effects of different tree species on soil at Gisburn. In *Annual Report of the Natural Environment Research Council 1979* pp 107–108.

Lines, R. 1982. Mixture experiments. In *Report on Forest Research, Edinburgh, 1982* pp 13–14. Her Majesty's Stationery Office, London.

Madgwick, H A I. 1994. *Pinus radiata*–biomass, form and growth. Rotorua.

Madgwick, H A I and Ovington, J D. 1959. The chemical composition of precipitation in adjacent forest and open plots. *Forestry* ***32***, 14–22.

Moffat, A J and Boswell, R C. 1990. Effect of tree species and species mixtures on soil properties at Gisburn, Yorkshire. *Soil Use and Management* ***6***, 46–51.

Nicholson, I A, Brown, A H F, Cape, J N, Howson, G, Peterson, I S and Robertson, S M C. 1986. Throughfall and stemflow under different trees. In *Annual Report of the Natural Environment Research Council 1985* pp 94–97.

Ogden, J M. 1986. Some effects of afforestation on soil organic matter. PhD Thesis, Stirling University.

Ovington, J D. 1953. Studies of the development of woodland conditions under different trees. 1. Soils pH. *Journal of Ecology* ***41***, 13–34.

Ovington, J D. 1954a. Studies of the development of woodland conditions under different trees. 2. The forest floor. *Journal of Ecology* ***42***, 71–80.

Ovington, J D. 1954b. A comparison of rainfall in different woodlands. *Forestry* ***27***, 41–53.

Ovington, J D. 1955. Studies of the development of woodland conditions under different trees. 3. The ground flora. *Journal of Ecology* ***43***, 1–21.

Ovington, J D. 1956. Studies of the development of woodland conditions under different trees. 4. The ignition loss, water, carbon and nitrogen content of the mineral soil. *Journal of Ecology* ***44***, 171–179.

Ovington, J D. 1957. The volatile matter, organic carbon and nitrogen contents of tree species grown in close stands. *New Phytologist* ***56***, 1–11.

Ovington, J D and Madgwick, H A I. 1955. A comparison of light in different woodlands. *Forestry* ***28***, 141–146.

Ovington, J D and Madgwick, H A I. 1957. Afforestation and soil reaction. *Journal of Soil Science* ***8***, 141–149.

Rennie, P J. 1955. The uptake of nutrients by mature forest growth. *Plant and Soil* ***7***, 49–95.

Yanai, R D. 1992. Competitive interactions between Norway spruce and Scots pine at Gisburn Forest, NW England. *Forestry* ***65***, 435–451.

Will, G M and Ballard, R. 1976. Radiata pine—soil degrader or improver? *New Zealand Journal of Forestry* ***21***, 248–252.