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A Selected Bibliography

S. Rodhouse and E. R. Wilson

National School of Forestry
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FOREST RESEARCH REPORT 2

Continuous Cover Forestry: A Selected Bibliography

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A project like this inevitably has to set limits and boundaries. While we have attempted to include as many recent and relevant papers as possible we also acknowledge that, to some readers, there will some important omissions or oversights. Such errors and omissions are the responsibility of the authors.

SR and ERW
January 2006

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Front Cover: Natural regeneration of beech (*Fagus sylvatica* L.) at East Wood, near Stokenchurch, Buckinghamshire. This woodland is managed according to principles of continuous cover forestry. A full description of the methods used to promote, protect and sustain natural regeneration is given in Pakenham (1996) [see reference 128 in this report]. Photo: © 2005 Rik Pakenham

Contents

Introduction

Background

Continuous cover forestry (CCF) is a collective term for a wide range of silvicultural systems that lead to or maintain a continuous forest cover over the site being managed. CCF also embodies a philosophy in forest management that works "close-to-nature", emulates natural patterns of disturbance, promotes multiple forest values and, through time, focuses on steady improvements in stand quality. In the vast majority of situations, this approach leads to the development of stands with an irregular structure.

Four guiding principles are central to the practice and spirit of CCF in Britain and Ireland (CCFG 2005):

1. Adapt the forest to the site
   CCF seeks to work with the site and to respect ecological processes and inherent variation rather than impose artificial uniformity. In practice this leads to a presumption towards the use of natural regeneration and the development of mixed-species and mixed-aged stands.

2. Adopt a holistic approach to forest management
   CCF regards the forest ecosystem as the production capital of the forest. This includes the soil, the forest microclimate, associated fungi, flora and fauna as well as the trees themselves. Management for timber production is directed towards the creation, maintenance and enhancement of a functioning ecosystem rather than the periodic creation and removal of individual crops of trees.

3. Maintain forest conditions and avoid clearfelling
   CCF regards the maintenance of forest conditions as an essential tool in achieving its aims. The use of overstorey to influence the amount of light reaching the forest floor, to limit ground vegetation, trigger regeneration and then control its development is crucial. If clearfelling takes place, forest conditions are lost, the benefits of shelter reduced and regeneration becomes more difficult.

4. The growing stock
   Under CCF management, stand improvement is concentrated on the development of preferred individuals rather than the creation of a block of stems with uniform spacing and average stem characteristics. The handling of individuals or groups of stems takes place within the context of the whole growing stock of the stand, the size and composition of which is manipulated to achieve the desired rate of regeneration and to produce the required range of timber products. A characteristic of permanently irregular stands is that yield control is based on measurements of stem diameter and increment rather than area and age.

Other terms associated with irregular-structure forestry, including ‘low impact silvicultural systems’ (LISS) and ‘alternatives to clearfelling’ (ATC), have a narrow technical meaning and fail to account for the wider range of silvicultural, environmental and management concepts implied by the term ‘continuous cover forestry’.

In recent decades, there has been renewed interest in continuous cover forestry on the international scene. Of particular note is the Pro Silva movement (founded 1989), a federation of European foresters who advocate forest management based on natural processes (Pro Silva 2005). In 1991, the Continuous Cover Forestry Group (CCFG) was formed and has since gone on to be the most vocal organisation dedicated to promoting continuous cover forestry in Britain and Ireland. Concurrent developments in North America have seen a growing interest in irregular structure forests, though the term continuous cover forestry is not generally applied in that region. Consequently, a large body of literature has now been published in scientific and professional journals, covering a wide range of topics of direct or indirect relevance to CCF.

This selected bibliography is designed as a practical tool for members of the CCFG. The project arose following discussion within the committee of the CCFG, where it was felt that many members, students and other professional foresters would benefit from an up-to-date compendium of CCF information.

Development of the CCF Bibliography

The bibliography covers a broad range of topics that make specific reference to continuous cover forestry, or deal with related aspects of forest ecology, silviculture and management. The papers were selected for their historic importance, their current scientific relevance or because they contributed to the on-going debate about continuous cover forestry in Britain and Ireland. In making the selection, we focused on species and systems that had application to UK conditions. However, some international papers have been selected where they deal with species employed in Britain or where they articulate theoretical or management issues that apply to CCF in general. As such the bibliography includes books, articles, peer-review papers and technical reports.

It is anticipated that foresters (specifically members of CCFG) will be able to access and use this database in their day-to-day work. The database is structured in three sections in order that it might serve as a useful reference tool. The first comprises a list of papers, organised alphabetically by author and date. A coding system has been developed to aid the reader in deciding on the relevance and importance of any paper. This includes: (1) the main subjects and themes (Table 1); and, (2) the main species mentioned. Species names and codes are provided in Table 2.

The second part of the database consists of abstracts of the majority of papers in the list. This is largely assembled from the CABI “Forest Science” database (CAB International, Wallingford, Oxon.). In a few cases we have used author abstracts or, where missing, produced our own summary of the respective paper.

The third and final part of the database is a coded index of papers by main subject class and species.

Subject Class and Species Codes

1. Subject Class

Subject classes were devised to aid with cross-referencing of papers (Table 1).

Table 1. Key to subject classes identified for cross-referencing in the bibliography.

Subject Class code	Subject areas
C	Concept, philosophy and approaches to continuous cover forestry
E	Economics, financial appraisal and economic modelling
H	Habitat, environment and amenity
M	Management and inventory of forest stands and working groups
P	Pests and damaging agents, including impact of deer and other browsing animals
R	Regeneration, including natural regeneration
SiS	Silvicultural systems, including timing, planning and intensity of designed stand interventions
SD	Stand dynamics, including tree development in forest stands, natural patterns of stand development, competition and response of stands to natural disturbance
W	Wind effects

2. Species Codes

The list of 2-letter (sometimes 3-letter) species codes is adapted from Forestry Commission Management Codes (Table 2). Where the code “xxx” is given, it implies that the paper is of a general nature dealing with a large number of species and/or the species discussed are not commonly found in UK or Ireland.

Table 2. Species names and codes. The codes used in this report are based on Forestry Commission management codes (FC Codes).

Common name	Scientific name[1]	FC Codes
CONIFERS		
Scots pine	*Pinus sylvestris* L.	SP
Caledonian Scots pine	*Pinus sylvestris* L.	SPC
Corsican pine	*Pinus nigra* var. *maritima* (Ait.) Melville	CP
lodgepole pine	*Pinus contorta* Dougl. ex Loud.	LP
Sitka spruce	*Picea sitchensis* (Bong.) Carr.	SS
Norway spruce	*Picea abies* (L.) Karst.	NS
European larch	*Larix decidua* Mill.	EL
Japanese larch	*Larix kaempferi* (Lamb.) Carr.	JL
hybrid larch	*Larix × eurolepis* Henry	HL
Douglas fir	*Pseudotsuga menziesii* (Mirb.) Franco	DF
western hemlock	*Tsuga heterophylla* (Raf.) Sarg.	WH
Wellingtonia	*Sequioadendron giganteum* (Lindl.) Bucholz	WE
coast redwood	*Sequioa sempervirens* (D. Don) End.	RW
western red cedar	*Thuja plicata* D. Don	RC
Lawson cypress	*Chamaecyparis lawsoniana* (Murr.) Parlatore	LC
silver fir	*Abies alba* Mill.	SF
grand fir	*Abies grandis* Lindl.	GF
noble fir	*Abies procera* Rehd. synonym = *Abies nobilis* Lindl.	NF
yew	*Taxus baccata* L.	YEW
other conifer	-	XC
BROADLEAVES		
oak	*Quercus* spp. L.	OK
pedunculate oak	*Quercus robur* L.	POK
sessile oak	*Quercus petraea* (Mattuschka) Lieblein	SOK
red oak	*Qercus rubra* du Roi	ROK
beech	*Fagus sylvatica* L.	BE
sycamore	*Acer pseudoplatanus* L.	SY
ash	*Fraxinus excelsior* L.	AH
birch	*Betula* spp.	BI
downy birch	*Betula pubescens* Ehrh.	PBI
silver birch	*Betula pendula* Roth	SBI
wild cherry	*Prunus avium* L.	WCH
hazel	*Corylus avellana* L.	HAZ
sweet chestnut	*Castanea sativa* Mill.	SC
hornbeam	*Carpinus betulus* L.	HBM
poplar	*Populus tremula* L.	PO
field maple	*Acer campestre* L.	FM
Norway maple	*Acer platanoides* L.	NOM
alder	*Alnus glutinosa* (L.) Gaertn.	AR
common lime	*Tilia × europaea* L.	LI
small-leaved Lime	*Tilia cordata* Mill.	SLI
elm	*Ulmus procera* Salis.	Elm
rowan	*Sorbus aucuparia* L.	ROW
willow	*Salix* spp.	WL
other broadleaves	-	XB

Table 2, continued.

Common name	Scientific name[1]	FC Codes
MIXED SPECIES STANDS		
native mixed broadleaves	-	NBL
mixed broadleaves	-	MB
woody shrubs	-	WSH

[1] Scientific names are taken from: Mitchell, A. 1974. A field guide to the trees of Britain and northern Europe. Collins, London. 416 pp.

The "CCF Hot List"

A "hot list" of ten papers that give a good overview of CCF has been identified by the authors. This is, by its nature, somewhat subjective, but is designed as a useful guide for the forestry practitioner or student who is coming fresh to this topic. The original idea for this hot list came from Gary Kerr (Forest Research).

The ten papers, in alphabetical order, are:

1. Anderson, M.L. 1953. Plea for the adoption of the standing control or check in woodland management. Scottish Forestry 7(2): 38-47

2. Evans, J. 1988. Natural regeneration of broadleaves. Forestry Commission Bulletin No. 78. HMSO, London. 46 pp.

3. Hart, C. 1995. Alternative silvicultural systems to clearcutting in Britain: a review. Forestry Commission Bulletin 115. HMSO, London. 93 pp.

4. Kerr, G., B. Mason, R. Boswell and A. Pommerening. 2002. Monitoring the transformation of even-aged stands to continuous cover management. Forestry Commission Information Note 45. Forestry Commission, Edinburgh. 12 pp.

5. Mason, B. and G. Kerr. 2004. Transforming even-aged conifer stands to continuous cover management. Forestry Commission Information Note 40 (revised). Forestry Commission, Edinburgh. 8 pp.

6. Mason, B., G. Kerr and J. Simpson. 1999. What is continuous cover forestry? Forestry Commission Information Note 29. Forestry Commission, Edinburgh. 8 pp.

7. Matthews, J.D. 1989. Silvicultural Systems. Clarendon Press, Oxford. 284 pp.

8. Oliver, C. D., and B. C. Larson. 1996. Forest Stand Dynamics. Update edition. Wiley, New York, 520 pp.

9. Pommerening, A., and S. T. Murphy. 2004. A review of the history, definitions and methods of continuous cover forestry with special attention to afforestation and restocking. Forestry 77(1): 29-44

10. Yorke, D.M.B. 2001a. Practical Aspects of Transforming Plantations into Continuous Cover Woodlands. Privately published. Copies from: Mark Yorke, Tyddyn Bach, Llanegryn, Tywyn, Gwynedd LL37 9UF. 35 pp.

CCF Archive

In addition to the bibliography, a CCF Archive is being maintained at the National School of Forestry. This will include hard copies of all the papers in the bibliography, wherever possible. The archive will be updated regularly. Students at NSF and Members of CCFG will be able to access the archive and obtain copies of material. Further information can be obtained from the authors or the National School of Forestry research office.

Literature Cited

Continuous Cover Forestry Group (CCFG). 2005. Principles of the Continuous Cover Forestry Group [online]. Last accessed 29 November 2005 at URL: http://www.ccfg.co.uk/principle.html

Pro Silva. 2005. Pro Silva forestry principles [online]. Last accessed 4 December 2005 at URL: http://ourworld.compuserve.com/homepages/J_Kuper/prosilva.htm

Part 1. Complete List of References

No.	Reference	Subject Class	Species code	Abstract
1	Ancelin, P., B. Courbaud and T. Fourcaud. 2004. Development of an individual tree-based mechanical model to predict wind damage within forest stands. Forest Ecology and Management. 203:101-121	W, SD	NS	Yes
2	Anderson, M. L. 1951. Spaced group planting and irregularity of stand structure. Empire Forestry Review 30: 328-341	R, SD, SiS	xxx	Yes
3	Anderson, M.L. 1953. Plea for the adoption of the standing control or check in woodland management. Scottish Forestry 7(2): 38-47	SiS, C	xxx	Yes
4	Anderson, M.L. 1960. Norway spruce-silver fir-beech mixed selection forest. Is it possible to reproduce this in Scotland? Scottish Forestry 14(2): 87-93	SiS, C	NS, SF, BE	Yes
5	Baylis, P., and J. Everard. 1992. Natural regeneration of oak in Normandy. Quarterly Journal of Forestry 86(3): 173-180	R	POK	Yes
6	Bell, S. 1992. Landscape design for irregular forestry. CCFG Newsletter 2: 6-7	H	xxx	No
7	Benecke, U. 1996. Ecological silviculture: the application of age-old methods. New Zealand Journal of Forestry. 41: 27-33	SiS, C	xxx	Yes
8	Black, K., P. Davis, J. McGrath, P. Doherty and B. Osborne. 2005. Interactive effects of irradiance and water availability on the photosynthetic performance of *Picea sitchensis* seedlings: implications for seedling establishment under different management practices. Annals of Forest Science 62(5): 413-422	R, SiS	SS	Yes
9	Blyth, J., and D. C. Malcolm. 1988. The development of a transformation to irregular forest: 35 years experience at the Glentress trial area. OFI Occasional Paper 37. Oxford Forestry Institute, Oxford. p. 33-41	SD, SiS, R	xxx	Yes
10	Bradford, Lord. 1981. An experiment in irregular forestry. Y Coedwigr 33(1): 6-18	SD, SiS, R	xxx	No
11	Cameron, A.D. 2002. Importance of early selective thinning in the development of long-term stability and improved log quality: a review. Forestry 75(1): 35-36	E, SiS	xxx	Yes
12	Clarke, G.C. 1995. Using a spreadsheet to calculate the ideal uneven-aged stand structure. CCFG Newsletter 7: 10-13	M, SiS	xxx	No
13	Crockford, K.J., M.J. Spilsbury and P.S. Savill. 1987. The relative economics of woodland management systems. OFI Occasional Paper 35. Oxford Forestry Institute, Oxford, UK. 64 pp.	E	xxx	Yes
14	Dutton, J.C.F. 1993a, Grey squirrel control in Britain - part 1. Forestry and British Timber 22(9): 30-35	P	BE, SY	Yes

No.	Reference	Subject Class	Species code	Abstract
15	Dutton, J.C.F. 1993b, Grey squirrel control in Britain - part 2. Forestry and British Timber 22(10): 31-35	P	xxx	Yes
16	Edwards, I. D. 1981. Conservation of the Glen Tanar native pinewood, near Aboyne, Aberdeenshire. Scottish Forestry 35(3): 173-178	R	SPC	Yes
17	Evans, J. 1984. Silviculture of broadleaved woodlands. Forestry Commission Bulletin 62. HMSO, London. 232 pp.	SiS, R, SD, M, H, P	xxx	Yes
18	Evans, J. 1988. Natural regeneration of broadleaves. Forestry Commission Bulletin No. 78. HMSO, London. 46 pp.	R	xxx	Yes
19	Fairbairn, W. A. 1963. Some observations on group regeneration. Forestry 36(1): 113-123	SiS, R, W	xxx	Yes
20	Ferlin, F. 2002. The growth potential of understorey silver fir and Norway spruce for uneven-aged forest management in Slovenia. Forestry 75(4): 375-383	SiS, SD, M, R	SF, NS	Yes
21	Forestry Commission. 2004. The UK Forestry Standard: The governments approach to sustainable forestry (2nd Edition). Forestry Commission, Edinburgh. vi + 74 pp.	C, M	xxx	Yes
22	Gadow, K. 2001. Sustainable forest management: theory and applications. Baltic Forestry. 7(1): 2-9	SiS, M	xxx	Yes
23	Gadow, K., J. Nagel and J. Saborowski (eds.) 2002. Continuous Cover Forestry. Assessment, Analysis, Scenarios. Kluwer, Dordrecht, 348 pp.	M, SiS, E, C, H	xxx	No
24	Gadow, K.V., J. Puumalainen. 2000. Scenario planning for sustainable forest management. Pp. In: 319-356. Gadow, K.V., T.U. Plukkala and M. Tome. (eds.) Sustainable Forest Management. Kluwer Academic Publisher, Dordrecht.	SD, SiS, M, E	NS, BE, xxx	Yes
25	Gamborg, C., and J. B. Larsen. 2003. ‘Back to nature’ – a sustainable future for forestry? Forest Ecology and Management 179: 559-571	C, M, H, SiS, SD	xxx	Yes
26	Gardiner, B.A. 1995. The interactions of wind and tree movement in forest canopies. Pp. 41-59. *In* Coutts, M.P. and J. Grace, eds. Wind and Trees. Cambridge University Press, Cambridge.	W, SiS, SD	xxx	No
27	Gardiner, B. A., and B. Marshall. 1997. An investigation into the stability of irregular forests using a wind tunnel. Unpublished report. Scottish Forestry Trust, Edinburgh, 18 pp.	W	xxx	No
28	Gardiner, B.A., and C.P. Quine. 2000. Management of forests to reduce the risk of abiotic damage – a review with particular reference to the effects of strong winds. Forest Ecology and Management 135: 261-277	W, SD, M	xxx	Yes
29	Gardiner, B.A., G.R. Stacey, R.E. Belcher and C.J. Wood. 1997. Field and wind tunnel assessments of the effects of respacing on tree stability. Forestry 70(3): 233-252	W, SiS, SD	SS	Yes

No.	Reference	Subject Class	Species code	Abstract
30	Gardiner, B., B. Marshall, A. Achim, R. Belcher and C. Wood. 2005. The stability of different silvicultural systems: a wind-tunnel investigation. Forestry 78(5):471-484	SiS, W	SS	Yes
31	Garfitt, J. E. 1963. Treatment of natural regeneration. Forestry 36(1): 109-112	R, SiS	AH, SY	Yes
32	Garfitt, J. E. 1977. Irregular forestry in the service of amenity. Quarterly Journal of Forestry 71(1): 82-85	H, SiS	xxx	Yes
33	Garfitt, J. E. 1980. Treatment of natural regeneration and young broadleaved crops. Quarterly Journal of Forestry 74(4): 236-239	R	MBL	Yes
34	Garfitt, J. E. 1984. The group selection system. Quarterly Journal of Forestry 78(3): 155-158	SiS, C	xxx	Yes
35	Garfitt, J. E. 1987. Yield control of irregular woodlands. Quarterly Journal of Forestry 81(3): 181-184	M	xxx	Yes
36	Garfitt, J.E. 1995. Natural management of woods – continuous cover forestry. Forestry Series No. 2. Research Studies Press, Tavistock, Somerset. 152 pp.	SiS, M, R	xxx	Yes
37	Goucher, T. and C. Nixon. 1996. A study of age structure in three native pinewoods in Lochaber. Scottish Forestry 50(1): 17-21	SiS, SD, H, R	SP	Yes
38	Grassi, G., G. Minotta, G. Tonon and U. Bagnaresi. 2004. Dynamics of Norway spruce and silver fir natural regeneration in a mixed stand under uneven-aged management. Canadian Journal of Forest Research. 34(1): 141-149	SD, SiS, R	NS	Yes
39	Grayson, A. J. 2002. Progress towards continuous cover woodland: Ipsden estate. Forestry 75(3): 257-271	E, M	xxx	Yes
40	Hale, S.E. 2001. Light regime beneath Sitka spruce plantations in northern Britain: preliminary studies. Forest Ecology and Management 151: 61-66	SiS, SD	SS	Yes
41	Hale, S.E. 2003. The effect of thinning intensity on the below-canopy light environment in a Sitka spruce plantation. Forest Ecology and Management 179: 341-349	SD,SiS, H, R	SS	Yes
42	Hale, S. 2004. A short note on light measurement. CCFG Newsletter 23: 14-18	R, SD	SS, SP	Yes
43	Hale, S.E., P.E. Levy and B.A. Gardiner. 2004. Trade–offs between seedling growth, thinning and stand stability in Sitka spruce stands: a modelling analysis. Forest Ecology and Management 187: 105-115	R, SD, SiS, M	SS	Yes
44	Hanewinkel, M. 2001. Economic aspects of the transformation from even-aged pure stands of Norway spruce to uneven-aged mixed stands of Norway spruce and beech. Forest Ecology and Management 151: 181-193	SiS, SD, E	NS, BE	Yes

No.	Reference	Subject Class	Species code	Abstract
45	Hanewinkel, M. 2002. Comparative economic investigations of even-aged and uneven-aged silvicultural systems: a critical analysis of different methods. Forestry 75(4): 473-481	E, SiS	SF, NS	Yes
46	Hanewinkel, M. 2004. Spatial patterns in mixed coniferous even-aged, uneven-aged and conversion stands. European Journal of Forest Research 123(2):139-155	M, SiS, SD	xxx	Yes
47	Hanewinkel, M., and H. Pretzsch. 2000. Modelling the conversion from even-aged to uneven-aged stands of Norway spruce (*Picea abies* (L.) Karst.) with a distance-dependant growth simulator. Forest Ecology and Management 134: 55-70	SD, SiS, R	NS	Yes
48	Hann, D. W. 2001. Stability and density management in Douglas-fir plantations. Canadian Journal of Forest Research 31(2): 367-368	M, SD	DF	Yes
49	Harmer, R. 1994a. Natural regeneration of broadleaved trees in Britain. I. Historical aspects. Forestry 67(3): 179-188	R, C	MBL	Yes
50	Harmer, R. 1994b. Natural regeneration of broadleaved trees in Britain: II. Seed production and predation. Forestry 67(4): 275-286	R, P, H	MBL	Yes
51	Harmer, R. 1995. Natural regeneration of broadleaved trees in Britain: III. Germination and establishment. Forestry 68(1): 1-9	R, P	MBL	Yes
52	Harmer, R. and G. Kerr. 1996. Natural regeneration – is more advice needed? Quarterly Journal of Forestry 90(3): 190-196	SiS, R, M	xxx	Yes
53	Harmer, R., G. Kerr and D. Fisher. 1994. The potential for natural regeneration of broadleaves in central southern England. Quarterly Journal of Forestry 88(4): 297-302	R	MBL	Yes
54	Harmer, R., G. Kerr and R. Boswell. 1997. Characteristics of lowland broadleaved woodland being restocked using natural regeneration. Forestry 70(3): 199-210	R, SD, M, P	MBL	Yes
55	Harmer, R., N. Tucker and R. Nickerson. 2004. Natural regeneration in storm damaged woods – 1987 storm sites revisited. Quarterly Journal of Forestry 98(3): 183-190	R, SD	xxx	Yes
56	Harmer, R., R. Boswell and M. Robertson. 2005. Survival and growth of tree seedlings in relation to changes in the ground flora during natural regeneration of an oak shelterwood. Forestry 78(1) 21-32	R, H	POK	Yes
57	Harris, E. 1994. Bradford plan and other systems - can we get a quart out of a pint pot? Quarterly Journal of Forestry. 88(4): 303-308	SD, SiS, C	xxx	Yes
58	Harris, M.J., and M. Kent. 1987a. Ecological benefits of the Bradford-Hutt system of commercial forestry. 1. Ground flora and the light climate. Quarterly Journal of Forestry 81(3): 145-157	SiS, M, H	xxx	Yes

No.	Reference	Subject Class	Species code	Abstract
59	Harris, M.J., and M. Kent. 1987b. Ecological benefits of the Bradford-Hutt system of commercial forestry. 2. The seed bank and the ground flora species phenology. Quarterly Journal of Forestry 81(4): 213-224	SiS, M, H	xxx	Yes
60	Hart, C. 1995. Alternative silvicultural systems to clearcutting in Britain: a review. Forestry Commission Bulletin 115. HMSO, London. 93 pp.	SiS, SD, E, M	xxx	Yes
61	Heitzman, E. 2003. "New Forestry" in Scotland. Journal of Forestry 101(1): 36-39	SD, SiS, C, R	xxx	Yes
62	Helliwell, D. R. 1985. The need for an experimental study of different silvicultural systems. Scottish Forestry 39(1): 8-12	SiS, H, W, E, C	xxx	Yes
63	Helliwell, D.R. 1997. Dauerwald. Forestry 70(4): 375-380	SiS, R, C, SD	SP	Yes
64	Helliwell, R. 2002. Continuous Cover Forestry (2nd edition). Privately published. Copies from Rodney Helliwell, Yokecliffe House, West End, Wirksworth, Derbyshire DE4 4EG	C, SiS, M, R	xxx	Yes
65	Hiley, W.E. 1953. Irregular forestry. Quarterly Journal of Forestry 47(4): 231-237	C, SiS, R, P, M	xxx	Yes
66	Hiley, W. E. 1956. Underplanting of Japanese larch. Quarterly Journal of Forestry 50(3): 189-196	SiS, E, M, W	JL, WH	Yes
67	Hiley, W. E. 1959. Two-storied high forest. Forestry 32(2): 113-116	SiS	xxx	Yes
68	Hodge, S. and H. Pepper. 1998. The prevention of mammal damage to trees in woodland. Forestry Commission Practice Note 3 (FCPN003), Forestry Commission, Edinburgh. 12 pp.	P	xxx	Yes
69	Humphrey, J.W. 2005. Benefits to biodiversity from developing old-growth conditions in British upland spruce plantations: a review and recommendations. Forestry 78(1): 33-53	SD, H	SS	Yes
70	Humphrey, J.W., and M. D. Swaine. 1997a. Factors affecting the natural regeneration of *Quercus* in Scottish oakwoods. I. Competition from *Pteridium aquilinum*. Journal of Applied Ecology 34(3): 577-584	R, SD	POK, SOK	Yes
71	Humphrey, J.W., and M. D. Swaine. 1997b. Factors affecting the natural regeneration of *Quercus* in Scottish oakwoods. II. Insect defoliators of trees and seedlings. Journal of Applied Ecology 34(3): 585-593	R, P	POK, SOK	Yes
72	Humphrey, J. W., R. Ferris, M.R. Jukes and A.J. Peace. 2002. The potential contribution of conifer plantations to the UK Biodiversity Action Plan. Botanical Journal of Scotland 54(1): 49-62	SD, SiS, H	xxx	Yes
73	Hutt, P. A. 1974. 'Bradford plan' continuous cover forest: an experiment in uneven-aged forestry [in the UK]. Timber Grower. 53: 26-27, 29-36	SD, SiS, M	xxx	Yes

No.	Reference	Subject Class	Species code	Abstract
74	Johnston, D.R. 1978. Irregularity in British forestry. Forestry 51(2): 163-169	SiS, SD, C, E	xxx	Yes
75	Jones, E.W. 1945. The structure and reproduction of the virgin forest of the north temperate zone. New Phytologist 44: 130-148	SD, R	xxx	Yes
76	Kenk, G. 1997. Long-term experiment based transition from even-aged to uneven-aged silver fir and pine stands in the Black Forest, southern Germany. Pp. 211-224 *In* Emmingham, W.H., Compiler. Proceedings of the IUFRO Interdisciplinary Uneven-aged Management Symposium. Oregon State University, Corvallis, Oregon, USA	SiS, SD, R, M	xxx	No
77	Kenk, G. and S. Guehne. 2001. Management of transformation in central Europe. Forest Ecology and Management 151: 107-119	SD, SiS, R, M, C	NS, SP, BE, POK, SOK	Yes
78	Kerr, G. 1999a. European silver fir (*Abies alba*) in Britain: time for a reassessment? Quarterly Journal of Forestry 93(4): 294-298	R, SiS, P	SF	Yes
79	Kerr, G. 1999b. The use of silvicultural systems to enhance the biodiversity of plantation forests in Britain. Forestry 72(3): 191-205	C, SiS, H, M	xxx	Yes
80	Kerr, G. 2001a. An improved spreadsheet to calculate target diameter distributions for use in uneven-aged silviculture. CCFG Newsletter 19: 18-20	M	xxx	No
81	Kerr, G. 2001b. Uneven-aged silviculture in Britain. Pp. 34-41 *In* Report on Forest Research 2000-2001. The Stationary Office, Edinburgh.	M, SD, SiS	xxx	Yes
82	Kerr, G. 2002a. The potential for sustainable management of semi-natural woodlands in southern England using uneven-aged Silviculture. Forestry 75(3): 227-243	H, SD, SiS, M	xxx	Yes
83	Kerr, G. 2002b. Uneven-aged silviculture: putting ideas into practice. Quarterly Journal of Forestry 96(2): 111-116	SiS, SD, M	xxx	Yes
84	Kerr, G., and K. O’Hara. 2000. Uneven-aged silviculture: common myths explored. Quarterly Journal of Forestry 94(2): 145-150	SiS, SD, M, H, C	xxx	Yes
85	Kerr, G., B. Mason and R. Boswell. 2003. A sampling system to monitor the transformation from even-aged stands to continuous cover. Forestry 76(4): 425-435	M, R, SiS, SD	xxx	Yes
86	Kerr, G., B. Mason, R. Boswell and A. Pommerening. 2002. Monitoring the transformation of even-aged stands to continuous cover management. Forestry Commission Information Note 45. Forestry Commission, Edinburgh. 12 pp.	M, R, SiS, SD	xxx	Yes
87	Kerr, G., C. Edwards and B. Mason. 2005. Successful CCF from 48p per year! Forestry and British Timber 34(1):16-20	E, M	xxx	Yes

No.	Reference	Subject Class	Species code	Abstract
88	Kirby, K.J. and G.P. Buckley (eds). 1994. Ecological responses to the 1987 Great Storm in the woods of south-east England. English Nature Science Report No. 23. English Nature, Peterborough, UK. 170 pp.	R, SD	xxx	No
89	Knoke, T., and N. Plusczyk. 2001. On economic consequences of transformation of a spruce (*Picea abies* (L.) Karst.) dominated stand from regular into irregular age structure. Forest Ecology and Management 151: 163-179	SiS, E	NS	Yes
90	Knuchel, H. 1953. Planning and control in the managed forest. [translated from German by M. L. Anderson] Oliver and Boyd, Edinburgh. 360 pp. (Chapter 9: Check Method)	R, E, SiS, P, M,	xxx	Yes
91	Long, J. N., T. J. Dean and S. D. Roberts. 2004. Linkages between silviculture and ecology: examination of several important conceptual models. Forest Ecology and Management 200: 249-261	SD	xxx	Yes
92	Low, A. J. 1988. Scarification as an aid to natural regeneration in the Glen Tanar native pinewood. Scottish Forestry 42(1): 15-20	R	SP	Yes
93	Maguire, D. 2005. Uneven-Aged Management: Panacea, Viable Alternative, or Component of a Grander Strategy? Journal of Forestry 103(2): 73-74	SiS, C, M	xxx	Yes
94	Malcolm, D. C. 1971. Corrour management trial. Scottish Forestry 25(4): 262-271	R, SiS, E, M	xxx	Yes
95	Malcolm, D. C., W. L. Mason and G. Clarke. 2001. The transformation of conifer forests in Britain – regeneration, gap size and silvicultural system. Forest Ecology and Management 151: 7-23	SD, SiS, R	xxx	Yes
96	Mason, B. 2001. Challenges to the use of continuous cover forestry in the management of coniferous forests in Great Britain. CCFG Newsletter 18: 36-51	C	xxx	Yes
97	Mason, W.L. 2002. Are Irregular stands more windfirm? Forestry 75(4): 347-356	W, SD, SiS, M	SS	Yes
98	Mason, W.M. 2003. Continuous Cover Forestry: Developing Close to Nature Forest Management in Conifer Plantations in Upland Britain. Scottish Forestry 57(3): 141-149	R, SiS, SD, M, H	SS	Yes
99	Mason, B. and G. Kerr. 2004. Transforming even-aged conifer stands to continuous cover management. Forestry Commission Information Note 40 (revised). Forestry Commission, Edinburgh. 8 pp.	M, SD, SiS	xxx	Yes
100	Mason, W.L., and C.P. Quine. 1995. Silvicultural possibilities for increasing structural diversity in British spruce forests: the case of Kielder Forest. Forest Ecology and Management 79: 13-28	SD, SiS	SS, SP	Yes
101	Mason, B., G. Kerr and J. Simpson. 1999. What is continuous cover forestry? Forestry Commission Information Note 29. Forestry Commission, Edinburgh. 8 pp.	C, SD, R, M	xxx	Yes

No.	Reference	Subject Class	Species code	Abstract
102	Mason, W. L., C. Edwards and S.E. Hale. 2004. Survival and early seedling growth of conifers with different shade tolerance in a Sitka spruce spacing trial and relationship to understorey light climate. *Silva Fennica* 38(4): 357-370	SiS, H, R	SS, SP, EL, DF, WH	Yes
103	Matthews, J. D. 1990. The evolution of silvicultural systems in western and central Europe. Pp 1-18 *In* Gordon, P. (editor) Silvicultural Systems: Proceedings of a Discussion Meeting, Institute of Chartered Foresters, York, 6 – 8 April 1990. Institute of chartered Foresters, Edinburgh. 232 pp.	SiS, SD, H, W, C	xxx	Yes
104	Matthews, J.D. 1989. Silvicultural Systems. Clarendon Press, Oxford. 284 pp.	SiS, SD	xxx	Yes
105	Mayle, B. 1999. Managing deer in the countryside. Forestry Commission Practice Note 6 (FCPN006), Forestry Commission, Edinburgh. 12 pp.	P, H	-	Yes
106	Mayle, B., H. Pepper and M. Ferryman. 2004. Controlling grey squirrel damage to woodlands. Forestry Commission Practice Note 4 (FCPN004), Forestry Commission, Edinburgh. 16 pp.	P	xxx	Yes
107	McIntosh, R. 1995. The history and multi-purpose management of Kielder Forest. Forest Ecology and Management 79: 1-11	C, M, SiS, H	xxx	Yes
108	McNeill, J. D, and D. A. Thompson. 1982. Natural regeneration of Sitka spruce in the Forest of Ae. Scottish Forestry 36(4): 269-282	R	SS	yes
109	Miller, G.R., R. P. Cummins and A.J. Hester. 1998. Red deer and woodland regeneration in the Cairngorms. Scottish Forestry 52(1): 14-20	P, H	ROW, JU, SP, PBI	Yes
110	Miller, K.F. 1985. Windthrow Hazard Classification. Forestry Commission Leaflet No 85. HMSO. London. 11 pp.	SD, M	xxx	Yes
111	Mlinsek, D. 1996. From clear-cutting to close-to-nature silvicultural systems. IUFRO News 25(4): 6-8	SD, SiS, C, M	xxx	Yes
112	Mountford, E.P. 2002 Storm-damage and natural regeneration in Shellem Wood, an ancient semi-natural beechwood in south-east England. Quarterly Journal of Forestry 96(3): 195-204	SD, R, P	BE	Yes
113	Mountford, E. P., and G. F. Peterken. 1999. Effects of stand structure, composition and treatment on bark-stripping of beech by grey squirrels. Forestry 72(4): 379-386	P, SiS, SD, M	BE	Yes
114	Mountford, E. P., and G. F. Peterken. 2000. Natural developments at Scords Wood, Toy's Hill, Kent, since the Great Storm of October 1987. English Nature Research Report No. 346: 27 pp.	R, SD, H	xxx	Yes
115	Mountford, E. P., and G. F. Peterken. 2001. Long-term changes in an area of The Mens, a minimum intervention woodland damaged by the Great Storm of 1987. English Nature Research Report No. 435. English Nature, Peterborough, UK.	R, SD	xxx	Yes

No.	Reference	Subject Class	Species code	Abstract
116	Nixon, C. and E. Cameron. 1994. A Pilot Study on the Age Structure and Viability of the Mar Lodge Pinewoods. Scottish Forestry 48(1): 22-27	SD, H, R	SP	Yes
117	Nixon, C.J., and R. Worrall. 1999. The potential for the Natural Regeneration of Conifers in Britain. Bulletin 120, Forestry Commission, Edinburgh. 50 pp.	R, SiS, E, M, SD	xxx	Yes
118	Nyland, R.D. 1996. Silviculture: Concepts and Applications. McGraw-Hill, New York. 633 pp.	SiS, SD, R, H, P	xxx	Yes
119	Nyland, R.D. 2003. Even to uneven-aged: the challenges of conversion. Forest Ecology and Management 172: 291-300	SiS, M, SD, R	xxx	Yes
120	O'Callaghan, A. 2005. Continuous forest cover: are there worthwhile benefits in an Irish context? Irish Timber and Forestry 14(5): 10, 13	C	xxx	Yes
121	O'Hara, K.L. 1988. Stand structure and growing space efficiency following thinning in an even-aged Douglas-fir stand. Canadian Journal of Forest Research 18: 859-866	SD, SiS	DF	Yes
122	O'Hara, K. L. 2001. The silviculture of transformation – a commentary. Forest Ecology and Management 151: 81-86	SiS, C	xxx	Yes
123	O'Hara, K. L. and R. F. Gersonde. 2004. Stocking control concepts in uneven-aged silviculture. Forestry 77(2): 131–143	SD, M, SiS	xxx	Yes
124	O'Hara, K.L., and N.I. Valappil. 1999. MASAM – a flexible stand density management model for meeting diverse structural objectives in multi-aged stands. Forest Ecology and Management 118: 57-71	M, SD	xxx	Yes
125	Oliver, C.D., and B.C. Larson. 1996. Forest Stand Dynamics. Update edition. Wiley, New York, 520 pp.	SD, SiS, R	xxx	Yes
126	Page, L. M. and A. D. Cameron. 2006. Regeneration dynamics of Sitka spruce in artificially created forest gaps. Forest Ecology and Management 221: 260-266	R	SS	Yes
127	Page, L.M., A.D. Cameron and G.C. Clarke. 2001. Influence of overstorey basal area on density and growth of advance regeneration of Sitka spruce in variably thinned stands. Forest Ecology and Management 151: 25-35	R, SiS, SD	SS	Yes
128	Pakenham, R. 1996. Natural regeneration of beech in the Chilterns. Quarterly Journal of Forestry 90(2): 143-149	R, P	BE	Yes
129	Parsons, R. 2002. Continuous Cover Forestry: Report of the University of Bangor Study Tour to Germany 18-22 March 2002. Scottish Forestry 56(4): 237-240	SD, SiS, H, M, R, E	NS, BE, OK	Yes
130	Paterson, D.B. 1958. A study in stand structure and management of irregular forests. Bulletin 5. Department of Forestry, University of Edinburgh. 53 pp.	SD, M, SiS	xxx	No

No.	Reference	Subject Class	Species code	Abstract
131	Paterson, D.B. 1990. The potential to apply different silvicultural systems to upland British forests, predominately of Sitka spruce. Pp.120-138 *In* Gordon, P. (editor) Silvicultural Systems: Proceedings of a Discussion Meeting, Institute of Chartered Foresters, York, 6 – 8 April 1990. Institute of Chartered Foresters, Edinburgh. 232 pp.	R, SiS, SD, E	SS	Yes
132	Penistan, M.J. 1938. The selection system-irregular silviculture. Quarterly Journal of Forestry 32(1): 51-54	SiS	xxx	No
133	Penistan, M. J. 1952. The alternative to extensive regular clear felling. Scottish Forestry 6(1): 18-22	C, SiS, SD	xxx	Yes
134	Penistan, M. J. 1960. Transforming plantations to forests. Scottish Forestry 14(4): 185-198	C, R, SD	xxx	Yes
135	Penistan, M. J. 1974. The silviculture of beech woodland. Forestry 47(supplement): 71-78	SiS, R, H	BE	Yes
136	Pepper, H. 1999. Recommendations for fallow, roe and muntjac deer fencing: new proposals for temporary and reusable fencing. Forestry Commission Practice Note 9 (FCPN009), Forestry Commission, Edinburgh. 6 pp.	P	-	Yes
137	Peterken, G. F., D. Ausherman, M. Buchenau and R. T. T. Forman. 1992. Old-growth conservation within British upland conifer plantations. Forestry 65(2): 127-144	H, SiS, E, R	xxx	Yes
138	Pommerening, A. 2002. Approaches to quantifying forest structures. Forestry 75(3): 305-324	SD, SiS, H	xxx	Yes
139	Pommerening, A., and S. T. Murphy. 2004. A review of the history, definitions and methods of continuous cover forestry with special attention to afforestation and restocking. Forestry 77(1): 29-44	SiS, SD, P, C	xxx	Yes
140	Poore, A. 1988. British uneven-aged silvicultural systems. OFI Occasional Paper 37. Oxford Forestry Institute, Oxford. p. 2-11	SiS	xxx	Yes
141	Pryor, S. 1990. Practical aspects of irregular silviculture for British broadleaves. Pp. 147-166 *In* Gordon, P. (editor) Silvicultural Systems: Proceedings of a Discussion Meeting, Institute of Chartered Foresters, York, 6 – 8 April 1990. Institute of Chartered Foresters, Edinburgh. 232 pp.	R, SiS, M, C	MBL	Yes
142	Quine, C.P. 2001. A preliminary survey of regeneration of Sitka spruce in wind-formed gaps in British planted forests. Forest Ecology and Management 151: 37-42	W, R, SiS	SS	Yes
143	Quine, C. P., and K. F. Miller. 1990. Windthrow – a factor influencing the choice of silvicultural system Pp. 71 – 81 *In* Gordon, P. (editor) Silvicultural Systems: Proceedings of a Discussion Meeting, Institute of Chartered Foresters, York, 6 – 8 April 1990. Institute of Chartered Foresters, Edinburgh. 232 pp.	M, W	xxx	Yes

No.	Reference	Subject Class	Species code	Abstract
144	Quine, C.P., J.W. Humphrey and R. Ferris. 1999. Should the wind disturbance patterns observed in natural forests be mimicked in planted forests in the British uplands? Forestry 72(4): 337-358	W, C, SD, SiS, H, R	WH, SS	Yes
145	Quine, C.P., M.P. Coutts, B.A. Gardiner and D.G. Pyatt. 1995. Forest and Wind: Management to Minimise Wind Damage. Bulletin 114. HMSO, London. 24 pp.	W, SD, SiS	NS, SS, SP	Yes
146	Reade, M. G. 1957. Sustained yield from selection forest. Quarterly Journal of Forestry 51(1): 51-62	M, SiS	BE, OK, AH, WCH	Yes
147	Reade, M. G. 1960. Lessons from Switzerland. Quarterly Journal of Forestry 54(2): 111-126	SiS	NS, SF, BE	Yes
148	Reade, M. G. 1965. Natural regeneration of beech. Quarterly Journal of Forestry 59(2): 121-131	R	BE	Yes
149	Reade, M. G. 1990. Chiltern enumerations. Quarterly Journal of Forestry 84(1): 9-22	M	BE, OK, AH, WCH	Yes
150	Reynolds, B. 2004. Continuous cover forestry: possible implications for surface water acidification in the UK uplands. Hydrology and Earth System Sciences 8(3): 306-313	H	xxx	Yes
151	Saksa, T. 2004. Regeneration process from seed crop to saplings - a case study in uneven-aged Norway spruce-dominated stands in Southern Finland. *Silva Fennica* 38(4): 371-381	R	NS	Yes
152	Sánchez Orois, S., and R. R. Soalleiro. 2002. Modelling the growth and management of uneven-aged maritime broadleaved species forests in Galicia (NW Spain). Scandinavia Journal of Forest Research 17(6): 537-547	SD, SiS, M	MBL	Yes
153	Sánchez Orois, S., J.S. Chang and K.V. Gadow. 2004. Optimal residual growing stock and cutting cycle in mixed uneven-aged maritime pine stands in Northwestern Spain. Forest Policy and Economics 6(2): 145-152	SD, SiS, E	MBL POK, xxx	Yes
154	Schabel, H. G and S.L. Palmer. 1999. The Dauerwald: its role in the restoration of natural forests. Journal of Forestry 97(11): 20-25	SiS, M, C	xxx	Yes
155	Schütz, J.-P. 1990. Sylviculture 1: Principes d'éducation des forêts. [in French] Presses Polytechniques et Universitaires Romandes Lausanne. 243 pp.	R,SiS, SD, P, M, W, C	xxx	Yes
156	Schütz, J.-P. 1997a. Sylviculture 2: La gestion des forêts irrégulières et mélangées. [in French] Presses Polytechniques et Universitaires Romandes Lausanne. 178 pp.	R,SiS, SD, P, M, W, C	xxx	Yes

No.	Reference	Subject Class	Species code	Abstract
157	Schütz, J.-P. 1997b. The Swiss experience: more than one hundred years of experience with a single-tree selection management system in mountainous mixed forests of spruce, fir and beech from an empirically developed utilization in small-scale private forest to an elaborate and original concept of silviculture. Pp. 21-34. *In* Emmingham, W.H., compiler. Proceedings of the IUFRO Interdisciplinary Uneven-aged management Symposium. Oregon state University, Corvallis.	SiS, M, C	NS, SF, BE	No
158	Schütz, J.-P. 1997c. Conditions of the equilibrium in fully irregular, uneven-aged forests: the state of the art in European plenter forests. Pp. 455-467 *In* Emmingham, W.H., Compiler. Proceedings of the IUFRO Interdisciplinary Uneven-aged management Symposium. Oregon state University, Corvallis,	M	xxx	No
159	Schütz, J.-P. 1999. Close-to-nature silviculture: Is this concept compatible with species diversity. Forestry 72(4): 359-366	SiS, SD, P, H, C	SF,BE, NS, POK	Yes
160	Schütz, J.-P. 2001. Opportunities and strategies of transforming regular forests to irregular forests. Forestry Ecology and Management 151: 87-94	SiS, M, C, R	xxx	Yes
161	Schütz, J.-P. 2002a. Silvicultural tools to develop irregular and diverse forest structures. Forestry 75(4): 329-337	SD, SiS, M	xxx	Yes
162	Schütz, J.-P. 2002b. Uneven-aged silviculture: tradition and practices. (Foreword to papers from a joint meeting of IUFRO working groups 1. 14 and 4.01.03, Zurich, Switzerland, 24-30 September 2001.) Forestry 75(4): 327-328	SiS, M, C	xxx	Yes
163	Seymour, R.S. and M.L. Hunter. 1999. Principles of Ecological Forestry. Pp. 22-61 *In* Hunter, M.L., ed. Maintaining biodiversity in forest ecosystems. Cambridge University Press, Cambridge.	C, H, SD	xxx	Yes
164	Shrimpton, N. H. 1988. Modelling the costs of uneven-aged forest management. OFI Occasional Paper 37. Oxford Forestry Institute, Oxford. Pp. 42-46	E, M	xxx	Yes
165	Smith, D.M., B.C. Larson, M.J. Kelty and P.M.S. Ashton. 1997. The Practice of Silviculture: Applied Forest Ecology. 9th edn. John Wiley and Sons, New York. 537pp.	SD, SiS, R	xxx	Yes
166	Stacey, G.R., R.E. Belcher, C.J. Wood and B.A. Gardiner. 1994. Windflows and force in a model spruce forest. Boundary Layer Meteorology 69: 311-334	W, SD	SS	Yes
167	Sterba, H. 2004. Equilibrium curves and growth models to deal with forests in transition to uneven-aged structure - application in two sample stands. *Silva Fennica* 38(4): 413-42	SD, SiS M	NS, SF, EL, BE, SP,	Yes
168	Summers, R.W., and R. Proctor. 2005. Timing of shedding seeds and cones, and production in different stands of Scots pines at Abernethy Forest, Scotland. Forestry 78(5):541-549	R	SP	Yes
169	Taylor, D. 2003. What price continuous cover? Forestry and British Timber 32(7): 50-52	M, E, SiS, C	xxx	Yes

No.	Reference	Subject Class	Species code	Abstract
170	Timmis, T. 1994. Bradford plan continuous cover forestry: development, history and status quo. Quarterly Journal of Forestry. 88(3): 188-198	SiS, M, SD	DF, WH, RC, RW, xxx	Yes
171	Torres Rojo, J.M., and S. Sánchez Orois. 2005. A decision support system for optimizing the conversion of rotation forest stands to continuous cover forest stands. Forest Ecology and Management 207: 109-120	SiS, C, M	xxx	Yes
172	Troup, R. S. 1928. Silvicultural Systems. Clarendon Press, Oxford. (later editions also available: 1952, 1966)	R,SiS, SD, P, M, W, C	xxx	Yes
173	UK Woodland Assurance Scheme (UKWAS). 2000. Certification Standard for the UK Woodland Assurance Scheme. Forestry Commission, Edinburgh, 42 pp.	M, SiS	xxx	No
174	Waters, T. L., and P. S. Savill. 1992. Ash and sycamore regeneration and the phenomenon of their alternation. Forestry 65(4): 417-433	R, H, SiS	AH, SY	Yes
175	Whitney McIver, H., J. F. Blyth and D. C. Malcolm. 1992. The application of group selection working in an upland forest in south Scotland (Glentress Forest). Scottish Forestry 46(3): 202-211	SiS, M	xxx	Yes
176	Wilson, E.R., H. Whitney McIver and D.C. Malcolm. 1999. Transformation to an irregular structure of an upland conifer forest. Forestry Chronicle 75: 407-412	R, SiS, SD	SS, EL, SP,DF	Yes
177	Wilson, J.S. and C.D. Oliver. 2000. Stability and density management in Douglas-fir plantations. Canadian Journal of Forestry Research 30(6): 910-920	W, SD, SiS	DF	Yes
178	Yorke, D.M.B. 1993 The permanent forest. Scottish Forestry 47(1): 6-14	C, SiS	xxx	Yes
179	Yorke, D.M.B. 1995. Continuous Cover Silvicultural Systems in Britain. Scottish Forestry 49(3): 162-165	C, R, SiS, E	xxx	Yes
180	Yorke, D.M.B. 1998. Continuous cover silviculture: An alternative to clear felling. Continuous Cover Forestry Group. Copies from: Mark Yorke, Tyddyn Bach. Llanegryn, Tywyn, Gwynedd LL37 9UF. 52 pp.	SiS, R, C, E	xxx	Yes
181	Yorke, D.M.B. 2001a. Practical Aspects of Transforming Plantations into Continuous Cover Woodlands. Privately published. Copies from: Mark Yorke, Tyddyn Bach, Llanegryn, Tywyn, Gwynedd LL37 9UF. 35 pp.	SiS, M	xxx	Yes
182	Yorke, D.M.B. 2001b. Some misconceptions of continuous cover silviculture. Scottish Forestry 55(2): 73-75	SiS, C, M	xxx	Yes
183	Yorke, M. 2004a. Continuous cover – dispelling some misconceptions. Forestry and Timber News 2004 (March): 32-33	SiS, M, C	xxx	Yes
184	Yorke, M. 2004b. The ‘cost’ of transforming even-aged coniferous stands to continuous cover. CCFG Newsletter 23: 11-13	E	xxx	Yes

Part 2: Selected Abstracts

Ref. No.	Author/Abstract
1	**Ancelin et al 2004** Models predicting forest stand wind-firmness are usually based on the calculation of a critical wind speed above which the mean tree of a stand is broken or uprooted. This approach is well adapted to regular stands, but in heterogeneous stands, not all the trees are necessarily damaged at the same time. Models used to analyse the distribution of damage within a population of trees can be a good alternative. In this perspective we developed FOREOLE, an individual-based mechanical model of tree response to wind. FOREOLE is based on a numerical description of tree structure allowing both wind and self-weight loads to be calculated at every level of the stem, as well as the bending moment at the tree base and mechanical stresses along the stem. We use a static approach to model wind forces in which the turbulent aspect of wind is taken into account through a gust factor. Stem breakage or uprooting is then predicted from comparisons to failure criteria, i.e. critical bending moment and critical compressive stress, respectively. Implemented in the software called CAPSIS, FOREOLE is compatible with a model of coniferous forest stand dynamics and allows wind-firmness to be simulated both in measured and virtual populations of trees. On individual trees, FOREOLE provided predictions of critical wind speed comparable to the existing models known as GALES and HWIND, despite differences in the method used to describe tree shape and to solve mechanics. These predictions appeared particularly sensitive to the gust factor and the drag coefficient. We then analysed the influence of stand structure, wind speed and individual tree characteristics on the type and amount of damage. From simulations in stands representing three different structures (regular, intermediate and selection stands), we showed that irregular stands experience scattered damage for a relatively wide range of wind speeds, whereas regular stands tend to collapse as a whole above a critical wind speed. Irregularity also increased the ratio between loss in volume of wood and loss in number of trees. Regarding tree characteristics, the highest and the slenderest subjects were the most sensitive, both to stem breakage and to overturning. Sensitivity to breakage was also increased by shorter crowns. In addition, statistical analysis of the simulation results also showed that wind speed remained the most significant variable in explaining wind damage.
2	**Anderson 1951** The present position respecting a number of experiments with a system of planting by dense groups, widely spaced, which were established in Scotland and the north of England in the years 1929 to 1932, is reported upon, with reference to a series of photographic illustrations taken in 1950. Earlier claims concerning advantages of such a system are discussed in the light of what these experiments now show. Expected disadvantages are similarly dealt with, as are new advantages which have emerged. The similarity of the method to the Russian method of “nest” sowing or planting is briefly considered. In general, it is concluded that results are very promising and that the system is deserving of extensive trial under a variety of conditions. Suggestions as to the forms such trials might take are offered. It is considered that the system is a plastic one and well-adapted to lead to the formation of stands, irregular in composition and age, which in certain circumstances are for several reasons to be preferred to those regular stands which derive from even-aged orthodox plantations.
3	**Anderson 1953** Progress in forest management and in silvicultural practice in this country cannot be made until we adopt some method of readily determining the effects upon production

Ref. No.	Author/Abstract
	of the various techniques and treatments we apply. This paper discusses an approach to assessing stand structure in continuous cover systems, using a method known as the “standing control” or “check” method. The approach follows techniques widely applied in central Europe, and over a long period of time. A case study is presented to illustrate how the method works in practice. The need for the adoption for some such easy and reliable method of checking the effects of silvicultural treatments is all the more necessary in a country such as ours, with its extremely varied combinations of locality factors.
4	**Anderson 1960**
	In this paper, the author argues that, if areas are carefully selected, there are certain localities in Scotland where it should be possible to reproduce the mixed Norway spruce-silver fir-beech forest type. This forest type offers distinct advantages under conditions of exposure and at high elevation. The forest type should initially have a group structure. Natural regeneration and deer management are highlighted as major issues to be explored. The paper concludes with a call for large-scale and long-term silvicultural research trials.
5	**Bayliss and Everard 1992**
	By coincidence two parties of foresters from the Forest of Dean visited the French oak forests in Normandy to study natural regeneration. The visits were separated by almost 100 years. The report made in 1896 by the then deputy surveyor is given in full together with comments made after the recent visit. British foresters who today are visiting Normandy will be interested to note how little has changed in oak silviculture in almost 100 years.
7	**Benecke 1996**
	The historical background, current trends, and forest management systems are presented that utilise the natural features of forests for sustainable wood production. Recent New Zealand legislation challenges the forestry profession to diversify management systems that can fulfil ecological, economic and social criteria for forests. The case is argued for ecological silviculture with examples of selection systems that maintain continuous forest cover while producing substantial harvestable increment with a high proportion of good-quality sawlogs. The key lies in skilful low-impact harvesting, working with natural regeneration, targeting increment to the best dominant trees, and using the stand canopy for silvicultural self-tending. Research provides forest process information for impacts of indigenous forest management to be kept within limits similar to those found in the natural patterns of forest growth. Much of New Zealand's existing native forest possesses the main structural attributes to practise selection systems for productive, near-natural forestry. New Zealand has great opportunity for natural forest management, especially in its beech (*Nothofagus*) forests, to fulfil society's expectations for ecological sustainability. Ecologically-based systems for natural forest will complement plantation forestry.
8	**Black et al 2005**
	The impact of water availability on the photosynthetic performance of three year old, commercially obtained, Sitka spruce (*Picea sitchensis*) seedlings under exposed and shaded conditions was evaluated to provide a physiological understanding of the factors controlling seedling performance under conventional and continuous cover forestry (CCF) management scenarios. Decreases in photosynthesis in response to water deficits, under exposed and shaded conditions, were associated with reductions in both stomatal (G_s) and mesophyll conductance (G_m), and an increase

Ref. No.	Author/Abstract
	in the proportion of electrons consumed in non-photosynthetic pathways. After re-watering, photosynthesis of plants subjected to higher irradiances was inhibited for up to 6 days due to high photorespiratory activity and damage to photosystem II. Waterlogged seedlings grown under both exposed and shaded conditions showed smaller decreases in photosynthesis that were also associated with an altered G_s and G_m, but no changes in chlorophyll fluorescence related parameters were observed. We conclude that the performance of seedlings will be more susceptible to management-related or environmentally-induced water deficits in exposed sites typical of temperate latitudes and may, therefore, be improved in CCF systems.
9	**Blyth and Malcolm 1988**
	This paper describes the transformation of an upland plantation to irregular structure at Glentress, near Peebles (25 miles south of Edinburgh). The paper includes site conditions, forest history and management of the trial, now half-way through the proposed 60-yr transformation period. The paper also discusses natural regeneration and financial aspects of the trial.
11	**Cameron 2002**
	There is increasing evidence that a decline in the practice of selective thinning in Britain may in part explain an observed reduction in log quality in recent years. The decline in use of selective thinning has been primarily influenced by the low value of early thinnings together with increasing pressure to make a financial surplus on harvesting operations. Since systematic or delayed thinning, used to improve the short-term economics, may result in stand instability, the no-thinning option has been widely adopted in stands at risk of damage by wind and snow or where a financial surplus on early selective thinnings is not possible. This review sets out to demonstrate that non-commercial, early selective thinnings can be seen as a long-term investment in future log quality and value without compromising stand stability. Low thinnings do not greatly destabilize stands even on exposed sites if carried out on time and will improve stability in the long term. While early low thinnings are unlikely to make a financial surplus on the operation, they significantly enhance the production of quality 'green' logs in comparison with a no-thinning regime. Evidence presented in this paper indicates that the wood-using industry is willing to pay a premium for this quality. The combination of these factors suggest that non-commercial, early low thinnings can be seen as a long-term investment using discounted cash flow methods. The implications of other silvicultural strategies, such as wide initial spacing, respacing, chemical thinning and self-thinning mixtures, on stand stability and wood quality are also discussed.
13	**Crockford et al 1987**
	A computer program has been developed to compare land expectation values and profitability for a wide range of management alternatives. Examples are given for 18 management systems in the UK ranging from intensive management of pure conifers, through mixtures of broadleaves and conifers, to low cost, low management-intensity options involving natural regeneration or coppicing. Variables in the program include site quality, choice of suitable species, silvicultural system, prices, establishment and maintenance costs, planting grants, taxation, sporting rentals, and discount rate.
14	**Dutton 1993a**
	The grey squirrel (*Sciurus carolinensis*) is now recognised as a major pest in broadleaf woodlands throughout lowland Britain. This review paper (part 1 of 2) deals with the causes of bark stripping and damage control policies.

Ref. No.	Author/Abstract
15	**Dutton 1993b** This paper is part 2 of a review of grey squirrel control measures. In this paper the emphasis is placed on cost of control and silvicultural preventative control measures on restock sites and on new farm woodland sites.
16	**Edwards 1981** This paper summarises the results of three years experimental work at Glen Tanar which contributes to an understanding of the population biology of Scots pine. It includes prescriptions for increasing the stock of young trees in stands of mature pines by improving ground conditions for seedlings establishment.
17	**Evans 1984** A comprehensive account relevant to the UK, covering high forest (4 chapters); coppice (3); and other woodland types (4) including growing decorative quality timber and woodlands on farms. Four chapters deal with management for non-wood values (landscape and recreation; conservation; sporting; urban woods). Six chapters give details of biology, silviculture and utilization by species (oak; beech; ash; alders; birches and maples; poplars and willows; other broadleaved species). Subject and species indexes are provided.
18	**Evans 1988** A review of experience with broadleaved species with special reference to the UK, including recommendations for suitable practices. Topics covered include: Use of natural regeneration (in existing high forest; in colonization of open or waste ground; in plantations; for landscape, amenity and recreation; and in the uplands); Preparing for natural regeneration; Regeneration operations in the stand; Protection and care of young regeneration; Advance regeneration, recruiting coppice regrowth, and suckers; and notes on natural regeneration by species (22 species are included).
19	**Fairbairn 1963** The history of the gradual change of thought towards the irregular type of forest and from the selection to the group selection system in Britain is briefly indicated. Suggested definitions are given in regard to the nomenclature for different sizes of felling area in group selection working. Statistics are recorded for climatic influences, including temperature, soil radiation, and the sun's seasonal azimuths and altitudes; the values for daily totals of total solar radiation on a horizontal surface are of value in comparing conditions for group regeneration throughout Britain. There are some observations of the effect of wind and precipitations in gaps, and a series of preliminary measurements of light intensity in group regeneration gaps in Cawdor Wood and in the Forest of Ae. There are further observations on the size, shape and orientation of regeneration gaps. It is suggested that if the group selection system comes to be used in Britain, then suitable management will have to be evolved because of the very diverse climatic conditions in the forest areas of Britain.
20	**Ferlin 2002** This paper describes dendrochronological and silvicultural investigations in natural or near-natural, and selectively managed, uneven-aged Dinaric silver fir-beech forests in Slovenia. The results indicate that relatively old understorey silver fir and Norway spruce trees still have a high capacity to tolerate shading and suppression, and can show a vigorous growth response after release. This capacity for growth after suppression did not depend on the tree age or duration of the juvenile stage. The tree-ring width trends of the released understorey trees shows that they have

Ref. No.	Author/Abstract
	clearly been increasing since around 1950. The current growth rate of released trees is from 3.2 (Norway spruce) to 5.7 (silver fir) times higher than that of suppressed trees. The results suggest that understorey silver fir and Norway spruce trees still have a high potential for application of single tree or small group selection silvicultural systems.
21	**Forestry Commission 2004**
	This is the second edition of the UK Forestry Standard which provides an account of the changes that have occurred over the last 5 years in international and UK governance and administration, and changes in regulations affecting forestry. An overview of forestry in UK is given which provides information on forestry/woodland grant schemes, forest plans, forest design plans, felling licence regulations, and environmental impact assessment regulations. An international background to sustainable forestry show where existing UK policies and practices fit in, and how the Standard works at both the national level and for the individual forest. Practical forest management practices in the region are described in detail. Finally, a keyword index, providing the link between this Standard and its supporting publications, is also included.
22	**Gadow 2001**
	Using a very simple classification based on the development of timber volume over age (or time), two types of sustainable forest management are distinguished: rotation forest management (RFM) and continuous cover forestry (CCF). This paper describes various methods of harvest control for RFM and CCF systems and both. The theory of sustainable forest management provides models for orientation and harvest control. However, we find that a good theory implemented in a computer system is no guarantee for good management. Especially in CCF systems, it is often necessary to establish a system of management demonstration plots for illustrating silvicultural objectives in the field. The concepts and methods of sustainable forest management can theoretically be applied to any landscape, including agricultural and urban landscapes.
24	**Gadow and Puumalainen 2000**
	By anticipating the future in a systematic way, forest scenario planning can reduce uncertainty and improve the chance that future developments will agree with specified objectives. Scenario planning models may be developed for large-scale applications on a national or sub-continental scale or for use in local planning. This contribution specifically deals with scenario techniques at the forest management unit level. A series of techniques for generating timber harvest scenarios, including age-class simulation, area change models, and multi-period harvest scheduling, for even-aged forests as well as continuous cover forests, are presented with numerical examples from various forest types, and including various optimization techniques. Specific end products require a particular quality of the raw material, and as the end products become more variable and the processing opportunities more sophisticated, the importance of raw material quality increases. Therefore, not only are total yields and volumes of interest in forest scenario planning, but increasingly so also are the distribution of tree species, tree dimensions and timber quality. For this reason, a specific application involving the structure of timber product yields is discussed. Finally, scenario techniques for evaluating forestry activities are presented with two examples: a beech forest in Europe (with compartments of beech (*Fagus sylvatica*) and of spruce (*Picea abies*) and a timber farm (of *Pinus taeda* and *Acacia mearnsii*) in South Africa.

Ref. No.	Author/Abstract
25	**Gamborg and Larsen 2003** In this paper, we examine a trend in forestry which may be dubbed 'back to nature' and ask if it offers a sustainable future for forestry. We analyze what is actually meant by 'back to nature', which type of nature we want to 'get back' to, and how ensuing silvicultural philosophies can be defined. 'Back to nature' can be understood in a temporal sense referring to a certain composition or structure of a forest at a given time. But it can also refer to the processes taking place in an actual forest. Thirdly—in a broader sense—'back to nature' may represent the wish to revert to a more 'simple' way of silviculture and forestry in general, doing away with habitual thinking and the creation of dogmatic approaches. Currently, there is no consensus on an interpretation of 'back to nature'. Moreover, quantitative data from long-term empirical field trials are still limited. Sound science is needed to underpin the claims of the advocates of various interpretations of back to nature silviculture. It might be difficult to pinpoint what a sustainable future for forestry entails, but it is clear that a sustainable future for forestry to a greater extent than previously will require balancing commodity and environmental and nature values both against one another and against any concerns felt to be relevant by the various stakeholders.
28	**Gardiner and Quine 2000** This paper has two main sections: (1) a review of risk management in forests with reference to abiotic risks, in particular the effects of strong winds; and (2) a demonstration of the application of a quantitative risk model (ForestGALES) in making appropriate choices. The review assumes that forests are managed in some way. A detailed description of the wind risk model is used to demonstrate the deterministic/probabilistic approach to risk assessment. The importance of quantitative risk estimation is illustrated by model output comparing a range of silvicultural strategies and site characteristics; the example used is a theoretical Sitka spruce *(Picea sitchensis)* plantation of moderate growth rate (Yield Class 14) located in different parts of Britain. The results illustrate how difficult it is to make general statements about risk and how management response has to be 'context sensitive'. Any response must be appropriate to the level of risk, the options for risk reduction and the implications of damage. Mathematical models provide an opportunity for objectively calculating the risks to forests and will in the future allow forest managers to make informed decisions about how best to manage forests in order to minimize these risks.
29	**Gardiner et al 1997** The change in wind loading on trees due to tree spacing and wind speed was examined in the field and in a wind tunnel. The field measurements were made in small blocks of Sitka spruce (*Picea sitchensis*) in Kershope Forest, Cumbria, UK, respaced 15 years previously to different stand densities. The wind tunnel measurements were made with dynamically correct 20-cm tall plastic trees. The maximum bending moment on trees showed a linear increase with the ratio of spacing to height. Estimates suggest that at the wider spacing tree diameter has increased sufficiently so that trees are less likely to break. However, the increase in resistance to overturning is not as rapid as the increase in wind loading, and wider spaced trees will be more vulnerable to overturning. Wind tunnel measurements were also carried out on a range of commercial thinning practices and showed that the critical factor in reducing stand stability is the size of gap made in the forest. The mechanical and dynamic characteristics of trees at different spacings are presented. These show that with increasing spacing the Young's modulus of trees decreases and their damping coefficient increases. This illustrates that wide-spaced trees have weaker wood than closely-spaced trees but they are less reliant on the support of neighbouring trees. The implications of the measurements on the overall stability of stands and the implications for forest managers are discussed.

Ref. No.	Author/Abstract
30	**Gardiner et al 2005** We report on a wind-tunnel study with 1:75 scale model trees designed to examine the influence of canopy structure on the formation of turbulent gusts above forests. This was to test the hypothesis that more irregular canopy structures produce less intense gusts because the change in wind speed with height at canopy top is less severe. Measurements were made of wind speeds and turbulence within and above the model forests and of the wind loading on model trees in four different silvicultural systems. The systems tested were even-aged, single-tree selection, shelterwood/ group selection and strip felling. The measurements showed that the profiles of different mean wind and turbulence characteristics above the forests are remarkably similar when vertical heights are normalized by the height of the tallest tree but differences do exist within the canopy. The wind loading measurements indicated no difference between the systems in terms of stability except possibly for the shelterwood/group selection. In the shelterwood/group selection system the presence of smaller sub-canopy trees appears to reduce the loading on the main canopy trees either by providing support and increasing damping or by absorption of energy from the canopy-penetrating gusts.
31	**Garfitt 1963** A short paper describing a simple and economical method of thinning dense natural regeneration over wide areas.
32	**Garfitt 1977** Landscaping the boundaries of plantations to soften harsh, straight lines may improve the foresters' image, but it does not solve the problem of unsightly gaps in beauty spots when felling is done; but a selective system of silviculture as described here can in some areas be the answer.
33	**Garfitt 1980** This paper describes and sets out the advantages of the 'Belgian System' of treating large areas of naturally regenerated hardwoods. A method for marking and releasing potential crop trees is described. Eight advantages are claimed for the system which enables efficient treatment of large areas of woodland.
34	**Garfitt 1984** A brief description of the system is given with suggested methods of conversion from managed forest, unmanaged forest, and scrub.
35	**Garfitt 1987** A method of simple ocular checks is proposed as providing sufficiently accurate control, for practical management purposes, of the growing stock and the distribution of size-classes in irregular woodlands.
36	**Garfitt 1995** This book reviews silvicultural practices that maintain forest cover, and so avoid clear-felling, with particular reference to the UK. The 23 chapters describe: Woods and forests for all; Natural regeneration; Assisted natural regeneration; Natural regeneration systems in even-aged wood, irregular woods (coppice-with standards, selection system, group selection system); Conversion to group selection of even-aged woods, and of unmanaged woodland and scrub; Control of the felling in irregular woods; Avoiding clear-felling in ornamental plantings; Re-stocking by

Ref. No.	Author/Abstract
	natural means; Planting (systems, techniques); Weeding; Cleaning, brashing, and de-wolfing; Pruning; Thinning; Felling; Extraction; and Big trees and compound interest. An index is included.
37	**Goucher and Nixon 1996**
	Native pinewoods *(Pinus sylvestris)* in Scotland exist only as remnants which have a much modified structure as a result of historical disturbance through tree felling and overgrazing. This study describes the age structure of three pinewoods in the western Highlands (at Glen Loy, Glengarry and Loch Arkaig) and evaluates the impact of recorded periods of disturbance. The results show that all three woodlands have an irregular structure with an incomplete range of tree ages. The implications of the current age distribution for the future regeneration and conservation of these important woodlands are discussed.
38	**Grassi et al 2004**
	In a 0.75-ha plot in a Norway spruce *(Picea abies* Karst.*)* - silver fir *(Abies alba* Miller*)* stand in Comelico (Italian eastern Alps), we analysed (i) the distribution and growth of natural regeneration of Norway spruce and silver fir as affected by stand structure and (ii) the age structure of all saplings between 0.2 and 10 m in height in a 30-year-old gap. In both species, most natural regeneration was clumped and located at the margin of the gaps; however, fir saplings were more represented in understorey environments and less represented in gaps as compared with spruce. Age structure of natural regeneration in the selected gap revealed that the majority (75%) of saplings appeared after the formation of the gap; however, for regeneration taller than 2 m (which has a better chance of reaching the uppermost canopy layer), saplings already present at gap formation predominated. We conclude that (i) gap edges represent a preferential regeneration niche in this forest and (ii) saplings established before gap formation can play an important role in gap refilling. These results provide useful information to ensure, through silvicultural practices, favourable conditions for the temporal and spatial continuity of the regeneration process.
39	**Grayson 2002**
	Increasing interest in continuous cover management of woodlands in Britain indicates the need for more study of the resulting wood production, since sales of wood remain the most important source of finance for established woodlands. Detailed enumeration data by 1 inch quarter girth (1”QG=3.23 cm diameter) classes and records of cut are available for 22 compartments of all-aged woodlands of the Ipsden estate, Oxfordshire, together with accounts compiled on a consistent basis since 1973. Predominant species are beech *(Fagus sylvatica)*, oak *(Quercus robur)*, ash *(Fraxinus excelsior)*, cherry *(Prunus avium)* with, usually younger, European larch *(Larix decidua)*, Scots pine *(Pinus sylvestris)* and other conifers managed on an irregular group selection system. Average growing stock volume of material over 5” QG increased from 1080 hoppus feet per acre (96.3 m^3ha^{-1}) in 1973 to 1800 h.ft per acre (160.4 m^3ha^{-1}) in 2000. Cut amounted to 593 h.ft per acre (52.8 m^3ha^{-1}). Total increment over the 27 years was 1312 h.ft per acre or 48.6 h.ft per acre per year (4.33 m^3ha^{-1}). An 'ideal' stand is defined. The net annual income relative to value of standing timber of this is 1.8 per cent. The current absence of simulations of growth and potential yield in mixed-age, mixed-species stands makes forecasts of volume and money yield difficult. A plausible profile of future net income suggests that net present value of the current stock lies between £1450 per acre at 2 per cent and £750 at 3 per cent, both values being substantially lower than the standing value of timber of £1670 per acre: equality occurs at 1.7 per cent. This result should be set alongside the return, without grants, of growing even-aged broadleaved stands in Britain of a little over 1 per cent in real terms.

Ref. No.	Author/Abstract
40	**Hale 2001** Hemispherical photographs were taken in a range of Sitka spruce *(Picea sitchensis)* stands in northern Britain. These were used to estimate the canopy gap fraction, and thereby estimate the transmission of light to the ground within each stand. Stands under routine management systems, whether thinned or unthinned, generally had too low a gap fraction to allow sufficient light through for seedling growth. The only stand with a gap fraction substantially higher than the other was a widely spaced (8 m) stand from a spacing experiment. The observations showed good agreement with a theoretical curve of canopy transmittance calculated using the Beer-Lambert law. The results indicate that a Sitka spruce stand should be thinned to a basal area < 30 m^2 ha^{-1}, which is below management table stocking, if the gap fraction is to be increased to levels suitable for seedling growth.
41	**Hale 2003** A Sitka spruce stand in central Scotland was thinned with five interventions from a basal area of 59-15 m^2 ha^{-1} before being clearfelled. For each stand density, the light environment beneath the canopy was characterised by making direct (with a ceptometer) and indirect measurements (using hemispherical photography) of the canopy transmittance. A comparison between the two methods of measurement showed that the indirect method discriminated poorly at low levels of transmittance (< 0.1). Above this, there was good correlation between the two methods, although the indirect method underestimated the transmittance when compared to the direct measurements. Transmittance increased exponentially as basal area was reduced, to a value of almost 0.5 at basal area 15 m^2 ha^{-1}. The relationship between basal area and transmittance conformed to Beer's law (transmittance=exp(-*kL*), where *k* is an extinction coefficient and *L* the leaf area index), which is most commonly applied to continuous canopies. The value of *k* fitted to the data (0.31) was much lower than the value of 0.6 associated with closed Sitka spruce canopies, indicating the reduced light interception efficiency in discontinuous canopies. The relationship between transmittance and proportion of basal area removed could be used as guidance for managers wishing to manipulate the light environment beneath a closed-canopy Sitka spruce stand, for example to encourage natural regeneration. However, there are other factors to consider, such as the effect of thinning on the stand stability. The vigour of the original stand is also important, as it determines whether the canopy will quickly regrow, or whether the increase in light levels will be sustained.
42	**Hale 2004** A short note on the measurement of light beneath a forest canopy. The article addresses two questions: 1. How to estimate light beneath canopies; and, 2. how much light is required by seedlings and other vegetation for sustained growth. The article outlines some of the technical challenges associated with measurements of light levels, and includes a brief description of the canopy-scope technique.
43	**Hale et al 2004** The forest industry is increasingly adopting alternative silvicultural systems, involving regeneration beneath an existing forest canopy, rather than clear felling and replanting. To apply these silvicultural systems in windy regions such as Britain and Ireland, it is essential that the interactions between thinning intensity, stand stability and seedling growth are properly understood. Here, we present a modelling analysis of the three key relationships between: (i) stand density and the proportion of incident radiation transmitted through a forest canopy as a stand is thinned; (ii) transmitted radiation and seedling growth, and (iii) stand density and stand stability. These relationships were examined using separate models of radiative transfer

Ref. No.	Author/Abstract
	(MAESTRO), seedling growth, and stand stability/wind risk (ForestGALES). The model was run for 1-year-old Sitka spruce *(Picea sitchensis)* seedlings. Output from the three models was synthesized to calculate whether a given stand thinned to a pre-defined stability limit would allow sufficient light to penetrate the canopy for seedling growth. A minimum transmittance of 20% was identified as a requirement for seedling growth, which corresponds to removing 45% of stand basal area. A thinning of this intensity left some stands susceptible to unacceptable wind damage, especially in old or previously thinned stands on soils where rooting is impeded. The results emphasized the fact that rooting conditions, thinning history and age of intervention are major constraints on the silvicultural options. In general, older stands are not suitable for conversion to continuous cover forestry systems, and the transformation process should begin at pole stage, when heavy thinning does not leave the stand unstable. The analysis approach used here illustrates the potential for combining models to address complex forest management issues.
44	**Hanewinkel 2001** This study deals with the problem of quantifying economic effects linked to the transformation of even-aged pure stands of Norway spruce *(Picea abies)* to mixed uneven-aged stands of Norway spruce and beech *(Fagus sylvatica).* The investigation is based on a simulation experiment with a single tree growth simulator. A theoretical approach is presented in which the economic effects occurring during the transformation process (the cost of the transformation) are separated from long-term economic effects occurring after the transformation. The results of the study showed that the costs of the transformation were highly dependent on the interest rate (IR) chosen. With IR=1%, the net present value of the transformation regime is 27% less than the net present value of a conventional age class regime. A discount rate of 3% reduces these costs of transformation to 13%. For the uneven-aged model the minimum perpetual yearly net revenue to achieve the same holding value as the age class variant was computed. A mixed uneven-aged stand should at least yield 347 Euro per year and per ha (IR=1%). This value is close to net revenues that are achieved by pure uneven-aged coniferous stands under the same price-cost relations.
45	**Hanewinkel 2002** This study is based on a literature review of comparative economic analyses of even-aged and uneven-aged forests, mainly in the European context. An initial hypothesis is formulated that silver fir/Norway spruce ‘Plenterwald’-type of uneven-aged forests yield higher financial outputs (net revenues) than similar even-aged forests under similar site conditions. A model study is described which avoids the weaknesses in the investigations reviewed in the literature. The results of the model study show that the initial hypothesis cannot be upheld. Assuming the same timber quality, the most favourable variants of the even-aged and uneven-aged systems yielded almost the same net revenues. The calculation of capital charges on the growing stock alters these results. The most important influence on the results in the even-aged model is the level of risk. The main difficulties in comparing the economics of even-aged and uneven-aged forests are discussed.
46	**Hanewinkel 2004** Different methodological approaches from the field of spatial statistics, the index of cluster size (ICS) and quadrat methods such as the two-term and three-term local quadrat variance (TTLQV and 3TLQV) and the new local variance (NLV) were tested to find a simple spatial measure to classify mixed coniferous uneven-aged, even-aged and conversion stands in the central Black Forest area of Germany. Altogether six stands were analysed with regularly distributed sample plots of 0.25 ha (50×50 m), each subdivided into 25 quadrats of 10×10 m. In each of the quadrats, diameter

Ref. No.	Author/Abstract
	at breast height (dbh) for trees of the overstory (dbh > 7 cm) was assessed and classified into three diameter classes. Height measurements were used to develop specific stand height curves for each stand and to calculate the standing volume per tree and per quadrat. The even-aged stands showed a regular distribution of the standing volume, while the conversion and uneven-aged stands were more clustered. This was detected using ICS, which proved to be a simple but very efficient measure for stand structure. The ICS also showed a highly random distribution of small and medium trees and a regular distribution of large trees of the overstorey in the uneven-aged stand. Large and medium trees of one even-aged stand were also regularly distributed while conversion stands showed a regular, random or slightly clustered distribution of these trees. The more uneven the ages in the stands were, the larger were the phases detected by the NLV. The findings of the ICS were generally supported by the TTLQV and 3TLQV. The more uneven the ages in a stand were, the less clustered were the trees of different sizes of the understorey. Clustering also decreased with increasing height of understorey trees. The patterns detected in the investigated stands were related to the effect of different management regimes. Implications for the management of conversions stands based on the findings of the study are given.
47	**Hanewinkel and Pretzsch 2000**
	A conversion regime is provided from even-aged to uneven-aged stands of Norway spruce *(Picea abies).* The regime was tested by the distance-dependent single-tree simulator SILVA 2.1. The initial data for the simulation and the assumed site productivity were deduced using inventory data from the north Black Forest, Germany. The conversion regime was compared with a typical future-tree orientated age-class treatment system. Thereby, 4 variants of the conversion regime, differing in the number and diameter of the regeneration-funnels (gaps in the canopy of the stand) which were created during the graded-regeneration-phase, were compared with a basal-area orientated future-tree age-class treatment. A simulation run of 110 years was conducted, divided into 22 periods of 5 years. The analysis of the simulation run showed that the possibilities of achieving uneven-aged structures in single-layered, even-aged stands through structuring measures during thinning or target-diameter harvesting were very limited. The success of the conversion depended mainly on the success of the regeneration during the conversion. The early creation of regeneration-funnels was linked with severe losses in increment and standing volume. As well as influences on different stand parameters (e.g. stem distribution) changes in structural parameters caused by the conversion could be assessed. In particular, the modified Shannon-index reacted distinctly to the implementation of the natural regeneration in the regeneration-funnels. Indeed, a steady state was only temporarily reached in the variant with the largest gaps. Finally, the results of the conversion experiment were subjected to a critical review, discussing the limits of the model in its current version and further research needs.
48	**Hann 2001**
	A close examination of the data, methods and results for predicting ratios of height to diameter at breast height in Douglas-fir (*Pseudotsuga menziesii*) plantations, reported by Wilson and Oliver (2000) [Canadian Journal of Forest Research (2000) 30: 910-920], indicates that there are several problems with their application of the two versions of ORGANON growth models. These problems are discussed and guidelines are suggested for reducing such problems.
49	**Harmer 1994a**
	Historical aspects of the use of natural regeneration and planting for restocking British broadleaved forests are briefly described. Study of the literature suggests that failure of natural regeneration to achieve widespread use has been due, in part, to

Ref. No.	Author/Abstract
	the evolution of reliable silvicultural methods based on planting which are simpler, more cost effective and more appropriate in woodlands managed for many uses.
50	**Harmer 1994b**
	The influence of seed production and seed predation on the successful natural regeneration of broadleaved woodland was investigated by literature survey - mainly covering beech (*Fagus sylvatica*), oak (*Quercus robur*), sycamore maple (*Acer pseudoplatanus*), ash (*Fraxinus excelsior*). Flowering and seed production are variable and influenced by a number of environmental and biological factors. Some studies have shown that these factors may have predictive value but relationships vary between species and the only sure way of determining quality of the seed crop is after seed fall. The number of seeds produced varies greatly between trees, species and years but it is unknown how many are required for successful natural regeneration. Seeds of oak and beech suffer heavy predation from a variety of animals and natural regeneration may be unsuccessful unless these are adequately controlled.
51	**Harmer 1995**
	Viability and germination of broadleaved tree seed are discussed within the context of natural regeneration. A survey of literature showed that viability of seedlots is variable. Ash is dormant until the second spring after seed fall and can remain in the soil seedbank for several years but other species germinate in spring of the year following their production. Field studies have shown that germination depends on position of the seed and that preparation of a seedbed is advantageous for some species. Effects of browsing, competition and shade on establishment of seedlings are briefly described. A wide variety of browsing animals can adversely affect success of natural regeneration by reducing tree growth and influencing the proportion of species regenerating. Although competition will reduce growth, severity of this effect depends on many factors including soil type and species of competing weeds. Overstorey trees suppress growth by casting shade and providing root competition. Possible areas for future research are discussed.
52	**Harmer and Kerr 1996**
	A survey of silvicultural practice on 78 sites in the UK being managed for natural regeneration suggests that current advice is not being used to the best effect.
53	**Harmer et al 1994**
	A survey of natural regeneration was conducted on 25 selected sites which were receiving Woodland Grant Scheme payments in the Forestry Authority's Hampshire and West Downs Conservancy. In total 15 broadleaved species and 9 conifer species were found to be regenerating, of which birch and ash were most abundant. For the most common species, variation in estimated number of seedlings was from 600/ha for beech to 25 900/ha for birch, but as the selected schemes were established after 1989 most seedlings were small. There was generally little evidence of effective weed control or protection from mammals.
54	**Harmer et al 1997**
	A survey of 78 sites in southern England with approved management plans for restocking by natural regeneration was made during the summers of 1993 and 1994. The following features were recorded: species, stocking, canopy cover and seed-bearing potential of trees present in the overstorey; species and canopy cover of the understorey; ground cover; and species, browsing damage, number and heights of tree seedlings. In general, sites were poorly stocked with overstorey trees having an

Ref. No.	Author/Abstract
	average of 135 stems ha^{-1} and a mean canopy cover of 36 %. Similarly, the understoreys were poorly developed with an average cover of only 23 %. Twenty-nine species of trees were found in the overstorey, with (*Quercus*) spp. and (*Fraxinus excelsior*) the most common. Many of the stems present had poor seed-bearing potential. Cover of the ground flora often exceeded 75%. Seedlings were present on most sites, with (*F. excelsior*) and (*Betula pendula*) being most abundant with mean seedling densities exceeding 10 000 ha^{-1}. Most seedlings were < 20 cm tall, few exceeded 120 cm. About 30 % of seedlings were browsed. The results are related to current guidance and the future prospects for use of natural regeneration.
55	**Harmer et al 2004** A survey was carried out in 2002 on 20 sites in southeast England (UK) that had been damaged by the 1987 storm. The amount, size and species of naturally regenerating trees were assessed and comparisons made with an initial survey made in summer 1988. A total of 22 tree and shrub species was found and saplings of the most abundant species were generally well established being up to 11 m tall and 7 cm in diameter. The predominant species regenerating changed between observations. At many sites seedling oak and beech were replaced by sapling birch. The type and amount of vegetation varied between sites wherein it appeared to be related to soil type and to influence sapling density. The number of species present on sample plots Varied between 0 and 8 with total sapling densities of up to 40 000 ha^{-1}. Successful regeneration of broadleaved trees (>1100 ha^{-1}) occurred on 75 % of sites, but the dominant species was usually different to the original crop.
56	**Harmer et al 2005** The development of the ground flora, and survival and height growth of tree seedlings, were observed annually over the 5-year period following a mast year in an oak woodland in southern England. After removal of the coppice understorey and thinning of the tree-canopy to leave 60–70 per cent cover there was a rapid development of the ground flora which was dominated throughout by *Rubus fruticosus* (bramble), although the frequency and amount of *Pteridium aquilinum* (bracken) increased with time. More than 10 woody species regenerated but only three, *Quercus robur* (oak), *Fraxinus excelsior* (ash) and *Betula pendula* (birch), were found in substantial amounts. Many birch and *Corylus avellana* (hazel) seedlings grew sufficiently well to emerge above the bramble and bracken; in contrast, after 2 years few oak and ash were taller than the bramble and none were taller than the bracken. The number of oak and ash seedlings was positively related to the number and proximity of parent trees. There were no consistent relationships between decreases in the sizes of the seedling populations and the type, amount and height of vegetation. The size of seedling populations generally declined with time with annual reductions varying from 0 to 90 per cent depending on species and year; for most of the study, oak and ash populations fell by 40–50 per cent each year. There were some significant relationships between seedling height and site characteristics but these were inconsistent, varying between tree species and year. Results are discussed in relation to the natural regeneration of oak.
57	**Harris 1994** The Bradford Plan is one of several systems that have been proposed in Britain during the post-war period, which aim to achieve enhanced yield and other objectives by similar means, using an uneven-aged stand structure. They draw on continental practice with natural regeneration, lay down specific prescriptions and claim fuller utilization of the site. This paper attempts to summarize these concepts but questions their validity on the basis that maximum stand yield is determined by available nutrients.

Ref. No.	Author/Abstract
58	**Harris and Kent 1987a** The Bradford-Hutt system seeks to create a group selection forest on a regular grid pattern, thus facilitating extraction, and has been used on the Tavistock Woodlands Estate, UK, over the past 28 yr. A study begun in 1979 showed that stages of ground flora and successional development were preserved and replicated throughout woodland under the system, conserving habitat diversity and species richness.
59	**Harris and Kent 1987b** A mosaic of woodland light environments is created by this system of group selection forest on a regular pattern. The resultant habitat diversity and species richness reported in Part I is reflected in the pattern of local succession in the soil seed bank and in the different phenological strategies that coexist within a small area.
60	**Hart 1995** The objective of this bulletin is to summarise British experience of alternative silvicultural systems to clear cutting. Management of woodlands for diverse objectives such as recreation, landscape, timber production and conservation is becoming increasingly important. Irregular forestry systems have been promoted as one way of maximising the potential benefits woodlands have to offer. This review explores this assumption and highlights the lessons which have been learnt in managing irregular forestry, and in converting high forest managed by clear felling to other systems. The examples described have been classified into: shelterwood, group selection, single tree selection and other silvicultural systems. In total 44 examples of managing forest areas using alternative silvicultural systems, in upland and lowland Britain, are described; these include the well known examples of Glentress, Ebworth, Weasenham and Dartington. Brief consideration is also given to the economics of irregular forestry and the effects of environmental factors on transformation to alternative silvicultural systems. Four key considerations influencing the use of irregular forestry are emphasized: (1) it is possible on a wide range of sites in upland and lowland Britain; (2) the key to its success is continuity of management; (3) the costs of management can be high compared with the clear felling system, hence it is not favoured by conventional economic analysis based on financial yield; and (4) the potential to produce non-market benefits can be high compared with the clear felling system. More research into the evaluation of such benefits is required so that irregular forestry can be compared objectively with other silvicultural systems.
61	**Heitzman 2003** In 1919, the Forestry Commission of Great Britain embarked on a successful programme of increasing Scotland's domestic wood supply by establishing plantations of non-native conifers. Softwood plantation silviculture remains the cornerstone of Scottish forestry, but Scots are increasingly seeking a variety of non-timber benefits. Non-industrial private landowners are planting native hardwoods for diversity, landscape, and heritage values, and the Forestry Commission is supporting their efforts through government policy, research, and cost-share programmes. Continuous cover forestry is becoming a popular alternative to clear felling this silvicultural concept uses partial harvests and natural regeneration to transform even-aged, simply structured forests to multi-aged, more structurally complex forests.

Ref. No.	Author/Abstract
62	**Helliwell 1985** The need for experimental work on the effects of different silvicultural systems on the soil, flora, fauna, visual amenity, windthrow and timber production is outlined and a suggested series of experimental plots is described.
63	**Helliwell 1997** The description of (Dauerwald) (the silvicultural method used in 650 ha of Scots pine (Pinus sylvestris) plantations on the Bärenthoren estate in northern Germany) which Troup, R. S. gave in the paper of the same name in the inaugural issue of this journal in 1927 remains valid today. (Dauerwald) is not a silvicultural system in itself, but encompasses a range of systems, and the management of forests under no particular system, but following the (Dauerwald) principles. The woodlands on the Bärenthoren estate which Troup described have changed considerably since then, but the (Dauerwald) approach has continued to be applied, with appropriate adaptation. Interest in this type of management has increased throughout Europe in recent years. The debate on the need for formal silvicultural systems and yield control is still current, but the outlook for (Dauerwald), in its widest sense, appears to be good.
64	**Helliwell 2002** An update of the first edition (1999). Continuous cover forestry involves a different approach towards forest management, compared with that which has been the norm in Britain for the last 100 years or more. Under continuous cover management, felling and regeneration are carried out continually or irregularly throughout the whole of the woodland area, and there is no clear felling of trees when they reach some predetermined age. The concepts of age and area, which govern the management of coppice woodland or clear felled high forest, are therefore not applicable to continuous cover forestry. The concept is not new. Troup (1927) described "Dauerwald' (continuous forest) as it was then being practised in Germany. The main principles were: (1) avoid clear felling, in order to secure 'a continuous harmonious cooperation of all factors of growth', i.e. the continuous maintenance of forest conditions; (2) every tree that is growing vigorously is retained, while trees that have ceased to grow vigorously are removed; (3) abandon the concepts of age-class and rotation; (4) obtain regeneration only as a secondary consideration; and (5) abandon elaborate calculations for fixing the annual yield, in favour of the determination of increment by periodic measurement (marking of trees for removal is carried out according to silvicultural criteria, rather than aiming for a specific volume or assortment of timber). Management along these lines may be seen as more natural than clear felling, but that may not always be the case, and arguments about what is and what is not natural may not always be helpful. The main advantages of continuous cover forestry are that forest conditions are retained at all times, so that there is no sudden or drastic change in the landscape. Plants and animals which thrive under permanent woodland conditions are conserved, and the production of timber is more even and more regular. It is relatively easy to leave some standing and fallen dead trees for wildlife and it is possible to concentrate on producing a steady supply of large diameter stems rather than a larger number of stems of less than average size. More recently, the Continuous Cover Forestry Group has defined 4 principles of Continuous Cover forestry (CCF): (1) adapt the forest to the site; (2) adopt an holistic approach to forest management; (3) maintain forest conditions and avoid clear felling; and (4) concentrate on the development of preferred individuals rather than blocks, but within the context of the whole stand growing stock. These principles, and the objectives of CCF, appropriate tree species, constraints, yield control, conversion of even-aged woodland to CCF, and natural regeneration are discussed.

Ref. No.	Author/Abstract
65	**Hiley 1953**
	"Irregular forestry" is forestry in which various silvicultural systems are jumbled together. Instead of clearfelling large areas, the best parts may be retained, patches of natural regeneration may be opened up and other parts may be heavily thinned and under-planted. Clearfelling and replanting may, however, be practiced where desirable. The advantages and dangers of the system are discussed.
66	**Hiley 1956**
	A 7.9 acre stand of Japanese larch, 25 years old, has been thinned to 50 trees per acre and under-planted. The thinning has removed 1203 h. ft. o.b. per acre and the volume of the remaining trees is 474 h. ft. per acre. The remaining trees average 56.4 ft in height, are nearly clear of branches to 30 ft and have a b.h.q.g. of 7.1 inches. It is estimated that after allowing for all expenses and overhead charges, the net income from previous thinnings has been £41 8s and from this thinning £147 per acre. Calculations suggest that, allowing present costs of planting, brashing and annual maintenance, a financial yield of 6.1 percent would have been earned if the stand had been clearfelled at 25 years. Evidence is advanced, however, to show that, if the remaining trees grow satisfactorily they are likely to earn a higher rate of interest than this if they are left for another 25 years. This treatment creates a two-storied high forest. The silvicultural implications of this system are discussed.
67	**Hiley 1959**
	The system has been adopted at Dartington with Japanese larch, and it has been suggested that it works there because Japanese larch grows fast. It is argued in this paper, however, that the system is best adapted to rather slowly-growing trees and the reason for its use with Japanese larch is that this species is characterised by rapid height growth but a small current annual increment, so that, unless the trees are isolated, they make extremely narrow annual rings. With Douglas fir and Sitka spruce the annual rings might become too broad if this treatment were applied, except at a rather advanced age. Nevertheless, the system has certain other advantages and, to attain these, it may be useful to adopt it more extensively, even if the annual rings become broader than we like.
68	**Hodge and Pepper 1998**
	This note is designed to help woodland managers to diagnose mammal damage, to evaluate severity, to consider management options and to determine the appropriate action to take. The guide is brief but suggests sources of more information on damage control operations.
69	**Humphrey 2005**
	European forestry strategies place emphasis on developing alternative management practices to clearfelling within commercial forests as a means of increasing the non-market benefits of sustainable forestry. In the UK, many thousands of hectares are being transformed to continuous cover forestry and a number of minimum intervention natural reserves are being created to encourage the development of old-growth conditions. This paper defines the term 'old growth' in the context of upland spruce-dominated plantations in Britain and evaluates different options for the location, design and management of old-growth areas to enhance biodiversity. Evidence outside of Britain from semi-natural analogues of upland spruce plantations suggests that old growth can develop 100-200 years after stand initiation in those parts of the landscape not subject to frequent catastrophic disturbance by wind and fire. Old-growth stands in these forests are characterized by a high proportion of large, old trees, multiple age classes and high volumes of fallen and

Ref. No.	Author/Abstract
	standing deadwood. Studies of old spruce stands in the British uplands suggest that old-growth features can begin to develop after 80-100 years, conferring substantial benefits to species-groups such as hole-nesting birds, mammals (e.g. red squirrel), bryophytes, lichens and fungi. Based on the likelihood of wind damage it is suggested that ~ 50 per cent of the current land area in upland Britain could support large patches (50-100+ ha) of old growth. To enhance colonization by woodland species, these old-growth patches should be within 2 km of existing semi-natural woodland, managed ideally on a minimum intervention basis. If production of timber was also an objective, old-growth stands could be managed by single tree selection or small group-fell silviculture, provided that the over-prolific regeneration of shade-tolerant conifers was controlled and some deadwood and veteran trees were maintained. In surrounding areas subject to normal patch-clearfelling, small enclaves of old-growth forest (0.25-2 ha) could be retained to provide temporary habitat for species and facilitate dispersal throughout the landscape. The planning and design of old-growth areas needs to be considered at the landscape scale to ensure an appropriate balance between old growth and other types of woodland and non-woodland habitats. An imaginative approach to incentives will be required to encourage positive management for old-growth.
70	**Humphrey and Swaine 1997a**
	In Scottish upland, semi-natural oakwoods, natural regeneration of oak (*Quercus petraea* and *Q. robur*) is frequently lacking. This threatens the long-term persistence of a habitat of considerable conservation importance. In the absence of excessive grazing pressure, large openings in the woodland canopy can provide suitable sites for regeneration, but these are often dominated by dense stands of bracken *Pteridium aquilinum*, which is thought to restrict woody growth severely. In this paper experiments carried out in a semi-natural oakwood in north-eastern Scotland are described which tested the hypothesis that shading by a *Pteridium* canopy in summer and smothering by the dying fronds in winter exert a detrimental effect on the growth of oak seedlings. Two separate types of *Pteridium* stand were selected: the first were more dense and growing in relatively large gaps in the oak canopy, and the second were less dense and growing in smaller gaps. In the large gaps, 3 treatments were used: *Pteridium* cut continuously all year, cut in winter only, and uncut all year; in the small gaps only the first and second treatments were used. Artificially raised seedlings (raised from acorns of a type intermediate between the 2 oak species) were planted in June 1990 at all the sites and protected from rabbit browsing by wire cages. The effects of a *Pteridium* canopy on photosynthetically active radiation (PAR) during the growing season were also measured. The presence of a *Pteridium* canopy during the growing season reduced PAR to 5.9% of full sunlight in the larger canopy gaps, and to 11.4% in the small gaps. Over two growing seasons (1991-92), significant reductions in accumulated oak seedling biomass were recorded in both large and small canopy gaps. Significant increases in specific leaf area, leaf area ratio, and a decrease in root:shoot ratio were also recorded. Smothering by dying *Pteridium* fronds in winter significantly reduced seedling biomass, but had no effect on biomass partitioning or seedling morphology. These results suggest that effective control of dense *Pteridium* stands is necessary to promote the successful regeneration of oak. However, this should be done in conjunction with measures to ensure the continued supply of early successional woodland habitats.
71	**Humphrey and Swaine 1997b**
	Defoliation of oak trees and seedlings (*Quercus robur, Q. petraea* and putative hybrids of the 2 species) by various lepidopteran species was investigated in 2 upland semi-natural oakwoods (Dinnet and Ariundle National Nature Reserves) within contrasting climatic zones in the Scottish Highlands. Experiments with artificially planted seedlings of *Q. robur* and hybrids in 1989-91 were designed to test

Ref. No.	Author/Abstract
	4 hypotheses: (i) the failure of oak to regenerate naturally is partly attributable to defoliation of seedlings by insects; (ii) seedling defoliation is linked to canopy density and composition; (iii) the degree of seedling defoliation is linked to the extent of canopy defoliation; and (iv) defoliation is positively correlated with insect population density in the canopy. The extent of canopy defoliation of oak was significantly different between the 2 woodlands, with trees at Ariundle, located within a wetter climatic zone, more defoliated than those at Dinnet, which is in a drier zone. Defoliation also varied significantly between individual trees and between years. Defoliation was positively correlated with degree of infestation by the larvae of several lepidopteran species. Leaf samples at Dinnet were dominated by *Operophtera brumata*, and those at Ariundle by *Erannis defoliaria*. The degree of infestation was higher at Ariundle. Experimental seedlings were significantly more defoliated under oak canopy than in the open or under a *Betula* spp. canopy. Canopy defoliation was positively correlated with defoliation of seedlings growing directly beneath, but seedling defoliation was negatively correlated with oak canopy density. A group felling system using coupe sizes of over 0.5 ha is recommended for encouraging oak regeneration in woods more susceptible to insect defoliation such as Ariundle, where seedlings need to be kept free from the influence of an overhead oak canopy. Shelterwood systems, where seed trees are retained after extensive thinning, are not recommended. In woods similar to Dinnet, both group felling and shelterwood systems are appropriate management options. Woodland managers should be aware of defoliation problems within their woods before deciding on which silvicultural option to choose.
72	**Humphrey et al 2002**
	The detrimental effects of conifer plantations on open ground habitats have been well catalogued and discussed, but the potential contribution of planted forests to the conservation of woodland biodiversity has not been quantified to the same extent. This quantification is needed urgently to help forest managers fulfil commitments to biodiversity enhancement as outlined in the UK Biodiversity Action Plan, the UK Forestry Standard and the UK Woodland Assurance Scheme. Results are presented from a five-year programme of research aimed at obtaining baseline information on biodiversity in planted forests and evaluating the contribution of planted forests to the conservation of native flora and fauna. Fifty-two plots were surveyed in total, covering a range of different tree crops (Scots pine, (*Pinus sylvestris*); Sitka spruce, (*Picea sitchensis*); Norway spruce, (*Picea abies*); and Corsican pine, (*Pinus nigra* var. *maritima*) and stand ages (pre-thicket, mid-rotation, mature and over-mature) in three contrasting bioclimatic zones (upland, foothills and lowlands) throughout Britain. Additional plots were established in semi-natural woodland to allow comparisons between the biodiversity of plantations and native stands. Over 2000 species were recorded in total, including 45 Red Data Book species. Planted stands had similar or richer fungal and invertebrate communities to those of the native stands but poorer lichen and vascular plant communities. The latter were strongly affected by shading, dense, mid-rotation Sitka spruce stands having the lowest species counts. In contrast, these stands had a high diversity of mycorrhizal fungi, including a number of rare and threatened species normally associated with native pinewood. Bryophyte species richness was related more to climate than woodland type, with the wetter upland spruce and native oak stands having the most diverse communities. Compared to the younger planted stands, over-mature planted stands had a higher proportion of species characteristic of semi-natural woodland stands. This related to greater structural diversity and higher deadwood volumes in the over-mature stands. It is concluded that conifer plantations make a positive contribution to biodiversity conservation in the UK and hence to the UK Biodiversity Action Plan. No single stand or crop type provides 'optimal' conditions for biodiversity, but the habitat value of plantations could be enhanced by increasing the area managed under alternative systems to clear-felling, such as 'continuous cover' and/or non-intervention natural reserves.

Ref. No.	Author/Abstract
73	**Hutt 1974**
	Describes a long-term experiment on the Earl of Bradford's estate in Shropshire, where 100 acres of woodland composed of a number of even-aged stands of conifers or conifer/hardwood mixtures 40-150 years old are being converted to selection-type forest. The conversion method consists essentially in: (1) dividing each compartment into a series of small contiguous square units each consisting of 9 square plots large enough to contain, at whatever rotation age is chosen, one 'mature' tree of the main species to be grown; (2) clearing and replanting (or regenerating naturally) the centre plot of each unit, and thinning the remaining plots as required; and (3) continuing to fell and regenerate the remaining plots in turn at regular intervals during the rotation, starting with a corner plot and working anti-clockwise round the centre plot. In the example given, the plot size is 20×20 ft (sufficient for one mature Douglas Fir 50-55 years old), the rotation age is 54 years, the 9 plots are felled on a 6-year cycle, and thinning is done on a 3- or 6-year cycle. Advantages of the method, especially flexibility of management, are pointed out, and problems of choice of species or mixtures, initial lay-out of units on the ground, marking, felling and extraction, yield control etc. are discussed.
74	**Johnston 1978**
	An examination and review of the concept of irregularity in forestry, in terms of mixed and all-aged crops, and thinning regimes. It is concluded that although aesthetically more pleasing, a complicated irregular system of forestry will be less stable and more expensive than a uniform, regular system.
75	**Jones 1945**
	His paper reviews features of the structure and reproduction of north temperate virgin forests, with reference to current ecological theories of disturbance and succession. The paper is based on data from North America, north-east Asia (Manchuria and Japan) and Europe. .
77	**Kenk and Guehne 2001**
	The historical background, the management practice, growth and yield aspects of transformation of artificial coniferous stands in Central Europe are outlined. Past management has reduced the proportion of natural broadleaved forests from 66 to 33 % of the forest area. The pure stands of planted Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*) show increased instability and susceptibility to damage by snow and wind. Proposals for transformation go back to the nineteenth century, but the diversity of sites, stand structures and different goals of owners make transformation a variable task. This paper outlines three case studies of transformation and some results of growth research into transforming coniferous stands, based on the situation in south-western Germany which is comparable to other parts of central Europe. The first case study deals with two experimental stands in the southern Black Forest which have been developed from an even- to an uneven-aged structure. Diameter distribution, residual volumes, harvesting results and periodic increments and yields are characterized. The second case study outlines the transformation of pure Norway spruce stands. On stable sites, an uneven-aged mosaic structure with 20-40 % beech can be reached by crop-tree oriented thinning from above, target-diameter harvesting, natural regeneration and under-planting of beech if needed. On unstable sites, transformation will be realized either by clear felling and sowing, conversion to oak by planting or by under-planting of silver fir and single-tree harvesting. The third case study deals with pure Scots pine stands: natural regeneration of Scots pine allows transformation options either rather fast in combination with clear felling and/or sowing, or delayed with lasting regeneration procedures, or as nearly continuous cover system with low density of

Ref. No.	Author/Abstract

overstorey. Some growth and yield problems in transforming coniferous stands are shown using the example of the 'Langenbrand-experiment', started in 1927 in the northern Black Forest. There are effects of differing regeneration periods on growth rates caused by the interaction between the old and the young stands. These have an influence on the growth reactions of the residual trees, their mortality and the pattern of height:diameter (*h:d*) ratios in the natural regeneration. The *h:d* relationships of the young stands depend on the length of the regeneration period with longer periods promoting more favourable ratios which should positively influence the stability of future stands.

78 **Kerr 1999a**

The silvicultural characteristics of European silver fir make it a potentially useful tree throughout Britain, particularly in continuous cover forestry. However, contemporary silvicultural wisdom is that the species suffers from devastating attacks of silver fir woolly aphid (*Adelges nordmannianae*) and is, therefore, not worth planting. This advice has been based almost exclusively on experience when the focus of forestry was timber production from plantations. Silviculturally, silver fir is unsuited to open plantings but can thrive as a component of mixed-species, uneven-aged woodlands. If used in such a way, this may reduce the problems associated with the aphid and would certainly protect the species from unseasonal frosts. Further work is required to re-assess the potential of silver fir in British forestry.

79 **Kerr 1999b**

This review considers possible changes in the silvicultural systems applied to plantation forests in Britain, in response to demands for enhanced biodiversity. The options considered are: (1) extension of rotation length of selected forest stands; (2) improvement in vertical structure through variations in stand treatments such as thinning, pruning and respacing, and the use of new methods such as snag creation and green tree retention; (3) increased use of species mixtures; (4) introduction of alternative silvicultural systems to harvest at a range of scales to improve spatial heterogeneity. The first 3 options can be achieved while maintaining clear felling as the predominant silvicultural system, and importantly, offer a way forward in the short term. The introduction of a range of alternative silvicultural systems poses the greatest challenge to current plantation silviculture. This is a longer term option, and requires testing of the systems on a range of site and forest types, and development of the skills base of forest managers. However, obstacles to these changes exist and it is concluded that unless benefits to biodiversity can be clearly demonstrated, which outweigh increased costs, any large-scale modifications to existing silvicultural systems will be limited.

81 **Kerr 2001b**

Results are presented of a study on the application of silviculture and on three uneven-age stands in the UK (Snake Wood, Plashetts Wood and Knightwood) and provides guidance on how uneven-age silviculture could be used in the UK.

82 **Kerr 2002a**

This paper describes an investigation into the potential use of uneven-aged silviculture in woodlands which have historically been managed using coppice with standards. The study is presented in two parts: the first examines criteria to help decide whether the structure of a woodland is suitable for uneven-aged silviculture, the second proposes two methods of implementation. Three woodlands were selected for the study and data on stand structure and natural regeneration were recorded for nine different strata within these areas. Three criteria were chosen to help decide which stands were suitable for uneven-aged silviculture, these related to

Ref. No.	Author/Abstract
	basal area, size distribution of trees, and the amount, height and species of natural regeneration. Data from the nine woodland strata were compared with the criteria and only one satisfied all of them. The woodlands had an adequate basal area and generally a good distribution of diameters. However, the main constraints were the failure of seedlings of the desired species to develop into saplings, and a lack of information on the use of neglected coppice to produce canopy trees. It was concluded that the criteria were useful but could not be used in isolation from silvicultural judgement. The two methods of implementation were the reverse-J diameter distribution and the frame tree method. The reverse-J method is a traditional approach to uneven-aged silviculture in which the diameter distribution is manipulated to resemble an 'ideal' structure. To determine a suite of 'ideal' reverse-J diameter distributions, data from the strata were investigated using a negative exponential function. The second approach, the frame tree method, is a more flexible approach compared with the reverse-J method, and could be used to produce a greater variety of uneven-aged stand structures. Neither of the approaches has been validated and both pose many questions which can probably only be answered by practical implementation.
83	**Kerr 2002b**
	This paper describes two methods for managing uneven-aged stands and demonstrate how they could be used with reference to three woodlands in England, namely, Plashetts Wood in East Sussex with an even-aged canopy, and a dense mixed-age understorey of sycamore (*Acer pseudoplatanus*); a mixed stand of grand fir (*Abies grandis*), Douglas fir (*Pseudotsuga menziesii*), sycamore and ash (*Fraxinus*) on a sandy soil overlying chalk at Snake Wood, Thetford Forest; and a stand of Sitka (*Picea sitchensis*) and Norway spruce (*P. abies*) at Knightwood Inclosure in the New Forest. The first method, the reverse-J diameter distribution, requires a reliable estimate of numbers of trees by species and size classes. The second method, equilibrium growing stock, uses volume and therefore, in addition to numbers of trees by species and size classes requires an estimate of form height. Although there are some areas where knowledge is incomplete, by making some assumptions, both methods could be readily used in Britain. A combination of increased experience and research is required to learn more about uneven-aged silviculture in Britain.
84	**Kerr and O'Hara 2000**
	An uneven-aged woodland is defined as a woodland with 3 or more age classes. Uneven-aged silviculture is then a sequence of stand interventions designed to perpetuate the presence of these classes, and to produce conditions of continuous cover. Common myths about the practice and benefits of uneven-aged silviculture are that uneven-aged woodlands consist of trees of many different sizes, mainly of shade-tolerant species, that they are managed using a reverse-J structure, and that they are more diverse and less productive than even-aged stands. This article explores these myths and attempts to suggest ways forward for this type of uneven-aged silviculture in Britain.
85	**Kerr et al 2003**
	The paper describes work carried out to devise a system of monitoring the change from even-aged management to continuous cover. The application of the system is described in Forestry Commission Information Note 45 (Kerr et al., 2002). It uses systematic grid sampling with plot size selected to assess a minimum number of trees, depending on the area of the management unit, and was designed by carrying out a number of simulations based on data for theoretical and real stands of trees. It was field tested in two woodlands being transformed to continuous cover, both of which had a mixture of tree sizes and a range of species. The results of these

Ref. No.	Author/Abstract
	studies suggest that the proposed sampling system will give an adequate representation of the trees in a stand in terms of diameter distribution and species proportions. However, the ability of the sampling system to collect data on sapling regeneration was not fully tested and requires further work.
86	**Kerr et al 2002**
	The aim of transformation is to change the structure of even-aged stands from one that is regular to one that is more diverse and varied. A system of monitoring is described which will allow forest managers to record these changes and select appropriate stand interventions. The method uses fixed-area plots, located on a systematic grid over the whole area being transformed; the plots can be permanent or temporary depending on the data required by the forest manager. The main assessments are species, number and diameter of trees (≥ 7 cm diameter at breast height (dbh)), and the species and number of saplings (trees< 7 cm dbh and ≥ 130 cm tall). Interpretation of the results of the monitoring depends on whether transformation is aiming for a simple structure (1 or 2 canopy strata) or a complex structure (3 or more canopy strata).
87	**Kerr et al 2005**
	This paper discusses the concept of ‘adaptive management’ as one way of carrying out continuous cover forestry. The paper includes examples of how stands can be monitored using new software developed by Forest Research. In addition, the issue of management and monitoring costs associated with continuous cover stands is addressed.
89	**Knoke and Plusczyk 2001**
	This paper compares a transformation strategy with an even-aged (EA) treatment (rotation period 98 years) that concludes in a clear-cut. Transformation began at a stand age of 41 years after which both strategies were considered for 77 years. In order to describe the treatments, data from a thinning trial and measurements from a two-aged stand (spruce 58 years, fir 15 years) in Freising (Upper Bavaria, Germany) were used. To project the data up to a stand age of 118 years simulations using the single tree, distance dependent growth model SILVA were carried out. The economic analysis showed a considerably lower amount on harvested timber and a considerably lower income earned for the transformation strategy. However, income from the transformation strategy occurred earlier and more uniformly distributed over time. Due to this fact, the net present value of transformation exceeded that of EA management during a limited time period of 77 years given an interest rate of 2.6% (break-even interest). Assuming an infinite time horizon, the break-even interest rate was 1.9%. Changes in stumpage price or rotation length showed minor impact on the break-even interest of transformation.
90	**Knuchel 1953**
	An important forest management text translated from German by Professor Mark Anderson. The section on the “Check Method” provides a detailed history and technical description of management systems in irregular structure stands. The focus is German and Swiss forest conditions.
91	**Long et al 2004**
	Responses to most silvicultural practices result from their influence on the amount of resources potentially available for growth, the ability of crop trees to acquire those resources, and the distribution of resources among components of the population. We review several conceptual models useful in accounting for important tree- and

Ref. No.	Author/Abstract
	stand-level responses to a variety of silvicultural treatments. These conceptualizations of stand dynamics and production ecology do not directly associate growth response to resources, such as water and nutrients; but they facilitate the use of leaf area as an integrator of the ecological processes being silviculturally manipulated. We discuss several common silvicultural practices, including early competition control, soil manipulation, thinning, and fertilization, in the context of their influence on the amount, distribution, and net efficiency of leaf area.
92	**Low 1988**
	A trial established at Glen Tanar in 1982 examined mechanical patch scarification as a means of encouraging natural regeneration in a native pinewood. Seedling development was monitored over five growing seasons, and by October 1986 there was an average of 13 seedlings per scarified patch with the tallest seedling height ranging from 3-35 cm. Results demonstrate the effectiveness of scarification as an aid to re-stocking managed native pinewood areas.
93	**Maguire 2005**
	This paper presents the results of comparisons of uneven-age systems of managing plantations, which were conducted through simulation. It was found that non-timber constraints on uneven-age systems can significantly reduce yield and value productivity; that is, stands optimized for timber productivity may not necessarily meet non-timber objectives, and uneven-aged stands meeting non-timber objectives will not necessarily produce as much wood as even-aged stands.
94	**Malcolm 1971**
	The Corrour management trial was established by Professor Mark Anderson in the early 1950s. This paper provides a history of the trial and information on regeneration, thinning, site conditions and economics. Data on stand development and increment are included.
95	**Malcolm et al 2001**
	There are about 1.5 Mha of conifer high forest in Great Britain composed almost entirely of even-aged plantations of non-native species established since 1900. Recent changes in forest policy require managers to introduce alternative silvicultural systems to clear felling into windfirm conifer plantations to provide greater structural diversity and so enhance aesthetic, conservation and environmental benefits. There are around 500-750 kha of British forest established on sites which are sufficiently windfirm to be affected by this requirement but only 10-20 kha that are being managed under an appropriate silvicultural system. Expanding the area in the latter category will confront managers and researchers with major ecological, silvicultural and practical challenges. The process of transformation from uniform to irregular stands is best achieved using natural regeneration, except where other species or genotypes are desired. The start of transformation must await adequate seed production which will probably not occur before 30 years of age for the four major conifer species; Sitka spruce (*Picea sitchensis*), Scots pine (*Pinus sylvestris*), Corsican pine (*Pinus nigra* var. *maritima*), and Douglas fir (*Pseudotsuga menziesii*) as well as a number of minor species. Once this age has been reached, manipulation of the canopy can create suitable microclimates for seedling germination and growth. Suitable conditions depend upon interacting ecological factors, the most important of which is the light climate at ground level. Because of the relative shade intolerance of the major tree species and the lower irradiance and greater cloudiness in Britain, appropriate gap sizes for regeneration may be quite large. Minimum gap sizes are usefully defined by the ratio of gap diameter to height of surrounding trees (*d:h*). Proposed *d:h* ratios range from

Ref. No.	Author/Abstract
	> 2.0 for Scots and Corsican pines, 1-2 for Sitka spruce and Douglas fir to 1.0 or less for more shade-tolerant species (e.g. *Picea abies*, some *Abies* spp., *Tsuga heterophylla*). Unless greater use is made of these shade-tolerant species, it appears that silviculture systems such as single stem selection will be inappropriate and more emphasis should be given to group selection and irregular shelterwood systems. Given the limited experience of irregular systems in Britain, it is probable that trials of transformation will be confined initially to windfirm areas of high amenity, conservation or heritage value.
96	**Mason 2001** This paper addresses some of the wider challenges facing adoption of CCF systems in Britain. These include: combination of a windy climate and shallow soils in some upland areas that results in stands vulnerable to windthrow; lower light intensities in an oceanic climate and the lack of shade tolerant species leading to the use of larger gap sizes to achieve regeneration; high deer numbers which limit regeneration potential; a lack of experience in alternative systems and confidence in their use. These challenges can be overcome by an adaptive management approach based on a network of field scale operational trials in suitable forests. The results from these trials can be the catalyst for the wider use of continuous cover forestry in the transformation of British conifer forests to meet multi-purpose objectives.
97	**Mason 2002** The proposed transformation of substantial areas of even-aged plantation forests in Britain to irregular structures ('continuous cover forestry') has raised concerns about the likely wind stability of irregular stands. A review of the literature suggests that the major difference between irregular and regular stands is the lower (i.e. more stable) height:diameter ratio associated with the dominant trees in the former. This appears to be a consequence of the greater wind loading that these dominant trees have to withstand. Wind tunnel studies show no difference in wind profile within or above the two types of canopy. There have been few comparative root investigations in the two types of stand and no differences in rooting depth have been reported, although changes in root architecture could be anticipated as a result of greater wind loading. The implications of these findings upon windthrow risk in regular and irregular Sitka spruce stands has been explored using the Forest GALES wind risk model on sites of different wind exposure. The results suggest no difference in wind risk on sheltered sites. On sites of moderate exposure, an irregular stand at close to 'steady state' conditions could be more wind stable than a conventionally thinned regular stand. However, this advantage disappears with increasing exposure. The conclusion is that the promotion of irregular stands may provide structures with more stable characteristics, but these cannot be considered in isolation from the prevailing wind climate and the local site type.
98	**Mason 2003** Recent British forestry policy statements envisage a much greater use of Continuous Cover Forestry (CCF) in the management of conifer plantation forests. The most recent example is the Welsh woodlands strategy, which proposes that at least 50 % of the predominantly coniferous Forest Enterprise woodlands should be transformed to CCF management by 2020. Greater use of CCF will require prolonging conventional conifer rotations into later stages of stand development of which there is little experience in Britain. The main limiting factors to transformation are the need for thinning to create a favourable regeneration environment and the risk of windthrow. Analysis of wind exposure suggests that perhaps 30 % of Forest Enterprise sites in Wales and Scotland are too exposed for CCF to be feasible and site feasibility decreases to approximately 50 % in Wales when soil limitations are considered. Comparative figures suggest soil limitations are even more serious in

Ref. No.	Author/Abstract
	Scotland so that perhaps only 25-30 % of sites are suitable for CCF, given current knowledge. Examination of wind risk on sites of different exposure under standard thinning regimes shows how, with increasing age, exposed stands become more vulnerable to damage following thinning. A modified thinning regime based upon heavy early thinning followed by no intervention for approximately 15-20 years during the most vulnerable period appears to be a less risky option, but this requires to be validated in practice. A survey of a 60-year-old Sitka spruce (*Picea sitchensis*) stand on a comparatively exposed site in Wales showed good regeneration of a range of species, which appeared to be linked to the comparatively low basal area providing a favourable light environment for seedling establishment. A model of potential stand development of Sitka spruce plantations on good rooting soils is proposed. This shows the importance of larger gap sizes (i.e. 0.1-0.3 ha) for successful regeneration of the main species, the likelihood of mixed species stands developing, and the continuing importance of wind disturbance. The most suitable silvicultural system for achieving CCF is likely to be some form of irregular shelterwood because of wind constraints and species requirements but this assumption will need to be validated in adaptive management trials.
99	**Mason and Kerr 2004**
	This Note is a revision of the previous Forestry Commission Information Note 40 incorporating experience from a number of trials in different parts of Britain. It outlines an approach to the transformation of even-aged conifer stands in Britain. There are three stages in the process. Firstly, the potential for transforming a stand to continuous cover management is ranked using windthrow risk, soil fertility and species suitability as criteria. This ranking is then checked in the field, paying particular attention to stand structure and condition. Secondly, the manager needs to decide whether a simple or a complex stand structure is desired. Thirdly, 1 of 4 stand management options is chosen, based upon the structure desired and the age of a given stand.
100	**Mason and Quine 1995**
	Kielder Forest comprises some 50 000 ha of first- and second-rotation spruce (*Picea* spp.) plantations created during this century on surface-water gley and peaty gley soils in northern England. The original limiting factors to tree establishment and growth, high water tables and low nutrient status, were largely eliminated by appropriate silviculture using soil preparation, cultivation, some drainage and remedial fertilizer application. The main limiting factor to tree growth is now wind disturbance compounded by shallow rooting on the gleyed soils. To avoid the risk of windthrow, stands are left unthinned and are clear-felled at 35-40 years of age. However, the deterministic nature of the windthrow hazard classification used to predict the onset of wind damage means that the possibility of retaining stands for longer rotations may have been underestimated. Recent evidence suggests that, provided stands are planted using cultivation techniques that promote a stable root architecture and are respaced at an early stage to promote stem diameter growth, it should be possible to maintain some stands for at least 75-80 years to enhance structural diversity. The spread of gaps formed by windthrow in spruce forests and the development of a 72-year-old self-thinning Sitka spruce (*Picea sitchensis)* /Scots pine (*Pinus sylvestris*) mixture exemplify these possibilities.
101	**Mason et al 1999**
	Continuous cover forestry (which has also been called close-to-nature, holistic or ecological forestry) involves the maintenance of a forest canopy during the regeneration phase with a consequent presumption against clear felling in favour of alternative silvicultural systems. Although there are likely to be cost penalties from the use of continuous cover systems these can be more than offset by the provision

Ref. No.	Author/Abstract
	of enhanced non-market benefits. The main constraints are the risks of windthrow and of regeneration failure through browsing or vegetation competition, and the lack of experience of alternative silvicultural systems in British forestry. However, despite these limitations, there is potential for greater use of continuous cover forestry on selected sites throughout Britain as one means of providing more diverse forests for multipurpose benefits.
102	**Mason et al 2004**
	Alternative silvicultural systems to clearfelling are being adopted in Great Britain as a means of increasing the species and structural diversity of conifer plantation forests. One area where knowledge is lacking is the critical level of below-canopy light for survival and growth of young seedlings. This was investigated by planting seedlings of European larch (*Larix decidua*), Scots pine (*Pinus sylvestris*), Sitka spruce (*Picea sitchensis*), Douglas fir (*Pseudotsuga menziesii*), and western hemlock (*Tsuga heterophylla*) in a Sitka spruce plantation thinned to 3 different spacings. The incident light intensity beneath the canopy ranged from about 2 to over 60 per cent of full light. Planting in an adjoining open area provided an indication of growth under full light. Growth and survival of these seedlings were followed for 4 growing seasons. The highest seedling survival was found under the widest spacing and declined with closer spacing and lower light intensity. Only Douglas fir and western hemlock seedlings survived at the closest spacing, and in low percentages. The tallest seedlings of each species were found in the open grown conditions but survival was variable due to increased weed competition. Species-specific growth responses showed little difference under high light conditions but performance at low light was generally consistent with shade tolerance rankings in the literature except that Sitka spruce shade tolerance was slightly lower than expected. Minimum light requirements for these species increased from 10 to 30 per cent of full light with decreasing shade tolerance. Other studies of incident light in Sitka spruce plantations indicated that target basal areas in the range 25-30 m^2 ha^{-1} are required if these light conditions are to be met, which suggests an irregular shelterwood system with frequent interventions should be favoured.
103	**Matthews 1990**
	A silvicultural system embodies three main ideas: the method used to regenerate individual crops, the form of crop produced and the orderly arrangement of these crops over the whole forest. The main groups of silvicultural systems used in western and central Europe today are coppice systems, high forest systems, and agroforestry systems. Their origins and evolution are traced, emphasising the period from 1750 to 1950. These developments originated in social, political and economic events, particularly the rise in population, the state of agriculture, the industrial revolution and a series of devastating wars. Progress in forest science, and changes in the attitudes and education of professional foresters and the owners of forests are also important. Some conclusions are drawn about the future development of silvicultural systems.
104	**Matthews 1991**
	This book is an update and modernisation of the text by Troup (1928)[see reference 172]. The text provides comprehensive coverage of both high forest and coppice silvicultural systems, and includes information of tree development and regeneration in forest stands.
105	**Mayle 1999**
	Deer are an important part of our wildlife and are attractive animals which people enjoy seeing in our countryside. However, they must be managed to keep them in

Ref. No.	Author/Abstract
	balance with their habitat and prevent serious damage to woodlands, trees, crops, gardens and other wildlife. This note is mainly for people who are not familiar with deer or their management but who own or manage woods, farmland, nature reserves, parks or gardens where deer may live now or may colonise in future. It provides information on: identifying whether there are deer present and of which species; deciding whether deer are causing damage; ways in which deer problems can be prevented and knowing where to go for more advice. The focus is mainly on lowland regions, particularly in England and Wales, but the principles can be applied elsewhere.
106	**Mayle et al 2004**
	Since their introduction into Britain in various locations between 1876 and the 1920s, grey squirrels have spread rapidly. They have displaced the native red squirrel throughout most of England and Wales, and in central and south-east Scotland. In addition to ecological impact on the native red squirrel, grey squirrels represent one of the most serious damaging agents in woodlands, stripping bark from the main stem and branches of trees. This practice note describes the nature of damage and species most at risk, effects of damage, damage prediction, damage control strategies and control methods. The report provides current advice on live trapping, tunnel trapping and poisoning with Warfarin as methods for controlling grey squirrel populations. There is additional information on current research in immunocontraception.
107	**McIntosh 1995**
	This introductory paper describes the site types and afforestation history of Kielder Forest in northern England and outlines current management practices which are intended to enhance the landscape, wildlife conservation and amenity values of the forest. A structured approach to forest design planning is described, involving zoning of the forest in terms of visual sensitivity and the production of long-term felling and restocking plans which aim to convert first rotation, even-aged plantations (72 % Sitka spruce (*Picea sitchensis*), 12 % Norway spruce (*P. abies*), 9 % lodgepole pine (*Pinus contorta*), 4 % larch (*Larix* spp.) and other conifers, and 1 % broadleaves) into a diverse and interesting forest. Tree species choice is a key factor in determining the productivity and environmental impact of the forest and a rationale for determining the optimum species mix is advanced along with an attempt to cost the consequences.
108	**McNeill and Thompson 1982**
	Sample counts of Sitka spruce (*Picea sitchensis* (Bong.) Carr.) seedlings were made across small (0.04 ha) circular clearings in mature stands. Survival of seedlings was found to vary with time after germination, position in the clearing, and micro-site conditions. Best germination and survival occurred on the southern edge of clearings. Greatest losses of between 20 and 30 percent happened during the first and second growing seasons. Mineral soil surfaces gave better survival than those of peat covered with needle litter. Competition from other forms of ground vegetation seemed less important immediately after the clearings were made than in later years.
109	**Miller et al 1998**
	Many of the few remaining patches of natural woodland in the Scottish Cairngorms are failing to regenerate because tree and shrub saplings are repeatedly checked or killed by browsing red deer (*Cervus elaphus*). Liability to browsing is governed by a complex of interacting factors including a sapling characteristics, season of year, availability of alternative foods, soil conditions, nature of surrounding vegetation and

Ref. No.	Author/Abstract
	local red deer density. Amongst common native tree and shrub species in the Cairngorms, deer prefer to eat rowan (*Sorbus aucuparia*) but generally take juniper (*Juniperus communis*) only when alternative foods are scarce. Young Scots pine (*Pinus sylvestris*) saplings are the most easily killed by browsing, whereas birch (*Betula pendula, B. pubescens*) and rowan can survive repeated damage. Many saplings, including pines, are maintained in a suppressed state by repeated browsing. These plants constitute an often long-lived 'sapling bank' from which rapid growth can occur once browsing pressure has been relieved. On unburnt ground in the Cairngorms, conditions for tree regeneration are currently most favourable at altitudes greater than 550 m because here there are (a) fewer deer and (b) more gaps for seedling establishment than is the case on lower ground. Reducing red deer density to fewer than about 5 animals/km^2 increases the possibility of woodland regeneration everywhere. However, this in itself may be insufficient to produce good seedling establishment in dense ericoid or graminoid vegetation with its associated deep mor humus layer. Ground preparation by fire or by mechanical disturbance may be necessary in such circumstances if rapid and extensive regeneration is required.
110	**Miller 1985**
	A revised and refined version of an earlier system of classifying hazards in coniferous forests in Great Britain based on regional windiness, altitude, exposure and soil conditions. Factors affecting windthrow, field assessment and mapping, management implications of the classification (planning felling and thinning) and its limitations and possible future refinements are briefly discussed.
111	**Mlinsek 1996**
	This article discusses some of the principles of transformation from clearfelling to close-to-nature silvicultural systems. Examples are given based on the author’s long experience in his native Slovenia.
112	**Mountford 2002**
	Shellem Wood was a mature beechwood (*Fagus sylvatica*) before half (1.4ha) of it was blown down in the Great Storm of October 1987 in southern England. Fallen trees were salvaged and about half of the damaged area was replanted, mainly with groups of beech. By 2001, few transplants remained alive and only cherry (*Prunus avium*) transplants had grown well. Vigorous natural regeneration had developed on shallow soils: ash (*Fraxinus excelsior*) was dominant on rendzinas and birch (*Betula pendula*) on brown earths. On deeper brown earths, natural regeneration was more mixed but less abundant, leaving bramble abundant in places. Grey squirrels (*Sciurus carolinensis*) had debarked many birch poles, particularly those ≥ 4 cm diameter at breast height, and pose the most serious threat to stand development. The implications for restocking broadleaved woodland are discussed.
113	**Mountford and Peterken 1999**
	Beech (*Fagus sylvatica*) is particularly vulnerable to bark stripping by grey squirrels (*Sciurus carolinensis*), especially when it is growing rapidly with a high average phloem volume. Patterns of bark stripping have been explained in various ways, but it seems more intense in stands which have been thinned (i.e. where growth rate and phloem volume have increased). This note records evidence for the influence of thinning on bark stripping intensity in Lady Park Wood, a mixed deciduous woodland on the river Wye, UK, where stand dynamics and growth rate have been observed for over 50 yr. The reserve comprises a non-intervention area containing both old-growth (80-190 yr old) and young-growth (50 yr old) stands, and an adjacent managed compartment which had had a similar composition and treatment history

Ref. No.	Author/Abstract
	until management (regeneration only by stump regrowth or natural seeding) started, containing stands thinned in 1982 and/or 1993 (canopy age about 50 yr), and unthinned stands intermediate between old- and young-growth in age. Bark stripping damage was recorded in the 4 stand types on different dates (in 1992, 1993 and 1997). The damage index was greatest in the thinned and young stands, and in trees of dbh (diameter at breast height) 10-35 cm. Faster growing trees also tended to be more damaged. The implications for stand management are discussed, and recommendations made include growing species less susceptible to bark stripping than beech, and growing beech as a minority component of mixtures until the final thinning, since there was evidence that squirrels did not attack vulnerable beeches where they were rare in the stand.
114	**Mountford and Peterken 2000**
	A permanent transect at Scords Wood (Kent, SE England) was resurveyed one, four and eleven growing seasons after a storm in October 1987 caused devastating damage, as part of a national programme of long-term monitoring in unmanaged woodland nature reserves. The aim was to monitor the performance of trees, shrubs and saplings in these woods at roughly decade intervals, thereby enhancing knowledge on natural woodland development and the processes that drive changes in these woods. The woodland was dominated by beech (*Fagus sylvatica*) pollards in a plateau wood-pasture, pedunculate oak (*Quercus robur*) coppice, and birch (*Betula pendula*), together with a few holly (*Ilex aquifolium*), rowan (*Sorbus aucuparia*) and willow (*Salix caprea/S. cinerea*). The ground vegetation was dominated by either bramble (*Rubus fruticosus*) or bracken (*Pteridium aquilinum*), although large areas remain covered solely by trunks and branches from fallen beech and oak. As a result of the storm, much of the plateau beech wood-pasture was levelled, while the marginal oak coppice was partly -damaged; overall, canopy cover was reduced to 2%. Eleven years after the storm, most fallen and large standing trees had died; survivors were growing weakly, and more by fresh sprouts than crown expansion. About half of smaller beech trees had survived and most were sprouting. Regeneration was patchy; birch regeneration was copious in patches that remained free of debris, but other recruits were scarce, amounting to 3 beech (one growing from a root nodule), 1 vigorous rowan, 2 weak oaks and 1 spindly willow. Volume of fallen dead wood remained very high after 11 years, at >400 m^3 ha^{-1}, comprising mainly bollings and trunks which were little decayed. Bramble and bracken were dominant ground flora in well-lit gaps. The changes in the transect appear to be representative of the reserve as a whole. Whilst there has been limited recovery of some standing and fallen beech and oak, the former old-growth beech/oak stand had been converted by the storm into birch-dominated young growth.
115	**Mountford and Peterken 2001**
	Changes in the trees, shrubs and ground vegetation in the central area of The Mens nature reserve, West Sussex, were quantified following the impact of a severe storm in October 1997. Recordings were made in 12 equally spaced, permanent, 20 m-diameter circular plots in winter 1988-89 and spring 1998, and in 9 canopy gaps in winter 1987-88 and spring 1998. Information was recorded on the mortality, damage, survival, growth and regeneration of trees and shrubs and general developments in the ground vegetation. Prior to the storm the stand was a well-stocked old growth, high forest, with beech and oak dominating the canopy over a patchy understorey of mainly holly, hawthorn and hazel. The development of the stand before the 1987 storm, its immediate impact, the responses and development to 1998, and a long term impact and likely role of the main tree and shrub species are discussed.

Ref. No.	Author/Abstract
116	**Nixon and Cameron 1994** The aim of this study was to estimate the period over which Scots pine in the Marr Lodge estate woodlands in Deeside can be expected to produce good quantities of viable seed. The age structure of the woodlands was found to be semi-irregular in nature with trees having a mean age of 226 years with a range of 132-352 years. Only a slight decline in cone and seed production was recorded in the older trees and no reduction in seed viability. Reduced seed production in all the trees was more often attributable to physical loss of crown through wind and snow damage. The seed viability was also found to be lower in areas of scattered pines possibly due to increased rates of self-pollination. The results suggest that whilst the majority of the trees might be expected to produce good quantities of viable seed for at least a further 100 years, the areas with older scattered trees are more at risk and it is in these areas that operations to encourage natural regeneration should be initially concentrated.
117	**Nixon and Worrall 1999** After an introductory chapter noting the historic and current use of conifer natural regeneration in the UK, and listing the advantages and disadvantages of its use in forest management, there are 6 further chapters. These cover: seed production and dispersal; seed dormancy and germination; seedling establishment; the assessment and management of established seedlings; economics (a comparison of the costs of natural regeneration and planting, and respacing costs); and forest management to encourage natural regeneration. An appendix provides notes on natural regeneration by species.
118	**Nyland 1996** A textbook of silviculture with detailed information on tree growth in forest stands and silvicultural systems. Mainly North American focus.
119	**Nyland 2003** Changing philosophies of management have encouraged some landowners to consider converting existing even-aged stands to an uneven-aged arrangement. This will require an extended time as managers partition the cut of original trees in periodically establishing new age classes and maintaining the vigour of ones that develop. Strategies might include forms of uniform partial cutting, or patch cutting combined with thinning. The approach depends upon the shade tolerance and regeneration potential of the component species. Also, the limited growth potential of original trees that occupied poor crown positions will force landowners to rely on the dominants and co-dominants as residual growing stock during the conversion of most even-aged stands. Stratified mixed-species stands would allow a different approach. While experience suggests some clear options for the first entry towards conversion, later cuttings are more difficult to envision at present.
120	**O'Callaghan 2005** This short article explores the potential benefits of continuous cover forestry in the Irish context.
121	**O'Hara 1988** The growth of individual trees from four thinning treatments in a 64-yr-old (*Pseudotsuga menziesii*) stand in western Washington was analysed to determine desirable residual stand structures after thinning. Dominant and co-dominant trees had the highest individual tree stem volume growth rates over the previous 5 yr and

Ref. No.	Author/Abstract
	accounted for most stand volume growth in thinned and un-thinned stands. Two measures of growing space, crown projection area and sapwood basal area (a surrogate for leaf area), were used to measure how efficiently individual trees used their growing space. Crown classes were useful in characterizing growing space efficiency (vol. growth per unit of growing space) only in the un-thinned treatment. In thinned treatments, tall trees with medium-sized crowns were most efficient, while in the un-thinned treatment tall trees with relatively large crowns were most efficient. A large crown in an un-thinned stand was comparable in size to a medium-sized crown in a thinned stand. Results suggest growing space is not limiting individual tree growth in thinned stands and that thinning to a particular stand structure is more appropriate than thinning to a particular stand density.
122	**O'Hara 2001**
	The present trend towards transformation of forest is the result of public dissatisfaction with the appearance and perceived unnaturalness of plantations. Many foresters are reacting to this political pressure by pursuing a complete shift from plantations to single-tree selection forestry. Many other options exist that can provide the structural variability desired while using simpler management strategies and our existing knowledge of even-aged stands. These include systems to produce two- or three-aged stands, or enhancing the variability of existing even-aged stands.
123	**O'Hara and Gersonde 2004**
	Stocking control refers to forest management operations that alter the number and arrangement of trees within a stand and is a central element of uneven-aged silviculture. Many alternative stocking control approaches have been developed for uneven-aged stands. Four methods are presented that represent a contrast in complexity and emphasis, but that conceptually build on each other. All are assumed to be tools for allocation of growing space. The BDq approach builds on a reverse-J diameter distribution that serves as a target stand structure. The Plenter system is similar to the BDq approach as it uses a diameter distribution to represent stand structure but provides more flexibility for structures with different growth patterns. Stand density index can be allocated among diameter classes to form a variety of structures. Similarly, leaf area index can be allocated among age classes or canopy strata without the constraints of a reverse-J diameter distribution. Other methods for controlling stocking in uneven-aged stands exist and many undoubtedly represent sound approaches to management. The trend in the four approaches described here is towards a better understanding of stand dynamics and greater flexibility for diverse structural goals.
124	**O'Hara and Valappil 1999**
	A flexible approach for density control of multi-aged stands (stands with two or more age classes) managed with the single-tree selection system is presented. This density management approach divides stands into components such as age classes, canopy strata, or species, and allocates growing space among components to control stocking. Growing space is represented by leaf area. Users specify a total stand growing space occupancy, the number of desired components, number of trees per component, and the percentage of occupied growing space allocated to each component. A series of equations can be developed and assembled in a simple spreadsheet to design and assess density management alternatives. Organization of these equations is presented as the Multi-aged Stocking Assessment Model (MASAM) and is used to design several example prescriptions for several species. Model outputs which aid in implementation of designed prescriptions include stand-level totals for basal area, stand density index, and average annual volume growth for a felling cycle. Other outputs may include component totals for basal area, stand density index, average tree vigour, and

Ref. No.	Author/Abstract
	quadratic mean diameter. This approach provides flexibility in designing density management regimes for multi-aged stands with a variety of stand structural characteristics, including two or more age classes or strata, or stands with a preponderance of large or small trees.
125	**Oliver and Larson 1996**
	A key text outlining the development of forest stands in response to different scales of natural and anthropogenic disturbance. Theoretical concepts underlying the development of silvicultural systems are explained in detail.
126	**Page and Cameron 2006**
	This study examined the variation in the development of naturally regenerated and planted seedlings of Sitka spruce (*Picea sitchensis* (Bong.) Carr.) within gaps cut in a 32-year-old stand of the same species. The circular gaps were 20 m in diameter and designed to allow sunlight into only half of the gap floor at midsummer given the latitude of 56°45′N. Eight plots (8 m × 3 m) were laid out along a north–south transect through each gap (four within the gap and two each under the closed canopy north and south of the gap). Each plot was sub-divided and seedlings were planted into one part and the other part was left to naturally regenerate. In subsequent seasons, plots were further subdivided into 'weed free' and 'vegetation left untouched'. Results showed that while the two central plots within the gaps had the highest value of canopy openness, the highest accumulated temperature and lowest soil moisture were recorded in plots that received direct sunlight. However, level of germination was significantly higher in the shaded area of the gap than in the part that received direct sunshine suggesting that higher moisture levels in shaded areas are important to successful germination. Minimal germination was recorded in the plots beneath the canopy. Seedling survival was significantly influenced by the influx of competing vegetation, but only in the part of the gaps that received direct sunlight. The success of Sitka spruce regeneration within gaps appears to depend on sufficient moisture and light to support regeneration and early growth, but not too much light to encourage the development of competing vegetation. The permanently shaded areas of the gaps appeared to offer ground conditions with sufficient moisture and light to ensure successful germination and early growth of seedlings, but without excessive competition from other vegetation.
127	**Page et al 2001**
	The aim of this study was to investigate the effect of the overstorey, as characterised by basal area, on seedling density and growth of advanced regeneration in two irregularly thinned stands of Sitka spruce (*Picea sitchensis*) and to investigate whether any relationships found were affected by the method in which basal area was determined. Surveys were carried out in two contrasting Sitka spruce plantations in which the age and height growth (total and current year's) of advance regeneration was measured and basal area of the crop trees was determined using different methods, including point sampling with a range of basal area factors. The density of young (up to 4-year-old) regeneration was found to be positively correlated with overstorey basal area, with the strongest significant relationship, albeit weak (r^2=0.18, P<0.01) found when basal area was determined using point sampling with a basal area factor of 7.5 (metric). Growth of natural regeneration, as determined by total height, leader length and leader/lateral ratio, was found to be negatively correlated with overstorey basal area. The strength of these relationships varied according to how basal area was determined and the significance of this is discussed. In the stand with older regeneration the basal area of the overstorey above those plots where natural regeneration was in check was significantly (P<0.001) higher than where natural regeneration was growing well. It would appear that in order to encourage growth of the advance regeneration, the stand should be

Ref. No.	Author/Abstract
	kept at a basal area of 30 m^2 ha^{-1} or less. This is less than the value (38 m^2 ha^{-1}) for a fully stocked stand in the UK.
128	**Pakenham 1996**
	The development of modern machinery specifically designed to aid natural regeneration has resulted in effective establishment systems. The Ledreborg plough was used to aid regeneration in one Chiltern beech woodland. Predators, disease and weed competition all needed to be controlled in the first few years of establishment. Herbicides proved ineffective on some species, so mechanical control using modern farm machinery was tried with considerable success.
130	**Parsons 2002**
	This report provides an overview of CCF systems used on a variety of forest types in northern Germany. Major tree species included beech, Norway spruce, oak and hornbeam. Consideration of mixed species stands, deer management and regeneration techniques were all included in the discussion.
132	**Paterson 1990**
	Silvicultural systems are bio-ecological means of achieving management objectives. Forestry is moving into a phase when more flexible silvicultural systems can be applied to meet a broad range of management objectives. The challenge is greatest in spruce forests on gley soils over clay tills on the exposed plateaux. Even here where wind hazard is in the range of 3-4 it may be possible to experiment with a shelterwood and group selection systems. A number of factors influence the potential application of a silvicultural system, including: instability in ownership, emphasis on short-term income generation, focus on small roundwood production in mills, lack of tax and grant incentives for alternative systems, and a preponderance of Sitka spruce dominating the upland forest scene.
133	**Penistan 1952**
	On a large estate in the south of Scotland it was recently decided to limit very strictly the existing policy of clear-felling and replanting, especially in the old hardwood areas. A very interesting situation arose, both from the point of view of instructing the forestry staff and of securing enough timber to maintain the estate sawmills. This article was complied from notes made after discussion of necessary steps to be taken.
134	**Penistan 1960**
	In 1956, and later, visits were made to those NW European countries with extensive conifer plantations. This article describes their present condition and the steps taken by European foresters to safeguard and sustain their yield. It suggests briefly the lines which British practice should follow to secure sustained yield into the future.
135	**Penistan 1974**
	A review of British practice and problems. Beech is considered important both for its timber and its contribution to the environment. Management for both objects is desirable and possible.
136	**Pepper 1999**
	Recent research on deer control has aimed to reduce costs of fencing without reducing efficiency. The minimum requirements for the criteria of height, wire

Ref. No.	Author/Abstract
	spacing, strength and durability were determined separately for fallow, roe and muntjac deer. The effect of adding repetitive high voltage electric pulses along a fence was also investigated. At the same time, the opportunity was taken to investigate and, where practical, develop new material. This note provides recommendations on practice as a result of these various studies. The note also includes details on deer behaviour at fences, details of construction and suppliers of materials.
137	**Peterken et al 1992**
	Efforts to improve Britain's upland conifer plantations as wildlife habitats have largely concentrated on retaining and creating habitats on unplanted land. Here we argue that, in addition, it would be beneficial to assign 15–25 per cent of the plantations to long rotations containing small permanently uncut cores, while shortening the rotations of the plantations not assigned to long rotations. This should allow significant ‘old-growth’ habitats to be created, and increase the extent of temporary open space, apparently without a disproportionate sacrifice of wood production. We consider the ideal distribution and treatment of long-rotation stands, and illustrate how these ideals must be modified in practice when they are implemented in three representative forests.
138	**Pommerening 2002**
	For some time, structure indices - quantifying spatial stand structure - have been integrated into forest research and are used to provide a measure of biodiversity. In addition, correlation functions - developed initially for problems outside forestry - enable analysis and characterization of forest stand structures, generating more accessible information. This paper outlines a classification of structural indices measuring alpha diversity and examines typical representatives of the classification groups such as the Shannon index, the aggregation index of Clark and Evans, the contagion index, the coefficient of segregation of Pielou, the mingling index, the diameter differentiation index, the pair correlation and the mark correlation function. These can be used to measure differences between forests in time and space, to generate forest structures, to analyse the differences between observed and expected structures and to characterize modifications of forest structure resulting from selective harvesting. These algorithms are the keys for assessing complex forest structures, which can be the result of continuous cover forestry methods. Continuous cover forests with selective harvesting are being promoted in the new forest policies of Britain. Case studies have shown that from given spatial forest structures one can possibly conclude the suitability for habitats, a hypothesis which has yet to be proved by further appropriate analysis. The equations for the quantification of stand structure presented in this paper have the advantage that they are easier to survey during forest inventory than the more direct measures of ecological variety.
139	**Pommerening and Murphy 2004**
	Continuous cover forestry (CCF) is not a new idea in forest management but there has been renewed interest in it for the potential it has to meet the sustainability requirements which are part of the Rio/Helsinki process and certification. Broadly speaking CCF includes those silvicultural systems which involve continuous and uninterrupted maintenance of forest cover and which avoid clearcutting. However, there is considerable confusion with regard to terms and definitions and even the phrase continuous cover forestry is not universally known. CCF systems are being introduced throughout Europe, where there is emphasis on the direct transformation of existing even-aged plantations to some form of mixed, uneven-aged woodland. There is also the opportunity to establish such woodlands either at re-stocking or when afforesting former agricultural land but so far there has been little discussion of

Ref. No.	Author/Abstract
	the methods that can be used to do this. One approach would be to use nurse crops to aid establishment of desired species, especially where there are difficult site conditions or the trees naturally require cover for optimal growth. The use of nurse crops is already a familiar part of forest practice and has found various applications in Britain, Scandinavia and other parts of Europe. This paper outlines the historical roots of continuous cover forestry, discusses definitions and features of the current debate and explores potential silvicultural methods with special attention to the direct establishment of mixed forest stands through afforestation and restocking.
140	**Poore 1988**
	A review paper dealing with the basic practical features of the relatively small number of irregular silvicultural systems which are likely to be applied widely in Britain. The paper also deals with application of systems and nomenclature. Comments are included on the Bradford Plan, as an example of the group selection system.
141	**Pryor 1990**
	The classification of silvicultural systems is confusing, and it is perhaps more useful to consider the five main parameters that define a silvicultural regime:- canopy structure, method of regeneration, scale and uniformity, rotation length and species composition,. It is recommended that, rather than adopting classical systems, a flexible approach is taken, varying each of these parameters to achieve a silvicultural regime which achieves today’s multi-purpose objectives. Ideas are put forward on how the basic systems can be adapted and modified in practice with the emphasis on increased reliability and simplification of the implementation. Finally, suggestions are given on how some of the problems of utilising natural regeneration can be overcome. The paper is based on a research review of irregular silviculture as practiced in Britain in the mid-1980s and subsequent experience of implementing “irregular management” in the Welsh borders.
142	**Quine 2001**
	A transect survey of wind-formed gaps was conducted in planted Sitka spruce (*Picea sitchensis*) stands in the British uplands. Observations were made of gap size (as cover and opening) and presence of regeneration. Gaps ranged in size from 4 to 7900 m^2, but the size distribution was highly skewed with a predominance of small gaps less than 100 m^2. Sitka spruce seedlings were present in 27% of the gaps, while germinants were present in 62% of the gaps. The largest seedlings most often occurred on raised positions provided by the upturned root plates. Mean gap size (cover and opening) was significantly greater for gaps with spruce seedlings than those without. Measures of gap opening provided the best guide to presence of regeneration, and no seedlings were observed in gaps with an aperture (proportion of hemisphere without canopy) of less than 0.15. This threshold is consistent with results from natural forests of Sitka spruce in the Pacific Northwest, whereas comparison of gap areas was less reliable due to the influence of tree height. The results provide guidance on the minimum size of opening required to regenerate Sitka spruce that has application in the development of new silvicultural systems.
143	**Quine and Miller 1990**
	The severity of Britain’s wind climate is contrasted with that of continental Europe and emphasised as a major constraint. Factors that affect stand vulnerability to windthrow are reviewed, and the role of stand management in influencing wind damage is examined. Stand management can determine the timing and extent of change to stand edges, canopy roughness and the proportion of the crop that is vulnerable at any one time. Silvicultural systems are reviewed with reference to

Ref. No.	Author/Abstract
	these factors and recommendations are given to match appropriate systems with sites of different hazard class.
144	**Quine et al 1999**
	Recent developments in UK forestry policy require the adoption of management practices that maintain and improve the biodiversity of managed forests. One approach is to use natural disturbance in unmanaged forests as a template for setting the scale, frequency and pattern of forest operations in managed forests. This review considers the relevance of this approach for conifer plantations in upland Britain. The dynamics of British planted forests are compared with the disturbance dynamics of analogous natural forests, with particular reference to disturbance by strong winds. Western hemlock-Sitka spruce (*Tsuga heterophylla-Picea sitchensis*) forests in the Pacific Northwest of North America, and particularly in southeast Alaska, provide the most promising comparison. There are few reports on disturbance in these forests, but the regime includes both gap-phase and stand replacement dynamics due to wind. However, the landscape proportion and pattern of resulting structural types are not well defined. The dynamics of planted forests in Britain are dominated by rotational patch clear felling which results in regular stand replacement and little possibility of the stands developing beyond the stage of stem exclusion towards old-growth. The pattern and timing of felling is driven by economic and visual amenity considerations rather than by an attempt to mimic natural disturbance patterns. Moreover, the structural complexity and remnant elements (such as dead wood, large trees, vegetation patches) left after large-scale disturbance are rarely found after conventional timber harvesting. The authors conclude that natural wind disturbance regimes have potential as a reference point for management in British upland forests, but at present are not relevant as a model to mimic explicitly. This is because the biodiversity benefits of adopting a 'natural' approach in planted forests are unclear compared with management guided by other criteria such as rarity. Furthermore, the spatial and temporal pattern to be mimicked is not sufficiently well understood. Improved knowledge could inform decisions on the scale and distribution of harvesting across a landscape, and modify silvicultural operations to create and maintain the structures and patterns associated with natural disturbance. However, further research is needed to quantify the spatial and temporal characteristics of wind disturbance in upland forests in Britain and in natural forests elsewhere.
145	**Quine et al 1995**
	Wind damage is a serious threat to managed forests because it results in loss of timber yield, landscape quality and wildlife habitat. This Bulletin seeks to guide management by presenting a brief but comprehensive review of why and how storms damage trees, and the measures that can be adopted to mitigate such damage. Main technical terms are defined ina glossary and the further reading section provides sources of additional information by specific topic.
146	**Reade 1957**
	Brief details are given of the application of the Swiss “method of control” in the author’s private Chiltern woods. In order to be able to make comparisons between the yields realisable under differing systems of management, the author has developed an increment formula by means of which yield table and similar data can be re-computed in selection forest form. The formula appears to be an extension of the well-known Von Mantel formula. Typical sustained yields for slightly idealised Chiltern and Swiss selection forests are compared, together with a preliminary estimate of the yield of mixed hardwood-conifer “irregular” forest under Chiltern conditions. The Swiss sustained yield is further compared with even-aged yields for the same species as given by Mar Moller’s Danish yield tables. The conclusions give

Ref. No.	Author/Abstract
	no clear victory to the proponents of any particular system, but indicate the approximate proportion of the total yield which must be cut out as thinnings, whatever the system. There is prima facie evidence suggesting that the thinnings yield may be even greater in selection forest than in even-aged forest.
147	**Reade 1960**
	A summary of some of the main points of general interest which were brought to notice in the course of the Society's autumn 1959 tour in Switzerland and South Germany.
148	**Reade 1965**
	A summary of the principal points concerning natural regeneration which were raised in the course of the Society's visits to Belgium in 1961 and France in 1964.
149	**Reade 1990**
	A report on application of the Swiss "Method of control" to 140 hectares of privately owned and managed South Oxfordshire Chiltern woodland over a period of 36 years.
150	**Reynolds 2004**
	The effects of widespread conifer afforestation on the acidity of lakes and streams in the acid sensitive uplands of the UK has been researched extensively and has contributed to the development and implementation of national forest management guidelines (e.g. Forest and Water Guidelines; Forestry Commission, 1993). However, a recent policy document (Woodlands for Wales; National Assembly for Wales, 2000) has proposed a major shift in the management of 50% of the Forestry Commission estate in Wales from the current system of patch clearfelling to Continuous Cover Forestry (CCF). This scale of change is without precedent in the UK; no studies in the UK forest environment have examined the likely environmental impacts of CCF. However, the wealth of environmental data from studies of UK forests managed by patch clearfelling enables an assessment of the impact of a change to CCF on three issues of particular relevance to surface water acidification in the uplands; forest harvesting, soil base cation depletion and atmospheric pollutant deposition. Whilst there is uncertainty as to how even-aged stands will be transformed to CCF in the UK, guiding principles for CCF on acidic and acid sensitive sites should focus on those aspects of management which minimise nitrate leaching, encourage base cation retention within the soil-plant system and enhance base cation inputs from external (atmospheric) and internal sources (weathering). CCF may provide opportunities to achieve this by reducing the scale of clearfelling, increasing species diversity, changing the structure of plantation forests and maintaining uninterrupted woodland cover.
151	**Saksa 2004**
	The dynamics of spruce regeneration, from seed crop to saplings, was studied based on five permanent plots in uneven-aged, spruce-dominated, boreal forest stands, cut with single-tree selection in the beginning of the 1990's. The annual fluctuation of the spruce seed crop was very similar in uneven-aged and even-aged stands. The correlation between seed crop and number of germinants was significant; but stem number, basal area or volume of the stand did not influence on seedling emergence. The effects of good seed crops were seen as peaks or an increase in the number of germinants and smallest seedlings. The mean number of 'stabilised' spruce seedlings (height 11 cm to 130 cm) varied from 6000 ha^{-1} to over 25 000 spruce seedlings ha^{-1} from one monitoring plot to another. On a monitoring

Ref. No.	Author/Abstract
	plot the number of 'stabilised' spruce seedlings was stable over time. Neither stand basal area nor stand volume influenced the number of 'stabilised' spruce seedlings, but the height of these seedlings was higher on subplots with lower stand volume and smaller basal area. In this study the monitoring period, 5-10 years, was too short to obtain reliable figures for ingrowth, i.e. the transition of seedlings to the sapling stage (h>130 cm). The adjusted mean ingrowth was 26 stems ha^{-1} year^{-1}.
152	**Sánchez Orois and Soalleiro 2002**
	The state of mixed forests of maritime pine (*Pinus pinaster* Ait.) and broadleaved species in the coastal region of Galicia (north-western Spain) was described using data from 213 circular sample plots selected among the available 4700 plots of the Spanish National Inventory. A matrix model was developed for this forest type to obtain information about the productivity and potential for sustainable management. The broadleaved species had a diameter distribution close to the inverted J-shape typical of the uneven-aged forests but for maritime pine there were many medium-sized trees and a lack of trees in the first diameter class of 15 cm. The matrix growth model was used to predict the development of mixed forests for three different management options: no harvesting in a well-stocked stand, a regime with a 5 yr harvest cycle and a residual basal area of 15 m^2 ha^{-1} in a well-stocked stand, and a rehabilitation management applied to an under-stocked stand. The results showed the possibility of applying uneven-aged silvicultural systems to these forests, leading to the production of high-value timber and to the maintenance of continuous cover and a biodiverse forest.
153	**Sánchez Orois et al 2004**
	This study analyses two important phases of the continuous cover forestry (CCF) management. The first phase involves the determination of the optimum cutting cycle and residual growing stock level for mixed uneven-aged *Pinus pinaster* Ait. stands in Galicia (NW Spain). The Faustmann formula to calculate the land expectation value (LEV) was used for the economic evaluation of the different management options. In addition, sensitivity analysis was carried out assuming varying price levels and discount rates. The second phase deals with a comparison between CCF management and rotation forest management (RFM). The LEVs for four commonly used RFM practices were calculated. The results of the comparison indicate that on low sites (SI≤13) CCF management is superior, whereas on high sites (SI>13) RFM gives higher returns.
154	**Schabel and Palmer 1999**
	Following an almost 80-year discussion, several European countries recently mandated natural forest management based on uneven-aged silvicultural systems. This shift from traditional forestry is envisioned to eventually restore forests to a near natural condition, while promoting large volumes of high-quality wood. A review is given of the evolution of the Dauerwald concept, which greatly influenced this significant shift, and with a brief assessment of its relevance for North American conditions.
155	**Schütz 1990**
	This book has been written for foresters, silviculturists, and land managers or conservationists, and is arranged in two parts. In the first part, the principles of forest stand structure are outlined, and current theories about silvicultural intervention in irregular (uneven-aged) and mixed stands are discussed - 'mixed' is used both for a mixture of tree species, and for a mixture of age classes. In the second part, after an introduction giving a historical context to selection forestry, three chapters outline silvicultural techniques for classic European selection systems, other types of

Ref. No.	Author/Abstract
	selection, and silvicultural conversion.
156	**Schütz 1997a**
	This book has been written for foresters, silviculturists, and land managers or conservationists, and is arranged in two parts. In the first part, the principles of forest stand structure are outlined, and current theories about silvicultural intervention in irregular (uneven-aged) and mixed stands are discussed - 'mixed' is used both for a mixture of tree species, and for a mixture of age classes. In the second part, after an introduction giving a historical context to selection forestry, three chapters outline silvicultural techniques for classic European selection systems, other types of selection, and silvicultural conversion.
159	**Schütz 1999**
	The concept of close to nature silviculture is an old one. It was developed by K. Gayer at the end of the last century, and has been applied for more than a hundred years, for example in Switzerland and Slovenia, mostly with success. There are different ways to characterize such silviculture, depending on the relative emphasis which is given to 'culture' and 'nature'. In the past there have been different interpretations. Leibundgut adopts a liberal interpretation, which he relates to primeval forests, whereby he accepts the use of all forms of regeneration, including regeneration on large areas. On the other hand, Möller gives a more strict interpretation based on successional processes. Nowadays the concept needs to be extended to include the importance of favouring diversity of forest biotopes and the potential for using natural processes for economic reasons. It is necessary to utilize a great diversity of silvicultural techniques, following Leibundgut's principle of 'free choice of fellings'.
160	**Schütz 2001**
	Transformation from a regular forest to a full irregular one is a long and difficult task which needs time and frequent intervention. Looking back over Swiss experience allows us to analyse the reasons for success and failure. One of the main reasons for transformation failure is that differentiation has been established too evenly over the entire surface and has been started too late. The tendency towards forming over-regular two-storied stands increases if it is not possible to maintain adequate crown cover of the upper storey over the entire transformation period. This is linked to the ageing of the first generation main trees and to good crown formation. It is possible to establish concrete rules about transformation management and decision-making during the different transformation stages. As with plant succession, transformation follows a set sequence of stages which must occur in the correct order. The process must also start at the correct time and in the correct manner. A decision must be made whether to attempt transformation on the present generation of trees or on the subsequent one. Otherwise, one runs the risk of unwittingly opening the cover when mature trees die, before transformation has been achieved. For such purposes, we use a specific hierarchy of objectives in the decision-making process. These are principles such as stability; longevity of cover-building trees; optimizing regeneration with regard to recruitment and its confirming to an irregular vertical structure. This hierarchical order must be followed. The activation of regeneration and recruitment is of utmost importance in the subsequent transformation stages.
161	**Schütz 2002a**
	This paper discusses the dynamic definition of irregularity; it looks at conditions of sustainability and considers under which conditions irregularity could be promoted efficiently. Irregularity is not usually innate in natural forest ecosystems, the

Ref. No.	Author/Abstract
	exception being in certain developmental stages of old or over-mature stands. Because of these natural tendencies, it is necessary to differentiate between temporary stand structures and sustainable irregular systems. Therefore, any assessment of irregularity needs to take the rules of demographic regulation into account. Different kinds of irregularity are discussed, as is the reference scale for implementation. This makes it possible to distinguish between genuine irregularity within the crown layer, full (vertical) irregularity on stand level (plenter system) and horizontal irregularity (for greater reference scales), by creating irregular patches (as under the irregular shelterwood system). The paper presents the differences between broadleaved species and conifers in a full irregular plenter system with a developed vertical structure. These differences are due to the degree to which tree species can support shade, without losing the ability to recover qualitative capacity and, for older stages, to use crown space efficiently. Other factors are also important: the reaction of tree species to openings, the production of epicormic branches, topology and crown expansion. Therefore, broadleaved plenter forests need much lower equilibrium standing volumes than classical conifer plenter forests and there are also losses in volume increment and stem quality. The silvicultural results produced by the different models for differentiating stands and promoting irregularity are also discussed. It is assumed that for broadleaved species, the compromise between the necessary educative steps (shaping of the stem form within tree populations) and closure control function are better in small populations (openings) than in stands with a single tree structure. Because the ultimate aim is to create not one, but several, co-existing forms of heterogeneity, in the sense of creating varied habitats, modern silviculture should make use of all silvicultural tools. This is a significant challenge for silvicultural expertise.
162	**Schütz 2002b** This special issue contains 22 selected papers from the joint meeting on the techniques and practices of the plenter system (selection system) in Europe. Topics included the concept of irregularity in different forest sites (uneven-sized and uneven-aged) in Europe, tree species and harvesting, history and development of the plenter system in (France, Germany and Switzerland), and new insights, ideas and future developments regarding irregular forest management. In the foreword, the author describes the development of uneven-aged management systems and the recent advances made in Europe and elsewhere.
163	**Seymour and Hunter 1999** Ecologically sound stewardship has long been a cornerstone of the forestry profession. But just what does “ecologically sound” mean in practice? Historically, foresters were taught that forest ecosystems could be engineered at will for human benefit. Ensuring ecological integrity meant not violating “constraints” associated with soil, water quality, and wildlife. Recently the definition of ecological integrity has expanded to include the maintenance and even restoration of native biodiversity. At the same time, a growing worldwide demand for forest products has encouraged foresters to expand traditional high-yield practices, amidst growing evidence that such systems often conflict with biodiversity. While not discounting the difficulty of these conflicts, the authors believe there is a vision of ecological forestry that offers hope. In this review, they define ecosystems, stands and landscapes. A historical review of forestry is provided, to place “ecological forestry” in a historical, scientific and professional context. Important principles of ecological forestry are defined and discussed, in relation to traditional timber production forestry. Finally, a balanced forestry paradigm, which blends elements of traditional and ecological forestry, is described.

Ref. No.	Author/Abstract
164	**Shrimpton 1988** The objective of this study is to quantify the costs involved in converting from even-aged to uneven-aged forest management, by developing a computer model to simulate the time taken for various forest operations under each system. This same model will then be used to quantify the costs of managing uneven-aged forest. Comparisons are based on a fixed size forest block which is divided into different group sizes to represent a continuum from clear-felling to single-tree selection. The model can then be used to compare the effects of various management strategies – such as harvesting method and machine time – on yearly or periodic incomes and costs. Eventually the aim is to produce an interactive programme which could then be used to investigate the financial implications of changing to uneven-aged management.
165	**Smith et al 1997** This major textbook addresses silviculture from an ecological and eco-physiological perspective. Tree structure and function in forest stands, in addition to forest stand dynamics provides a framework for explaining the full range of silvicultural systems that can be applied to meet prescribed management objectives. For practical purposes, the text is primarily of relevance to forest conditions in the north-east United States, but principles can be applied more universally. .
166	**Stacey et al 1994** Wind tunnel tests have been conducted on a 1:75 scale model of a Sitka spruce forest in a correct scale turbulent boundary-layer flow. 12000 tree models were manufactured with mass, flexibility and aero-dynamic drag characteristics chosen to give dynamical similarity with typical 15 m trees in a 30 ms^{-1} gale. To measure the dynamic response of a sample tree, set within this model forest, a miniature, fast-response strain-gauge balance was designed and built. Linked to a computer for online data sampling, this balance provided measurements of the fluctuating along-wind and cross-wind components of the over-turning moment at ground level, leading to values of mean and extreme moments and a frequency spectrum of the sway motion. Associated measurements of local windflow characteristics were made with hot-wire anemometers and a laser anemometer. The response of the tree has the characteristics of classical lightly damped vibration and there is evidence that resonant sway motion increases the extreme over-turning moments significantly above the values produced by wind-gust forces alone.
167	**Sterba 2004** Stem number distributions in uneven-aged forests are assumed to be stable, if they follow special functions, e.g. de Liocourt's reverse J-shaped breast height diameter distribution. These distributions therefore are frequently regarded as a target in all-aged forests. Intending to convert an even-aged forest or any other forest, not yet exhibiting this sort of equilibrium, towards a steady state forest, the question arises, how to choose an appropriate equilibrium curve and how to achieve this stem number distribution by an appropriate thinning and harvesting schedule. Two stands are investigated: One dominated by Norway spruce (*Picea abies*), having developed from a 120 year old even-aged stand 25 years ago, after several "target diameter thinnings". The other one is a mixed species stand of Norway spruce, white fir (*Abies alba*), larch (*Larix europea*), common beech (*Fagus sylvatica*), and Scots pine (*Pinus sylvestris*), having lost its typical uneven-aged structure 20 years ago. These stands were used, together with the distance independent individual tree growth model PrognAus, to reveal that (1) there are more than only one equilibrium curve per stand, (2) not every hypothesised equilibrium can be reached with any stand, (3) an equilibrium in stem number does not necessarily mean a stable species

Ref. No.	Author/Abstract
	distribution, and (4) growth models provide an excellent help to decide between several equilibrium curves and harvesting schedules to reach them.
168	**Summers and Proctor 2005**
	A study was carried out over 11 seed years on the timing of shedding of seeds and cones, and annual seed fall and cone production in three stands of native Scots pinewood and a Scots pine plantation in Abernethy Forest, Scotland. Peaks in seed fall took place mainly in May, and cones were shed mainly between June and August. There were few residual seeds remaining in shed cones. Synchronized peaks in seed fall and cone production (mast years) took place at 3-year intervals across the different stands. The difference between cohorts of high and low cone production ranged from factors of 5 to 20 among sites. Coefficients of variation for cone production ranged from 62 to 84 per cent among sites. There were no significant differences in cone production among sites, but there were site-related differences in seed fall. The larger canopy cover in the plantation probably accounted for the higher seed fall per square metre there, though variations in the amount of seed eaten by birds and mammals may also have been important. Canopy cover needs to be considered when converting cone densities under crowns to cone density per unit of woodland area. A similar calculation is difficult for seeds because they are lighter than cones and many fall outside the area under the crowns. The results are discussed in relation to the potential for tree regeneration and the availability of food for birds and mammals prior to seed dispersal.
169	**Taylor 2003**
	A discussion article that challenges the view that one approach should dominate the future direction of forestry in Britain. Continuous cover systems have their place, but only where they can be justified in economic or environmental terms. Silviculture systems should be applied carefully, given that they determine long-term productivity and management costs on any particular site. Clear-felling is unlikely to be replaced as the most efficient means of producing large volumes of fibre to meet the demands of the forest industry.
170	**Timmis 1994**
	A background to the design and yield theory of the Bradford Plan continuous cover forestry is given together with a report on the progress and extent of the continuing experiment. The reader can start to form personal judgements against this background. Brief conclusions are drawn, suggesting the on-going importance of the experiment. Results to date indicate that progress towards a successful conclusion of the conversion phase is possible.
171	**Torres Rojo and Sánchez Orois 2005**
	Continuous cover forestry (CCF) management is becoming increasingly popular all around the globe. Its popularity stems from the ecological and silvicultural advantages for some species, especially those with medium to low growth rates compared to traditional even-aged management. In addition, CCF offers more environmental services and benefits than traditional even-aged management. The decision support system (DSS) described in this paper focuses on the conversion of a rotation forest stand to CCF by searching for optimized thinning regimes for conversion. The system integrates a transition matrix growth and yield model for *Pinus pinaster* with a nonlinear optimization routine which maximizes net present benefits (monetary values) derived from thinning the forest stand throughout the conversion period. The system requires as inputs the initial and targeted stand structure, the length of the conversion period, thinning constraints in terms of minimum volume to be harvested per entry or minimum residual basal area after

Ref. No.	Author/Abstract
	thinning, as well as economic and site information. Hence, the system can be used to analyse the effect of different initial stand structures, thinning constraints, target uneven-aged structures at the end of the conversion period, as well as market conditions along the conversion period. Some simulations for representative stands from Galicia, Spain, are presented. Optimization constraints, growth model limitations and DSS's sensitivities are discussed.
172	**Troup 1928**
	The text provides comprehensive coverage of both high forest and coppice silvicultural systems, and includes information of tree development and regeneration in forest stands. There are detailed descriptions of the "classical" silvicultural systems developed in France, Germany and central Europe. An update and revision of this text was published by Matthews (1991). [see reference 104]
174	**Waters and Savill 1992**
	A survey of ash and sycamore regeneration patterns was conducted in six woods in Oxfordshire and Gwent during the summer of 1990 in order to investigate suggestions that canopy tree replacement in stands of the two species tends to proceed in cyclic rather than serial fashion. It was shown that the regeneration under either canopy species is dominated, normally to the extent of well over 80 per cent, by individuals of the other species. The pattern was consistent across the size classes of regeneration, manifesting itself early in the life cycles of the two tree species. It is concluded that alternation of regeneration is a real phenomenon for these two species. The degree of threat that sycamore poses to the British ash woods is questioned and the necessity for a more realistic attitude to sycamore is emphasized.
175	**Whitney McIver et al 1992**
	The Glentress forest trial (117 ha) in S. Scotland is described. The trial, which began in 1952, aims to transform the original even-aged (then 30-yr-old) largely coniferous plantation to a mixed species forest of irregular structure through a group selection felling system over a 60 yr period, with some 2 ha being regenerated each year either by natural regeneration or plantings. Recent work has been the establishment of permanently marked sample plots to monitor the transformation on the same 6-yr cycle of forest operations. Broadleaves (*Quercus petraea*, *Fagus sylvatica*, *Alnus incana*, *Acer pseudoplatanus*, *Acer platanoides*, *Prunus avium*) will form about 10% of the stocking on the lower (< 300 m altitude) slopes, with (*Picea sitchensis*) and (*Picea abies*) the main conifers (60 % stocking). On the upper slopes, fewer broadleaf species are proposed, mainly *Betula pendula*, *Alnus glutinosa* and *Sorbus* spp. at 5 % stocking, with *P. sitchensis* (60%) and other conifers. The value of the trial for research and education is mentioned and its application discussed as a model for other suitable sites as a means of achieving multiple objectives in British forests.
176	**Wilson et al 1999**
	The Glentress Trial was established in 1952 to demonstrate the transformation to irregular structure of an upland conifer forest in southern Scotland. The dominant tree species are Sitka spruce, European larch, Scots pine and Douglas fir (respectively, (*Picea sitchensis*, *Larix decidua*, *Pinus sylvestris*, *Pseudotsuga menziesii*). The most important silvicultural system is group selection, with group size of 0.1-0.2 ha. Groups are restocked by planting or natural regeneration. Interim results indicate the development of an irregular forest structure, although the transformation will not be complete until 2033. The trial demonstrates the value of continuous cover forests in meeting multiple forest management objectives, and is a

Ref. No.	Author/Abstract
	resource for silviculture education and long-term research.
177	**Wilson et al 2000**
	Limited tree size variation in Douglas fir (*Pseudotsuga menziesii*) plantations in coastal Oregon, Washington, and British Columbia makes them susceptible to developing high height to diameter ratios (*H/D*) in the dominant trees. The *H/D* of a tree is a relative measure of stability under wind and snow loads. Experimental plot data from three large studies were used to evaluate the impact of initial planting densities and thinning on plantation *H/D* values. The *H/D* predictions from the experimental plot data match spacing trial results closely but are substantially different from distance-independent growth model predictions. The results suggest that plantation *H/D* values can be lowered and stability promoted through reduced planting densities or early thinning; however, later thinnings may not be effective in promoting stability, since they do not appear to lower *H/D* values. Higher initial planting densities shorten the time period during which thinning can be expected to effectively lower future *H/D* values. Time-sensitive thinning requirements in dense plantations make their management inflexible. The flexibility with which a stand can be managed describes the rigidity of intervention requirements and/or potential range of stand development pathways.
178	**Yorke 1993**
	An amended version of a paper (1992) published in Forestry & British Timber (1992) 21(10): 20-24. A brief outline is given of the principles underlying the transformation of even-aged conifer forest into a self-regenerating and uneven-aged 'permanent' conifer forest on suitable sites by using a modification of the Continental selection system.
179	**Yorke 1995**
	This article gives an outline description of four continuous cover silvicultural systems considered to be practical within Great Britain - shelterwood, planned group felling, group/single tree selection, and strip/group shelterwood. It considers the potential for transforming relevant parts of Britain's plantation forests into a continuous cover and uneven aged structure of permanent forest that is sustained primarily by natural regeneration. Some of the quantifiable and unquantifiable benefits and costs of adopting these systems as an alternative to clear felling and replanting are outlined.
180	**Yorke 1998**
	This booklet outlines measures which may be taken to transform even-aged forest plantations in Britain into "permanent" or "continuous cover" forest, without recourse to clear felling and replanting. Some of the perceived advantages and disadvantages are outlined and compared with the alternative of regeneration by clear felling and replanting. The methods of transformation into four alternative silvicultural systems - group felling, uniform and group shelterwood, strip/group shelterwood, and group/single tree selection - are explained. The contents and recommendations in this booklet are based on practices usual in continental Europe which have been adapted to British site conditions, together with some experience in these practices in parts of Britain. The management of continuous cover woodland as an alternative to clear felling and replanting is practical within appropriate circumstances and site types throughout Great Britain. It can deliver a variety of quantifiable and "non-market" benefits compared with clear felling. Practical and economic thinning together with ongoing natural regeneration are the main prerequisites for the transformation of an even-aged stand. The main principles of the methods outlined in this booklet are relevant to both coniferous and broadleaved woodland. A distinction needs to be made between the light-demanding species (larches, pines,

Ref. No.	Author/Abstract
	oak and ash) and the more shade-tolerant species (firs, spruces, beech and sycamore) when considering the introduction of an alternative silvicultural system.
181	**Yorke 2001a**
	The report discusses: silvicultural systems for achieving continuous cover; some pre-requisites for successful transformation and subsequent management; preferred site types; transforming the even-aged stand to continuous cover; and tree selection.
182	**Yorke 2001b**
	Responses are given to common misconceptions on continuous cover silviculture, drawn from over two decades of practical experience and observations both in Northern Europe and Great Britain and from discussions with European and British forest managers. Misconceptions about the transformation of even-aged monocultures to their subsequent management and regeneration with continuous cover circulate within both forestry and other professions, and some of the relevant literature. It is suggested that the majority of the given misconceptions and negative perceptions can be discussed and concluded as a result of in-depth observation of practical experience.
183	**Yorke 2004a**
	This paper attempts to dispel some of the misconceptions that continue to circulate concerning the management of CCF stands as an alternative to clear-felling and planting. These misconceptions may be acting as barriers to the transformation of even-aged plantations and their subsequent management with CCF where, of course, it is practical and relevant. Some of the points addressed include: stand complexity and detail in management; wind hazard and browse problems; intensity of extraction tracks; increased costs (penalties); higher timber harvesting costs combined with small machines and risk of stand damage.
184	**Yorke 2004b**
	This paper counters the perception that transformation to continuous cover is more costly than conventional woodland management, and that a move to CCF can only be justified if grant aid is forthcoming.

Subject Class Index

Species Index

This index provides links to papers that focus on a limited number of species. All papers with the “xxx” code are of a more general nature and/or deal with species not commonly found in the UK or Ireland. These papers are not indexed here.

Broadleaves

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