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Progress of adoption of alternative silvicultural systems in Britain: an independent review

Technical Report - March 2013

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The study was an independent one, and the views expressed in this technical report and the accompanying case-study reports are those of the author and should not be taken to be those of either of the sponsoring organisations.

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SMcGW, March 2013

Executive Summary

An independent review was undertaken of progress with adoption of alternative silvicultural systems to clearfell/ replant (ATC) in Britain. These are often termed "continuous-cover forestry" (CCF) or Lower Impact Silvicultural Systems (LISS). This project used conventional enquiry methods of literature review, expert and owner/ manager discussions and a programme of rapid-appraisal field visits by the author. Outputs of the work include a spatial register of ATC adoption examples, of which a sub-sample have been worked up as short, illustrated case-studies covering a range of ATC adoption contexts and objectives. Some locations have potential to serve as future demonstration sites with owner consent. This report highlights emerging issues in the field of ATC adoption and makes recommendations in support of its wider uptake, many of which would require a co-ordinated effort over time.

Since publication of a previous review on this subject by Cyril Hart OBE in 1995 [as FC Bulletin 115], there has been increased adoption of ATC. While regular clearfell/ replant systems remain predominant in upland coniferous plantations, alternative silvicultural systems are becoming the norm in many lowland and mixed woodlands and in most woods managed primarily for conservation and amenity objectives. Expansion of ATC adoption is noticeable even in more challenging upland forest types. Commonly stated objectives for ATC adoption remain preservation of the estate landscape and production of high quality timber, along with silvicultural curiosity in many cases. However, objectives of ATC adoption are more diverse than in the past - now embracing novel aims such as species diversification, increased climatic and pest/ disease resilience, compliance with UKWAS requirements, restoration of Plantations on Ancient Woodland Sites (PAWS), woodfuel production and reduced restocking costs/ regulations. Notably, ATC adoption is spreading beyond its traditional use on the private estates - many earlier-stage examples are now on the public forests and charitable land holdings. Reliance on natural regeneration is becoming a dominant feature of ATC adoption - this has been supported by a directed research effort, improving understanding of forestry species' light requirements and critical basal areas for their regeneration. There is an increasing tendency to informal working in the earlier stages of transformation to ATC, with limited enumeration of the growing stock. Many reported examples successfully address stated aims and continued expansion of ATC seems desirable.

Continued adoption of ATC faces a number of challenges over and above those, such as climate change and pest/ disease impacts, now affecting all managed forestry. The most acute remains the limited practical experience with ATC techniques in Britain and the associated lack of silvicultural skills as compared to the Continental situation. While many traditional ATC adoption examples relied on long-service estate foresters, these are becoming a rare commodity. With reduced uptake of detailed pre-service silvicultural training and a more generalist forestry profession, increased reliance is placed on in-service training, CPD and knowledge-exchange. This report makes the case for much wider, and better co-ordinated, implementation of quantitative enumeration and monitoring of transformation to ATC, with a suite of demonstration sites across the range of silviculture and ownership. These to address silvicultural, ecological, operational and economic factors of relevance to dissemination of ATC best practice. There also remain challenges to ATC from the development of British forestry machinery and processing capacity toward the Scandinavian model, emphasising industrial-scale harvesting and utilisation of small/ medium-dimension conifer stock. A wider range of harvesting, forwarding and processing equipment is now urgently called for.

Results of this project will be disseminated by journal articles and seminar presentations.

Background - previous record of alternative silvicultural systems in British woodlands

Forestry Commission Bulletin 115

The most important single source of information relating to previous adoption of alternative silvicultural systems in Britain remains Forestry Commission Bulletin 115 "*Alternative silvicultural systems to clear-cutting in Britain: a review*" which was authored by Cyril Hart OBE and published in 1995. This seminal publication discusses the various alternative silvicultural systems that had previously been applied in Britain and illustrates that discussion by reference to some 45 locations at which there was a track-record of their application (in one or two cases by then interrupted). Further forestry locations considered to have potential for future adoption of alternative silviculture were suggested as the possible locations for demonstration sites. A significant proportion of the information collated within that publication had earlier been collected as part of a study conducted at the University of Edinburgh forestry department by Dr. Helen Whitney McIver, with sponsorship from the Scottish Forestry Trust and the Institute of Chartered Foresters, in the period 1989-1991. That project had sought to create a register of locations in Britain at which "irregular silvicultural systems" (a subset of ATC) had previously been applied. Although some 60 sites were considered for inclusion, the rather tight criteria for inclusion that the author selected meant that only 18 examples were dealt with in detail in her final report. Unfortunately that report and the register of locations arising from this project were not widely published and are not easily accessed at the present time - the present author has a courtesy copy from Dr. McIver.

Long-established patterns of ATC adoption

Bulletin 115 implicitly identified three previous phases of alternative silviculture (ATC) adoption activity in Britain as observed from the perspective of the early-mid 1990's:-

- Pre-war examples - essentially those few examples of Victorian, Edwardian and inter-war ATC adoption on the private estates that had survived wartime fellings. It must be recognised that much of the forestry management that was conducted on the "great estates" between, say 1680 and 1940, amounted to some form of ATC, benefiting from the skills of long-service head foresters and their woodsmen. Objectives of management usually combined estate landscape amenity, game cover, timber production and silvicultural experimentation. The clear-fell/ replant system only became more commonplace with coniferous plantation afforestation of some upland grouse-moors and sheep-walks in the period 1880 onwards and was not a significant feature of pre-war private estate mixed forestry in the lowlands. Many of the better active examples of pre-war estate forestry were depleted by wartime selective and devastation fellings, but individual cases such as Weasenham Woods did survive. Some other sites have since fallen down to less active "policy woodland" regimes.

- Post-war experimental examples - the main body of examples reported by Bulletin 115, which arose from a period of silvicultural experimentation and trial ATC adoption in the period 1950-1970. A significant impetus to activity during this period was the remediation of existing estate woodlands that had suffered from exploitative wartime fellings, but there was also a major wave of returning experienced colonial foresters who took service on the private estates and worked together with knowledgeable owners to implement experimental silviculture. Key silvicultural luminaries were Anderson, Bourne, Garfitt and Reade. Occasional examples, such as

Anderson's upland trials at Glentress and Faskally were pursued on the public forest estates. A key feature of these examples is the application of the more intricate group selection systems, often involving the use of enrichment and under-planting to accelerate silvicultural development. Many of these older examples used complete enumeration or *Methode du Contrôle* as a method for inventory/ increment control.

- Recent adoption examples - a smaller number of the more recent "natural regeneration based" applications that were emerging by the time of writing. In some mature woodland areas, such as the Caledonian pinewoods of Scotland, the Forest of Dean oak, the Chiltern and Cotswold beech and some Scots pine plantations on the lowland heaths, natural regeneration had been widely recruited for many decades. However the advent of prolific natural regeneration of Sitka spruce, Douglas fir, western hemlock and the *Abies* firs in more recent plantations had encouraged more widespread adoption of largely shelterwood systems that aimed to utilise this to restock stands without the need for re-planting. In a minority of cases there was also an aspiration to develop an irregular group structure by extending the rotation of a proportion of the mature growing stock. Methods of working became more informal than in the longer-established examples and application of quantitative enumeration much less frequent. In the intervening years since publication of Bulletin 115, this has become a much more widespread category of adoption and is now the most significant in area terms. Hart had identified that, in many cases, it was uncertain how these stands would develop and to what extent natural regeneration could be relied upon in Britain.

Identification of potential benefits of wider ATC adoption

Hart and earlier authors had identified a number of potential benefits of wider adoption of alternative silvicultural systems in Britain, to which others have since been added. Those benefits becoming clearly evident by the mid-1990's can be conveniently grouped as:-

- Amenity benefits - avoidance of the visual landscape impacts associated with clear-fell operations, retention of a permanently wooded environment for game cover and public recreation, fostering of a proportion of impressive mature growing stock etc. These benefits were particularly identified with the major private estates and with areas of the National Forest Estate where recreation/ visual amenity were paramount.

- Protection benefits - avoidance of the environmental and ecological impacts associated with clearfell operations, protection of forest soils from desiccation, compaction and erosion, retention of a woodland environment for priority plant and wildlife species.

- Silvicultural benefits - ability to utilise natural regeneration where present rather than re-planting, provision of a more sheltered establishment microclimate for desirable later successional species, options to retain a stable proportion of the growing stock to larger diameter classes where this was economically beneficial (e.g. for Douglas fir), reduction in the proportion of juvenile wood laid down by the shade-tolerant species.

Identification of constraints, leading to research and development requirements

Hart and earlier authors had also recognised that there were a range of significant challenges to the wider adoption of alternative silvicultural systems in Britain as compared to the Continental situation, which would require ongoing research and development to tackle.

The major recognised constraints to adoption of alternative silvicultural systems were:-

- Stability issues in British plantation forests, especially in the uplands, which made it potentially more difficult to intervene in stands to promote structural development and risk-prone to retain these stands long enough to recruit advance regeneration. For many years a high proportion of British plantations had been under-thinned, implying that the opportunity for conversion to non-clearfell silviculture had been missed for the present rotation. There was also a perception (now seriously challenged) that regular stands were more stable in wind-prone environments. Advice on the adoption of alternative silvicultural systems remains that it is only practical on sites with low-moderate wind-risk (WHC 1-3), perhaps extending to WHC 4 over mineral soils. Considerable research on stability in irregular stands has been pursued in the interim.

- Regeneration issues - it has been recognised that experience with natural regeneration in British plantation forests has been more variable than in mature forest types of Continental Europe where it has been deployed over many decades (a) the beech-Norway spruce-European silver forests of the montane and alpine areas, (b) the lowland oak forests of France and (c) the Scots pine-Norway spruce-birch forests of Scandinavia. The most significant constraint on natural regeneration in Britain has been the immaturity of the growing stock, especially for those species such as Norway spruce, beech and oak that do not produce copious seed until they are older. Exceptions were the established areas of mature woodland in Britain such as the oak in the Forest of Dean, beech in the Cotswolds and Caledonian pine in Scotland. Understanding of the impacts of light regimes, vegetative competition in the understorey and the browsing regime have also pointed to greater difficulties. These have implied that foresters aiming to adopt alternative silvicultural systems dependent upon natural regeneration have faced the possibility of having to revert to re-planting. Much research since the 1990's has focussed on securing more reliable regeneration.

- Skills issues - the relatively small proportion of British forest area managed under alternative silvicultural systems has meant that the focus of pre-service and in-service training of British foresters emphasised the clearfell/ replant working system. This was to an extent counteracted during the period of colonial forestry service in India, Burma, Malaya and Africa, where British foresters were trained to implement selection forestry systems, often with a strong influence from French and German forestry schools. Those skills were then available to the private estates in Britain after the foresters' return from the colonies during the period 1945-1965. Some long-service estate foresters also accumulated experience of alternative silviculture "on the job" working together with enthusiastic private owners. However there has been a perceived lack of skills relevant to alternative silviculture among British foresters.

- Operational and economic issues - there has been a widely-held perception that operation of alternative silvicultural systems in Britain is more expensive than clearfell/ replant due to the need for more careful tree marking, pre-commercial thinning of natural regeneration, multiple entry working and inventory control. The progressive development of the British forestry and timber processing industry towards a standardised and highly mechanised model along Scandinavian lines, optimised for large volumes of small-medium diameter coniferous stock, has tended to accentuate this issue. In some cases regimes of grant-in-aid have also favoured the periodic costs of clearfell/ restock as compared with more "constant offtake" ATC.

Aims and objectives of the reported study

Against the above background, the specific aims and objectives of the present study were:-

1. To produce an up-to-date report on adoption of alternative silvicultural systems (ATC) in Britain, following some 20 years after the data collection leading to the previous publication of FC Bulletin 115, authored by Cyril Hart OBE. This report to improve understanding of the extent, context and objectives of current ATC adoption, together with those factors that are promoting or restraining its wider adoption into the future.

2. To quantify, in so far as may be practicable, the spatial extent of ATC adoption in Britain at 2012 and how this relates to the total area of managed forestry. Within the spatial envelope of ATC adoption, to develop understandings of the relative stages of progress of adoption and the species/ silvicultural contexts where it has been pursued. To consider how effectively current ATC adoption is addressing its stated and implicit aims.

3. To create a template spatial register of current examples of ATC across Britain (with an interactive GIS map interface) to provide information at a regional scale that should support wider information-exchange and technical discussions among those involved with its implementation. Few such resources exist at present that are readily accessible. This database to record basic details of example location, extent, species/ silvicultural context, stage of development/ transformation and owner/ manager adoption objectives.

4. From this spatial register, to select a sub-set of the better individual examples to be written up as short, illustrated case-studies describing successful ATC adoption in a range of silvicultural contexts across the regions of Britain. These to serve as inspirational examples of best practice to encourage wider adoption of ATC in the future. In many cases, reported case-study examples could also have the potential to serve as informal demonstration sites that could be visited by individual intending ATC adopters or by groups from professional organisations for in-service training/ CPD purposes. In certain cases a suitable access arrangement with the private landowner would then be required.

5. To identify means by which individual owners of ATC adoption sites can be encouraged to undertake more detailed quantitative enumeration/ monitoring of their stands. In that connection, to evaluate the case for developing a more formalised, and better quantified, series of silvicultural demonstration sites for ATC across Britain along the lines of those developed and operated by the Association Futaie Irrégulière (AFI) in France. Ideally such demonstration sites would have a higher level of public interpretation using on-site signage and/ or electronic-media presentation, allowing their use as self-guided teaching-aids. They would also be subject to standardised protocols of quantitative inventory and monitoring that would allow them to serve as research sites for silvicultural, ecological, economic and operational aspects of ATC adoption and would enable results from the set of sites to be readily compared. Development along these lines may well take some time.

6. To identify any remaining active constraints to the wider adoption of ATC and how those might be practically addressed. Relevant actions in support are thought likely to fall into the main categories (a) research requirements, (b) pre-service and in-service training/ skills development needs, (c) technical development requirements for forestry machinery and timber processing and (d) regulatory and grant-in-aid mechanisms. Certain fundamental climatic, edaphic and biotic constraints may not be amenable to remedy.

Sources of information collated within the reported study

Information relevant to current adoption of alternative silvicultural systems in Britain has been collated and reviewed from a number of sources:-

- Previous publications included within the literature review phase of the study. The most significant source in terms of the pre-identification of individual ATC adoption locations remains Forestry Commission Bulletin 115, published in 1995. A number of other previous publications identify individual ATC adoption sites that have been studied.

- Grey literature - for example on-line management plan information for Woodland Trust sites and Forest Research reports arising from the study of the network of 11 ATC demonstration sites established on the National Forest Estate over the last decade. In some cases this source was augmented by personal correspondence with key researchers and specialist practitioners involved with application and development of ATC in Britain.

- Meeting reports of numerous previous field excursion visits to ATC adoption locations by forestry groups - mainly the Continuous-Cover Forestry Group, the Royal Forestry Society, the Royal Scottish Forestry Society and the Institute of Chartered Foresters.

- Digital datasets as to adoption of ATC on the public forest estate as supplied by the Forestry Commission in support of the current project. Some information of this kind is also publicly available to download from the Forestry Commission internet site.

- Information submitted by owners or managers of ATC adoption sites across all ownership categories in response to notices placed in the forestry press or direct correspondence enquiries/ previous contacts. This information was usually provided verbally, but in some cases included access to compartment maps, stand inventory records or management plan documents for individual woodlands. Provision of such information is a self-selecting process favouring the most "ATC committed" owners and managers and hence on its own could provide a biased sample. Some private estate long-term forest plan (LTFP) data are now available to download from the Forestry Commission website, but details of ATC are usually very limited. Outputs of the current project should address that information gap.

- Field notes and photographs collected by the author personally on previous visits to ATC adoption locations, either (a) as part of previous consultancy projects on the potential of alternative conifers and the silvicultural restoration of PAWS sites, (b) on organised field visits by voluntary forestry groups or (c) on informal personal visits over recent years.

- Field notes and photographs collected by the author personally during a touring campaign of targeted fresh field visits for the present study, conducted throughout Britain between August 2012 and January 2013. These visits were to pre-identified candidate ATC adoption locations where the author had not visited previously/ recently or where notes and records held for the site were thought incomplete. Some such field visits allowed for personal discussions with owners/ managers either at the time of the visit or before/ after. This, and the previous source of information, were the predominant ones within the current study, accounting for the vast majority of the pre-identified locations included.

ATC adoption locations will only be included in the present study where it has been possible to collect recent/ fresh information about their silvicultural status over the past decade.

Summary insights from the literature review and technical consultations

Prior to examining individual ATC adoption locations and examples within the current study, a combination of review of the recent technical literature and informal consultation with relevant specialists/ practitioners had highlighted a number of changes to the patterns of, and context for, ATC adoption that were felt to have occurred since the earlier research that led to publication of Bulletin 115 in 1995. The principal changes and developments to report are:

Expanding adoption of ATC

Most sources reported expanding adoption of ATC in Britain across all ownerships. However it was also clear that much of this expansion was at an early stage of silvicultural development and would not necessarily resemble the more advanced and intricate examples reported upon in Bulletin 115. As regards the National Forest Estate, managed by the Forestry Commission, Scotland and Wales have set fairly ambitious targets for adoption of alternative silvicultural systems, in addition to those for long-term biological retentions. These range from 20-25% in the case of Scotland to 40-50% in the case of Wales, based largely on the theoretical biophysical suitability of their sites to support perpetual forestry. The Woodland Trust were reported to be using alternative silvicultural systems to restore Plantations on Ancient Woodland sites under their ownership and were strongly advocating such methods. A number of private estates had adopted or resumed alternative silviculture, particularly across areas of southern and western England and Wales, with a variety of objectives for this. Small private woodland owners and farm foresters were reported to be using alternative silvicultural systems to bring neglected woodlands back into management and to produce woodfuel. There was also said to be a wider range of flexible, adaptive approaches to ATC adoption in use. Hence the reported impression was of a relatively expansionist, confident ATC sector.

Changing objectives for ATC adoption

Alongside a reported expansion in extent of ATC activity over the past 15-20 years there has been a ramification of stated objectives for its adoption, in addition to the more traditional rationales of estate landscape preservation, quality timber production and silvicultural curiosity/ interest. The major new "objective sets" for ATC that were now emerging were:-

- Policy/ certification - particularly on the National Forest Estate, ATC adoption was usually seen to be responding primarily to policy drivers and targets, often associated with the wish for the forests to be certified under the UKWAS assurance scheme, which expects that managers will, over time, move a proportion of their holding towards lower-impact silvicultural systems where site conditions permit. Many public consultations on forestry policy, especially in Wales, have also highlighted public preferences for ATC systems that avoid clear-felling and preserve forest amenity. Certain private and charitable owners are also influenced by certification objectives. Interpretations of what was actually required or expected by UKWAS in terms of ATC adoption varied widely between commentators, as did the applicable criteria.

- PAWS restoration - a completely new rationale for ATC adoption that has arisen over the past 10-15 years is the restoration of Plantations on Ancient Woodland Sites (PAWS) in support of biodiversity conservation objectives. While earlier examples of such work tended to replicate the clearfell/ restock working system, more recent activity has more often used gradual silvicultural approaches akin to ATC working.

These have the advantage of limiting disturbance to the forest environment that may adversely impact biodiversity during the process of restoration to native composition. The Woodland Trust have been one major proponent of these approaches and many more recent restoration projects on the National Forest Estate now embrace them. As highlighted by the present author in a recent study, they also create greater opportunity for the commercial grower to realise and retain standing crop value. Avoidance of clearfelling on PAWS sites allows growers to retain a proportion of non-native growing stock by natural regeneration, whereas replanting non-natives would not be supported in these cases. Retention of premium Douglas fir is a typical objective for many innovative private foresters willing to consider gradual PAWS restoration.

- Diversification and increased resilience - over the past 5-10 years even those growers wishing to retain primarily introduced coniferous stocking have been pushed in the direction of crop diversification by increased climatic challenges (particularly drought effects on spruce and beech) and novel pests and diseases affecting forestry tree species. Notable example of the latter include *Dothistroma* needle blight in the pines, *Phytophthora* in the larches, and recently *Chalara* die-back in ash. Reducing dependence on susceptible species and creating a more species and structurally diverse forest architecture has been proposed as one way to increase resource resilience. Where possible, many growers are keen to accomplish this without liquidating maturing crops, by techniques drawn from the "ATC toolbox". The latter include encouraging intruded natural regeneration of broadleaves and under-planting with desirable conifers such as Douglas fir and western red cedar. In many cases, a successfully diversified replacement crop can more easily be established under ATC.

- Economic considerations - whereas economic and operational factors have previously been seen to favour simplified clearfell/ restock working in British forests, two recent trends have run counter to this. Increased natural regeneration levels in maturing plantations have allowed growers, by recruiting natural regeneration under an ATC system, to avoid the significant costs associated with re-planting clearfell sites. This has also been encouraged by reductions in the levels of grant-in-aid for restocking operations available under recent forestry grant regimes, and high levels of deer and squirrel in some areas which preferentially browse transplants. While there may be some loss of control over the immediate species composition of the growing stock, stocking levels are generally higher than on re-planted sites, allowing the opportunity for future selection on species and form of stems. The rising prices for woodfuel have also encouraged a recrudescence of early thinning in many British woodlands over the past five years, better preparing them for future natural regeneration working. A number of smaller estate and farm woodlands are being returned to management.

Changing adoption context - forestry machinery and skills

Varying and, to some extent conflicting, impressions emerged from desk review and consultation as to the situation regarding availability of skillsets and forestry machinery relevant to the implementation of alternative silvicultural systems. These have a dependency on who is asked, their level of exposure to alternative silviculture and their regional base. These can perhaps be captured by reference to two apocryphal caricatures of views heard:-

From the manager of a large upland commercial conifer plantation, using clearfell/ restock:-

"*Continuous-cover is just too expensive to operate in our situation. I have to cover 7,000ha of forest from all angles and don't have time to go round individual sites marking thinnings. Joe Bloggs who used to be the manager here had learnt all that stuff about selection and so on at uni back in the 50's but we didn't cover it at all when I was there. We would need to bring specialists in to do the marking and inventory and my manager/ client just won't wear the costs for that. The contractors round here only have the latest heavy harvesters and forwarders and they would just wreck the site if we had to go in several times to thin and so on. What's the point in growing Sitka to 70cm dbh when the mills will only take it up to 50cm? I can't get any chainsaw operators now that could do directional felling after Jack was injured last year and retired. If we get progressive windthrow that has to be cleared up, which is expensive and we're back to that problem with skilled chainsaw guys. Who would I get to respace natural regeneration - the gangmasters licensing business has shut them down. All in all its best just to stick with clearfell - but the replanting has to wait on the budget."*

From the head forester of a private estate in the lowlands, adopting alternative silviculture:-

"Going over to CCF was the best thing we have done on this place. For a start we got the woods back into better shape than they have been since the war - the woodfuel market round here is going like stink and we have got a good thinning programme going now. Thankfully we had underplanted that area of larch a few years ago with red cedar and so if the disease does come, we have a head start on restocking there. A lot of our ash is in mixtures with Douglas and if we get Chalara we hope the mixed regen will give us some options. The buyers were round last year asking if we could fell some of that 70cm Douglas fir for beams on the Olympic park, but our price-size curve told us that it was better to let them grow on to 90cm. We have started to offer silvicultural training courses on our estate which helps to pay for the enumeration work. I've been able to make a business case to Lord Bloggs for an estate woodfuel system to heat the cottages - that will go in under the Renewable Heat Incentive and guarantee us a market. We have built up a good relationship with Jane in the village who has started a small-scale harvesting business - she bought one of the little forwarders that were demonstrated at the APF show last year and we have paid for her chainsaw training and kit. She has picked up on the feller-select thinning we want now - I only have to mark a small plot and she get's on with it. We are aiming to create an arboretum to test species for the future. We have got a new guy moved down from London who has got the old estate sawmill going".

Clearly these caricatures are extremes and most forest managers operate somewhere between them. They reflect the fact that how foresters view the prospect of ATC adoption varies markedly depending on where they are located, the resources they are managing, the approach taken by the owner of the forestry and the manpower and machinery available to them. There undoubtedly remains an upland/ lowland split, which is of course the most durable division in British forestry. Even within an apparently centrally-directed organisation such as the Forestry Commission, there is a very wide spectrum of perspectives, confidence and skills, leading to a situation where some of the best ATC practice in the country is found on the national forests whereas beat foresters elsewhere feel under-resourced and under-pressure to adopt management approaches that they do not understand or feel confident in. In summary the changes apparent since the publication of Bulletin 115 would appear to be:-

- Decreased availability of traditional supervising foresters with pre-service graduate level training in silvicultural systems - this due to a decline in coverage of relevant topics in the universities and retirement of long-service foresters trained previously. Concomitant increase in the beat size/ territorial responsibility of remaining staff.

- Increased reliance on external specialist advice on the implementation of ATC, whether delivered through FC printed media guidance, computer decision-support systems or private-sector silvicultural specialist consultants. Smaller private growers finding difficulty in sourcing relevant ATC skills and advice on an affordable basis.

- Increasing emergence of self-taught adopters of ATC, including interested owners and woodland managers not having been formally trained in silvicultural systems. Very heavy demand for relevant CPD/ practical in-service training and machinery demos. Costs for training in the private sector are high, pushing demand onto the FC courses. Key skills are marking of thinnings, inventory control, stem selection, valuation.

- Increase in the size and weight of harvesting and forwarding equipment used by the "main body" of forestry contractors in upland areas making them less suitable for ATC adoption. Retirement of many former "county skidder" and cablecrane operators. Difficulty in sourcing suitable lighter/ flexible harvesting/ forwarding in upland areas.

- Upsurge of interest in light-weight forwarding equipment, especially in the lowland and mixed woodland areas, with increasing woodfuel demands. Many business start-ups, self-funding entrants, machinery demonstrations and some capital grant uptake. Some concerns over type-approval and licensing of small machines without cab-cover. Many estates seeking to establish long-term arrangements with such local contractors, to some extent replacing the largely lost "estate woodsman" role, so valuable for ATC.

- A serious to critical difficulty with motor-manual felling skills availability due to retirement of older operators and unattractive nature of the work to younger entrants, coupled with very high costs of chainsaw operation on a legitimate basis - initial training, refresher training, safety kit, saw maintenance and liability insurance. Question marks over who will fell the material the light forwarders want to haul out.

- Increased specialisation of the major sawmills on high volume spruce-pine lines with a maximum diameter in the range 45-55cm. Difficulties in selling "outsize spruce" (>55cm) leading to difficulty in perpetuation of upland spruce forests - i.e. the mature stock gets too big to sell before any regeneration is properly established. Markets for superior C24 stress-graded "architectural" spruce beginning to emerge in places. Increases in minimum lorry load of timber from 8-wheel/ 10 ton to artic load/ 25 ton make for difficulties in marketing small parcels of standard grades from thinnings.

- Re-emergence of more flexible smaller sawmilling capacity by a combination of re-start of former estate sawmills (usually re-equipped with Stenner bandsaws etc), widespread adoption of portable or semi-portable Woodmizer and Peterson saws and continued operation of traditional premium Douglas fir/ larch small industrial units. Very strong regional variation in this - areas such as Wessex, West Country, the Marches and Norfolk are fairly well-served while upland Scotland and Wales struggle. Species in demand include oak, Douglas fir, fine larch, red cedar, noble hardwoods.

- Rapidly expanding and developing sustainable woodfuel harvesting sector in areas such as south-west England, the Midlands and southern/ central Scotland. This is of considerable significance in improving the economic potential of thinnings during the earlier phases of ATC adoption and is a very significant development in that regard. This applies particularly to small private and farm woodlands, previously untended.

Research and development

The period since publication of FC Bulletin 115 has seen a considerable continued domestic research effort relevant to adoption of alternative silvicultural systems. Much of this work has been pursued by Forest Research, but some by the universities at Bangor and Aberdeen and a growing proportion by private practitioners, including SelectFor and the present author.

Key research and development strands relevant to ATC include:-

- Publication of improved basic introductory information for the non-specialist forest manager on the definition and adoption of Continuous-Cover Forestry (CCF). This takes the form of Forestry Commission Information Note 40 (revised) and allows managers to make a simple step-wise assessment of inherent site and crop suitability for CCF adoption. This is intended to be the "port of entry" to information for novice ATC adopters. Comparable advice for internal consumption within the Forestry Commission has been produced in the form of Operational Guidance Book 7 (OGB 7) and is well regarded.

- Research into the effects of light regime on natural regeneration of forest tree species in Britain and the resulting critical stand basal areas to secure advance regeneration. This work is reported in FC Information Note 63. There remain some issues with delayed natural regeneration in those species which reach fecundity later, such as Norway spruce and oak - if preparatory thinnings are made too early, weed competition can swamp the site, making for much greater difficulties in later natural regeneration recruitment.

- Development by Forest Research of a domestic protocol for the plot-based monitoring of stand transformation to Continuous-Cover Forestry (CCF). This takes the form of Forestry Commission Information Note 45 and is accompanied by supporting software including proformas for data recording and analyses. This is one of several methodologies now available for the task of enumeration, inventory and monitoring, with others developed on the Continent such as the Association Futaie Irrégulière (AFI) protocol from France.

- Sustained, more detailed, quantitative monitoring of the transformation process at some Forestry Commission demonstration sites (e.g. Glentress, Clocaenog and Wykeham) using the protocols as set out in FCIN 45. Similarly, work has been carried out at the Faskally site by the University of Aberdeen and at several sites in Wales by Bangor University.

- Research work on the use of alternative silvicultural systems approaches for the restoration of Plantations on Ancient Woodland Sites to native species composition. Work has been carried out by Forest Research and also by Oxford Forestry Institute for the Woodland Trust. The benefits of adoption of alternative silvicultural systems for this purpose have been emphasised, in terms of both ecological and economic considerations. However some in the conservation community still encourage more rapid conversion.

- Initial stages of individual-based growth-modelling work for stands managed under alternative silvicultural systems, such as research carried out on a number of stands in Wales under the Tyfiant Coed project at Bangor University forestry department and work by Forest Research involving the Austrian-derived MOSES modelling tool. This is an important strand of work, but will take some time to develop to its full potential, being demanding in terms of detailed measurements and positional data required as inputs. Few British stands under alternative silvicultural systems have been suitably enumerated.

- Review work by Forest Research on the benefits of adoption of alternative silvicultural systems for climate change mitigation (primarily wind stability and drought resilience). Many issues remain to be resolved in this area, particularly in terms of stand stability. The entire field of relative benefits of alternative silvicultural systems for carbon sequestration in managed production forestry remains poorly understood and is of vital importance. The scenarios in this regard set out by the Reid Report are a start, but need development.

- Technical development work on operational and economic aspects of alternative silvicultural systems operation, based on the experience gained from a series of 11 Forestry Commission demonstration sites. An important finding was that, in the earlier stages of stand transformation, thinning practice under ATC differs relatively little from that under regular forestry. There remains very limited information available on the economics of alternative silvicultural systems after stand transformation is advanced or complete. This is mainly due to the lack of properly recorded British examples for study.

- Technical development work, conducted by the Forestry Commission Technical Development Branch at Ae, on the available light-weight forest harvesting and forwarding machinery likely to be relevant to alternative silvicultural systems. A range of information on individual pieces of machinery has been published. Recently, emphasis has focussed on machinery and working methods for thinning stands on steep/ unstable slope sites, with a rejuvenation of cable-crane and skyline working along the A82 corridor in Scotland.

Monitoring, quantification and demonstration

Quantitative enumeration of stands under transformation is of considerable value in that it allows for objective inventory and monitoring assessments of the growing stock, species and size class distribution, standing volume, increment and sustainable harvest. It also allows stands to be used more effectively for demonstration purposes, including for non-invasive thinning exercises. There are a number of potential approaches to quantitative inventory with varying levels of intensity and associated costs to the forest manager. However in the absence of voluntary labour, many owners see the costs and complexity of such work as unsustainable.

Prior to the publication of Bulletin 115 it was known that a number of owners of woodlands managed under alternative silvicultural systems used detailed quantitative enumeration for their own management purposes or personal interest. The most common systems used were domestic variants of the classic Continental *Methode du Contrôle* and/ or Biollet "Check Method" - essentially a 100% stem enumeration above 7.5 cm dbh on a recurring cycle (typically 5 years). These are labour intensive methods which are difficult to justify in commercial forest management contexts, but provide detailed inventory and increment data. These were used in the earlier years of Prof. Anderson's transformation trials at Glentress and Faskally (where voluntary student labour was available) and were adopted by a number of private estates further south adopting alternative silviculture under Bourne, Garfitt and Reade. Only occasional applications of these detailed enumeration methods have been maintained, for example at Ipsden Estate in the Chilterns (managed by the Reade family) and in woods on the Rushmore and Cranborne Estates in Dorset and the Stourhead Western Estate in Wiltshire, now augmented by the AFI-derived methods under supervision of specialist consultants.

A network of eleven ATC demonstration sites has been designated over the past decade on the National Forest Estate across Britain. These are a varied set of examples - four of them

(Glentress, Clocaenog, N. Lakes and Wykeham) are at a relatively advanced stage of progress towards ATC management and have received periodic quantitative inventory and monitoring using the plot-based methodology as set out in FCIN45 (with supporting software). The Glentress and Clocaenog sites also have a history of university-based academic involvement. However the other seven FC demonstration sites are at an earlier stage of development and it has proved difficult to secure commitment/ resources from local forest management staff to consistently implement quantitative monitoring using the FCIN45 methods, which seems a lost opportunity. Of several sites in Wales enumerated under the former Tyfiant Coed project at Bangor University, work continues under Forest Research auspices at Clocaenog and on an *ad hoc* academic basis at Artist's Wood, Gwydyr. Equivalent work at Coed-y-Brenin and Trallwm is currently in abeyance. There are current plans to commence enumeration regimes at Dyfi-Corris Forest (Forestry Commission Wales) but these remain putative at present.

It has become clear from the consultation phase of work that very few other forestry sites currently managed under (or under transformation to) alternative silvicultural systems in Britain are subject to detailed enumeration. Examples on the National Forest Estate typically have a semi-quantitative record on the sub-compartment database, periodically updated based on sample tariff and visual assessment. Many private examples are managed on what is a "periodic visual inspection and intervention" regime which involves a visual assessment of stand stocking and natural regeneration prior to a thinning intervention. Removals may be quantified in terms of timber volumes for sale, but the growing stock standing volume, composition, size class distribution and increment accruing between interventions are not detailed. It is difficult in such situations to assess stand development and set harvest offtake levels reliably, unless there is ongoing supervision by a long-service owner/ forester familiar with the site, a situation which is only found today on a minority of the traditional estates. Use of this approach on the national and charitable forest estates where staff turnover is higher, and in private woodlands with non-retained advice only, can prove less satisfactory. The most commonly stated reasons for non-application of quantitative inventory/ monitoring are complexity of the methods, lack of available skills, high costs and perceived lack of benefit. There has been a disappointingly low level of private adoption of the key FCIN45 protocol.

One exception to this picture is a set of private woodlands in south-west England and Wales who are advised by members of the SelectFor consultancy, which specialises in application of alternative silvicultural systems. On these properties, an alternative approach to sample-based enumeration has been adopted, as developed by the Association Futaie Irrégulière (AFI) in France. This independent body is affiliated to *ProSilva* and is effectively the French counterpart of the British CCFG. A network of ~100 French stands have been monitored using a fixed protocol, as applied every five years. Some of the older examples have now been measured four times (over 20 years). Results are reported to a standard format, which also presents economic information. Initial establishment costs of the monitoring regime have, in some cases, been defrayed by regional public funds in France, but there is a strong dependence on philanthropic self-funding by forest owners and supply of voluntary time input by salaried academic collaborators. While there are some technical differences between the AFI and FCIN45 protocols, much of the information collected is very similar, and differences are only relevant to advanced users. It is possible that application of the full AFI methodology or a "cut-down/ AFI-lite" variant could be extended to other sites in Britain, across all forest ownership categories. However the requirement for self-funding and weaker availability of university-based implementation support in Britain are likely to slow and inhibit such uptake.

Categorisation of the alternative silviculture adoption examples studied

In order to structure the presentation and description of the ATC adoption examples studied within this project, it is necessary to adopt some form of categorisation scheme. However it is accepted that this can appear somewhat artificial when considering any individual adoption example that may embrace several tree species, silvicultural approaches and objectives. Also, there is a danger that adoption of technical terminology may be off-putting to the reader with less previous exposure to discussion of silvicultural systems. In some senses, there is no right answer to this problem, and it is difficult to present material in a way that suits all audiences. The approach adopted here to description and categorisation of examples is described below.

Traditional classification of silvicultural systems

Traditional silvicultural authors such as Schlich, Troup, Matthews and Anderson adopted an approach based on silvicultural systems, derived from classical Continental practice. Terms such as uniform shelterwood, group shelterwood, group selection and single-tree selection were used to describe the regimes under which stands were managed. This approach was also adopted by Hart in FC Bulletin 115, with variable success. There have always been greater difficulties in applying these classical descriptions in Britain as many stands remain under transformation to an intended alternative silvicultural system and the silvicultural end-point is often not yet clear or decided. These difficulties have grown in recent years with the tendency for much British alternative silvicultural practice to become adaptive, responding to advance natural regeneration, rather than pre-planned and formalised. Most examples reported in this project are in reality some composite of "irregular shelterwood-cum-group selection". Usage of these standard silvicultural terms is also now less common among some younger foresters. For these reasons, it has been decided not to emphasise use of these terms within the current work, although they will be used in the database entries and case-study reports where they are thought to add usefully to the description of the adoption work undertaken at those sites. Primarily, examples will be categorised by (a) their stage of silvicultural development and (b) the adoption context of tree species and management objectives within which they are found.

Categorisation by stage of transformation/ progress of stand development

An important basis for description of examples is the degree to which they have developed away from their normal silvicultural starting point, regular plantation forestry (very few examples of alternative silviculture in British forestry start from the point of new plantings). A five category scheme is set out below under which adoption examples will be categorised within this project. While a small number of mature adoption examples have developed into their intended final silvicultural condition (category 1), most remain in the course of transformation towards this - either well advanced (category 2) or early-stage (category 3). All examples reported as case-studies within this project fall into these first three categories. Evaluation of the state of progress will mainly be the judgement of the author, in some cases supplemented by views expressed by the land owner/ woodland manager. A fourth category of ATC adoption examples are those where there is a stated aim of adoption but the initiation work conducted to date has not yet led to significant departure from a regular plantation structure (category 4), while those where there is a stated aim of ATC adoption but no relevant silvicultural work has been undertaken to date are (category 5). These latter two categories will mainly be dealt with in the technical report of this project. An attempt has also been made to quantify the amount of land on the Forestry Commission holdings which is considered to be in categories 4 and 5, based on digital mapping data they kindly supplied.

Concept of "transformation period"

Earlier discussions of alternative silviculture, as well as emphasising the descriptive concept of a formal "silvicultural system", also used the predictive concept of "transformation period" and progression through the latter, to assess stage of silvicultural development towards that system. For example the transformation work at Glentress Forest was originally predicted to take 60 years, more recently re-assessed to 90 years. During the research for the current project it became clear that few forest managers adopting ATC systems thought it possible to define a predicted transformation period for the work that they were undertaking or thought that this was a useful approach. Much work is adaptive without a tightly defined "end point". Only those fairly expert managers attempting to manage stands towards a permanently irregular structure using the "reverse J-curve approach" favoured the concept at all, and then only as a broad indication (e.g. "over the next couple of growing stock rotations"). Hence the present author will not make any general use of the concept of predicted transformation period. With very few exceptions, British ATC stands are, and will remain, in transformation.

Categorisation by species context/ adoption objectives

The other important criteria for classification of the examples studied is their starting point - essentially a combination of the tree species already present on site at the outset, the previous development of the stands and the owner's objectives for adopting alternative silviculture. I have described this combination of factors within the current project as "adoption scenarios" of which 18 are set out below. While these can be grouped into a smaller number of clusters based on the major tree species involved at the outset, it must be recognised that alternative silvicultural systems can be adopted with a number of ends in mind. For example a forest manager with a given stand of maturing Sitka spruce might use ATC to perpetuate that stand with Sitka spruce natural regeneration, diversify it by underplanting it with shade tolerant conifers or restore the site to native tree species composition where it is a Plantation on Ancient Woodland site (PAWS). The alternative silvicultural approaches adopted will differ. Many of the case study examples reported in this project, especially those on private estates with mixed woodlands, will represent more than one of these adoption scenarios - for example Cowdray Park Estate illustrates Scenario 4 - restructuring of a lowland Scots pine plantation by natural regeneration, Scenario 7 - perpetuation of productive Douglas fir on a lowland site and Scenario 9 - management of shade-tolerant conifers on a productive site (in that particular case, naturally regenerating grand fir and western hemlock in separate stands).

A matrix of the reported case-study examples by developmental category and adoption scenario is provided below for ready reference.

Categorisation scheme by stage of silvicultural development

Category 1: Complete/ near-complete transformation examples
Those relatively scarce examples of traditional, long-established continuous-cover forestry where there is a well developed complex structure and a selection forestry system in place. Transformation to a permanently irregular structure is complete or approaching this status. Almost all examples are on traditional private estates, occasional examples on the NFE.
Coverage: Technical report, database (near comprehensive), case studies (few).

Category 2: Progressive/ maturing transformation examples
Examples where a clear pathway of development towards an alternative silvicultural system is in place and more than one silvicultural intervention to that specific end has often been implemented. For example the canopy has been crown-thinned, natural regeneration or under-planted enrichment is in place and maturing regeneration has been first-thinned. The structure may not be as fully developed as in Category 1, but the trend of development is clear. Many examples on the private estates, with some on the NFE and charitable forest holdings. Coppice-with-standards will be dealt with here, but only those few notable examples where it is being actively restored/ operated (not the numerous neglected or overstood examples).
Coverage: Technical report, database (near comprehensive), case studies (many).

Category 3: Early-stage adoption/ transformation examples
Examples where there is a stated aim of conversion to an alternative silvicultural system and at least one silvicultural intervention to that specific end has been carried out. For example an eligible first thinning might be either variable intensity (to promote groups), crown selected, aimed at frame-tree selection or heavier than usual (for uniform shelterwood). There should usually be at least some evidence of advance natural regeneration or underplanting. Many shelterwoods are in this category. Examples are found on all woodland ownerships. Some examples where there has been delayed natural regeneration following the initial ATC intervention, for example in Norway spruce or oak stands, will also be dealt with here.
Coverage: Technical report, database (listed where possible), case studies (some).

Category 4: Preliminary-stage adoption examples
Examples where there is a stated aim of conversion to an alternative silvicultural system but the structure of the stand has not yet departed from the regular condition. The stand may have been thinned but the thinning is regular/ systematic and not yet distinguishable from the standard regime that would be applied in regular plantation forestry. There will usually be little or no natural regeneration as yet and no underplanting in place. In many cases the aspiration to adoption of ATC is non-specific as to system and monitoring is minimal. Many examples on the national forest estate still fall into this category, along with some elsewhere.
Coverage: Technical report, database (aggregated national areas for FC/ NFE only).

Category 5: Adoption suggested but not yet commenced
Examples where there is an aspiration to future application of an alternative silvicultural system but where there have been no silvicultural interventions that might implement that aspiration. This will be taken to cover all newly planted woodlands, restocks or natural regeneration that have not reached first thinning age or if they have, have not yet been

thinned. This includes much or all of the post 1990 new native woodlands and land reclamation plantings. Also included here will be extensive areas of Forestry Commission untended young restock designated as LISS/ATC over the past decade, especially in Wales. All neglected or unmanaged woodlands above first-thinning age will also be included here, similarly with woodland managed on an explicit non-intervention basis for conservation (it is recognised that some such areas have recruited significant advance natural regeneration of shade tolerant species, which has not been deliberately released). Policy/ designed landscape/ parkland woodlands will be included here unless they meet the criteria for one of the higher silvicultural categories - occasional tree felling or specimen planting not being sufficient.
Coverage: Technical report, database (aggregated national areas for FC/ NFE only).

Category 6: Excluded from study as being regular silviculture.
Regular plantation forestry (including SRF). Simple coppice (including SRC).
Coverage: Not dealt with in this study.

Categorisation scheme by species context/ adoption objectives (adoption scenarios)

Scenario 1: Sustainable timber production from upland semi-natural oakwoods
Examining applications of alternative silvicultural systems for the restoration of active management in mature semi-natural and Atlantic oak woodlands. Picking up on work previously reported in this area by Richard Thompson, Rick Worrell and George Peterken.

Scenario 2: Management of mixed broadleaved woodlands for quality hardwood timber
Examining application of alternative silvicultural systems for production of quality hardwood timber from mid-rotation and mature broadleaved woodlands (OK, AH, BE, SYC, SBI). Examples must have active hardwood silviculture, not limited intervention management. This scenario will allow for some discussion of ATC responses to the emerging *Chalara* threat.

Scenario 3: Sustainable timber production from semi-natural Caledonian pinewoods
Examining application of shelterwood and group selection systems for the production of timber and promotion of natural regeneration in native Caledonian pinewoods. Picking up on work previously reported in this area by David Jardine, Colin Edwards, Rick Worrell etc.

Scenario 4: Diversification and restructuring of semi-mature Scots pine plantations
Examining application of alternative silvicultural systems for accelerated development of more natural structures and/ or diverse species composition in maturing Scots pine plantations for combined objectives of timber production, ecosystem services, landscape amenity and species conservation. The scenario will feature some plantation examples within the Native Pinewood Zone, but will also capture some notable examples elsewhere.

Scenario 5: Development of mixed coniferous understorey in upland larch plantations
Examining application of alternative silvicultural systems for initiation and recruitment of both medium-tolerant hardwood and shade-tolerant coniferous understorey to mature larch plantations to achieve timber, landscape conservation and disease mitigation objectives. Larch regeneration will also be present in some cases, but usually as a secondary element. This scenario will allow for some discussion of ATC responses to the *Phytophthora* threat.

Scenario 6: Perpetuation of pure Sitka spruce plantation stands on upland forestry sites
Examining application of alternative silvicultural systems for perpetuation of commercial Sitka spruce plantations by means of "rolling" natural regeneration. Both two-storey shelterwood models and more complex structured selection models to be examined. This is a predominant area of activity for the Forestry Commission and investment forestry landowners, including many examples of work at an early stage of silvicultural development.

Scenario 7: Perpetuation of high-quality Douglas fir stands on productive sites
Examining application of alternative silvicultural systems for perpetuation of high-quality Douglas fir stands by means of advance natural regeneration. Both two-storey shelterwood models and more complex structured selection models to be examined. Some stands will include an increasing naturally-regenerated component of complementary tree species.

Scenario 8: Perpetuation of high-quality Norway spruce stands on productive sites
Examining application of alternative silvicultural systems for perpetuation of high-quality Norway spruce stands by means of advance natural regeneration, often with red squirrel conservation as a management objective. Both two-storey shelterwood models and more complex structured selection models to be examined, considering minimum age requirement

for successful regeneration recruitment. The record here has been rather variable. Some stands may include an increasing naturally-regenerated component of alternative tree species.

Scenario 9: Management of shade-tolerant mixed coniferous stands on productive sites
Examining application of alternative silvicultural to perpetuate mature stands of shade-tolerant conifers on better sites (RC, RSQ, WH, GF, NF, ESF, JCR). Some stands may also contain BE/ SYC. Emphasis on the "future forestry" aspect, using these species as productive timber trees. Examples for this scenario are from National Forest Estate and private woods.

Scenario 10: Development of complex structures in mixed coniferous forestry
Examining the few more fully developed applications of complex-structure selection forestry techniques to stands containing a range of coniferous and broadleaved species. Will usually have been under alternative silviculture for a minimum of 50 years. Many examples for this scenario expected to come from the private estates, but more occasionally on FC land.

Scenario 11: Diversification of lowland pine and larch plantation stands
Examining silvicultural approaches to increasing the hardwood or shade-tolerant coniferous component of mature pine and larch plantations on lowland (often ex-heathland) sites. Emphasis will be on systems using tended hardwood regeneration or conifer underplanting following thinning of the pine or larch canopy. The lowland equivalent of scenarios 4 & 5. This scenario will allow for some discussion of ATC responses to the *Phytophthora* and *Dothistroma* threats. Many suitable examples arise in the FC forests of central England.

Scenario 12: Small group working in quality lowland hardwood stands
Examining group selection or small-coupe working systems in productive, potentially high-quality lowland hardwood stands (semi-natural or planted), especially where this represents a resumption of active management in previously neglected or under-managed woodlands. There is usually an aspiration to move towards the developed structures under scenario 2. Many examples of this kind of working arise on small private woodland ownerships, community woodland projects and on private estates where there has been "regime change".

Scenario 13: Perpetuation of high quality semi-natural beech stands
Application of traditional/ classic selection and shelterwood approaches to perpetuation of high-quality beech dominated stands, primarily within the semi-natural range of the species (Cotswolds and Chilterns). Objectives currently combine timber, landscape and biodiversity. Examples are found across National Forest Estate, National Trust, Woodland Trust and private estate holdings. Diversification may become a priority with current climate risks.

Scenario 14: Diversification of beech plantations (especially to mitigate climate risks)
Application of a variety of alternative silvicultural systems for diversification of beech plantations, including those vulnerable to increased drought incidence. Techniques include thinning to promote mixed hardwood regeneration, under-planting to desirable hardwoods and longer-established examples involving diversification with the shade-tolerant conifers. A large proportion of older beech plantations on the Chilterns and the Downs are relevant here.

Scenario 15: Application of alternative silvicultural systems in small private woodlands
Recent adoptions of low-impact silviculture in smaller private estate and farm woodlands, including those acquired by interested individuals with silvicultural/ conservation interests and those currently being brought back into management for woodfuel enterprises. Some examples here are only at the initial intervention stage, while others have progressed further.

Scenario 16: Accelerated diversification of productive Sitka and Norway spruce stands
By contrast with scenarios 6 and 8, those examples where there is a stated aim to accelerate conifer diversification within productive spruce stands, usually by under-planting or other introductions of NS, DF, RC, WH and other more tolerant conifer species. Such examples usually develop towards scenarios 9 and 10 over time as their structure evolves further. In Sitka spruce stands there is usually supplementary natural regeneration, less so in NS stands.

Scenario 17: Application to gradual silvicultural PAWS restoration
Examination of approaches to restoration or enhancement of PAWS sites by active silvicultural conversion (most case-studies adopted from author's earlier study on this). This scenario will be used to capture those examples under spruce, fir or hemlock where there is more deliberate establishment and tending of the native hardwood understorey by under-planting/ cleaned regeneration. More *laissez-faire* examples of natural recruitment of intruded hardwood understories will be dealt with under scenarios 5, 11(pine-larch) and 14 (beech)

Scenario 18: Restoration of coppice-with-standards working
Examination of <u>active</u> coppice-with-standards systems or deliberate restoration of such on sites in lowland England either for timber and woodfuel or for conservation/ biodiversity reasons. Examples where the understorey has become over-stood due to lack of management will not be considered as these are essentially a variant of neglected/ unmanaged woodland. This scenario will also capture a few British examples of classic oak uniform shelterwood.

<u>Grouping of adoption scenarios by principle species at outset</u>
Initial condition (species dominance):-

OK	Scenarios 1 (upland), 2,12 (lowland), *15*, 18 (C-w-S, U s/wood)
BE	Scenarios *10*, 13 (semi-natural), 14 (plantation), *15*
AH/SYC etc	Scenarios 2 (selection), *10*, 12 (group felling), *15*
SP/CP	Scenarios 3 (native), 4 (upland plantn), 11 (lowland plantn), *15*
EL/HL/JL	Scenarios 5 (upland plantation), 11 (lowland plantation), *15*
DF	Scenarios 7, *10, 15*, 17 (PAWS)
SS	Scenarios 6 (SS/SS), *10, 15*, 16 (diversification), 17 (PAWS)
NS	Scenarios 8 (NS/NS), *10, 15*, 16 (diversification), 17 (PAWS)
RC/WH/GF etc	Scenarios 9, *10, 15*, 17 (PAWS)

Scenarios 10 (complex mixtures) and 15 (small woodlands) are non species-specific

Synopses of the case-study examples reported in detail

Case Study 1 - Atlantic Oakwoods

This case-study deals with the application of a range of sensitive alternative silvicultural approaches to the management of semi-natural oakwoods in the west of Scotland. Many of these woodlands were former industrial coppices, with a legacy of an artificially dense, even-aged structure of oak poles. In normal circumstances, thinning would be recommended to produce some usable timber and to promote advance regeneration. However lower plant interests imply a presumption against sudden disturbance to light and microclimatic regimes. Recommendations of a number of appropriate silvicultural models were put forward by Richard Thompson of the Forestry Commission and consultants George Peterken and Rick Worrell and these techniques have been tested in woods at Sunart, Morvern and Loch Awe. Application of these forms of ATC will support future conservation and economic usage.

Case Study 2 - Cirencester Park Estate

This case-study deals with the 60-year record of application of alternative silviculture to the woodlands on the Cirencester Park Estate in the Cotswolds, owned by the Bathurst family. These woodlands are managed for a combination of economic timber production, estate landscape amenity and sporting cover. The traditional woodland cover in the area has been beech-ash. Post-war silviculture, led by head foresters Edward Garfitt, Arthur Lloyd and Keith Mills has used group selection and shelterwood techniques to restock over-mature stands and to increase the species diversity by introducing productive conifers such as Douglas fir, larch and Norway spruce. Group replanting with several species under older beech has produced attractive mixed stands with a wide range of age-classes, while a combination of underplanting and natural regeneration is used to restock semi-mature ash.

Case Study 3 - Newbyth Wood

This case-study deals with alternative silvicultural approaches applied on a small private estate in east-central Scotland by forestry consultant Colin MacBrayne. These woodlands are managed for a combination of private landscape amenity and hardwood timber production, with some sporting use. Improved markets for woodfuel make thinning of hardwood stands more attractive. Mature stands of oak hold potentially valuable timber and form important features in the lowland landscape, but can be difficult to regenerate naturally in the presence of roe deer. Approaches adopted have involved (a) partial replanting with oak and other hardwoods in treeshelters after felling or thinning of the mature canopy and (b) encouraging natural regeneration in gaps wherever possible. These approaches avoid the undesirable landscape and silvicultural effects of clear-felling operations on fertile lowland sites.

Case Study 4 - Cawdor Estate

This case-study deals with the application of alternative silvicultural systems to deal with a number of stands on the Cawdor Estate in northern Scotland, which retains a head forester. This is one of the most northerly estates in Britain using these systems. A mature plantation of Scots pine, forming an attractive recreational resource for the town of Nairn, is being regenerated by an irregular/ group shelterwood approach, encouraging concentrations of pine/ mixed conifer regeneration with birch. Elsewhere, fine larch plantations of similar age are developing a shade-tolerant naturally regenerated understorey of western hemlock and other

conifers, which might provide a future option in the event of disease in the larch. Finally a variety of natural regeneration-based techniques have been attempted in the ancient oakwoods at Cawdor, but with significant challenges from competitive ground vegetation and deer.

Case Study 5 - Ffrwdgrech Estate

This case-study deals with woodlands on the Ffrwdgrech Estate near Brecon, which has been recognised for many years as a fine example of alternative silviculture. The Evans family, owners since the early 1900's, have been enthusiastic silvicultural innovators in the area, advised later by noted continuous-cover specialist, the late Talis Kalnars. The woodlands are now managed for a combination of economic timber production and estate amenity with advice from agents, Pryor and Rickett Silviculture. Stands felled during both world wars were restocked by planting a range of species in groups, including Douglas fir, western red cedar, larch, Corsican pine, ash, oak and sycamore. Management now employs a combination of selective thinning, natural regeneration and small group felling/ replanting to maintain continuous cover. Douglas fir, red cedar and hardwood species produce valuable timber.

Case Study 6 - Blelack Woods, Glen Tanar and Glen Dye Estates

This case-study deals with three private estates in southern Aberdeenshire that are using alternative silvicultural systems to manage mature stands of Scots pine for timber production and nature conservation. In this region of Scotland it is usually possible to secure natural regeneration of Scots pine on freely-drained, infertile soils, and this offers a less expensive approach to restocking than replanting. Blelack Woods near Logie Coldstone employ the traditional seed-tree/ uniform shelterwood methods to restock mature Scots pine plantations. Glen Tanar Estate on south Deeside uses both this approach and a group selection method to secure regeneration in ancient semi-nature Caledonian pine stands. Glen Dye Estate near Fettercairn and Blelack Woods are diversifying mature Scots pine (and larch) plantations by promoting an understorey of natural regeneration of shade-tolerant noble and silver firs.

Case Study 7 - Curr and Anagach Woods (with Swinley Park, Windsor)

This case-study deals with three woodlands where natural regeneration is being used to restock mature plantations of Scots pine for timber production, conservation and amenity. At Curr Wood, near Grantown-on-Spey and at Swinley Park on the Crown Estate at Windsor, the traditional seed-tree/ uniform shelterwood method is being used to restock mature Scots pine plantations for timber production without the need for replanting. At Anagach Wood, near Grantown-on-Spey the local community are managing for amenity and conservation, with some timber production, using a wider range of alternative silvicultural systems. These examples show how well planned application of ATC in mature Scots pine on suitable sites can secure natural regeneration while helping to diversify and naturalise the structure of single-storey plantations. These techniques prove cost-effective for owners and managers.

Case Study 8 - Cowdray Park Estate

This case-study deals with the Cowdray Park Estate in Sussex, which has a long pedigree in conventional estate forestry management but is now making trials of alternative silvicultural systems in a minority of stands within its woodlands where natural regeneration has been observed. Most stands were established in the period 1950-1970, with some older pine. Natural regeneration has been successfully recruited in older Scots pine stands using the seed-

tree felling approach, in p1960's Douglas fir using a uniform shelterwood and in p1960's grand fir using an irregular shelterwood cum group selection approach. The head forester uses small plots to monitor levels of natural seedling regeneration and larger fenced exclosures to assess the impacts of deer browsing on its development. Cowdray Park, as a respected forestry estate, makes for a valuable demonstration of early-stage ATC in mixed woodlands.

Case Study 9 - Wykeham Forest

Wykeham Forest on the North York Moors is one of the Forestry Commission's existing network of ATC demonstration sites across the National Forest Estate. The matrix of the forest consists of stands of Scots pine and larches established from 1930-1960 on open moorland, with some spruce on wetter sites. Later a number of the pine stands were enriched by inter-planting with a range of shade tolerant conifers such as *Abies* firs, western hemlock and red cedar. This situation provides an unusual opportunity to achieve both structural and species diversification within the current rotation using ATC thinning approaches - this could prove valuable experience elsewhere given current disease pressures on pine and larch crops. A variety of ATC methods are being implemented and carefully monitored using the FCIN45 protocol, and the site has previously hosted a number of organised forestry training visits.

Case Study 10 - Fernworthy Forest

Fernworthy Forest on Dartmoor is one of the Forestry Commission's existing network of ATC demonstration sites across the National Forest Estate. The forest is composed mainly of Sitka spruce established from 1920-1960 on open moorland around Fernworthy Reservoir. Occurrence of advance regeneration and significant landscape pressures prompted the Forestry Commission to adopt alternative silvicultural systems to perpetuate forest cover with a diversified structure. Several different ATC approaches have been attempted and the site has provided valuable demonstration of operational and logistical aspects - harvesting of large spruce trees, provision of brash for extraction routes over peat and frame-tree thinning. Although the forest is quite remote and remains dominated by Sitka spruce, it is recognised that adoption of ATC approaches has consolidated and improved its recreational potential.

Case Study 11 - Cwm Berwyn and Cefn Llwyd Forests

This case-study deals with two even-aged upland spruce-dominated forests in Wales where alternative silvicultural systems have been implemented over 20-30 years. Cwm Berwyn Forest in Cardiganshire is owned and managed by the Forestry Commission, forming part of their ATC demonstration site network. A variety of silvicultural approaches are being applied in pure Sitka spruce stands. Cefn Llwyd Forest in Powys is privately owned (formerly by Shotton Paper) and is managed by UPM Tilhill. Under previous supervision of ATC specialists Talis Kalnars and Phil Morgan, strip shelterwood and group systems were implemented in spruce, with a more diverse area including Scots pine, larch and Douglas fir. These examples show the silvicultural opportunities and operational constraints relevant to ATC in exposed plantations on poorly drained soils, conditions met with by many managers.

Case Study 12 - Kilmichael and Penninghame Forests

This case-study deals with two even-aged upland spruce-dominated forests in western Scotland where alternative silvicultural systems have been implemented in recent years. At Kilmichael Forest in Argyll, areas have been selected for ATC adoption based on lower

elevation and better soils. Mid-rotation stands of Sitka spruce have been thinned to promote stability and natural regeneration. However some such stands have later suffered windthrow. At Penninghame Forest in Galloway, similar spruce stands have been subject to group selection fellings to promote natural regeneration in canopy gaps. Sitka spruce is also regenerating well under neighbouring crops of Scots pine and larch where basal area is lower. These examples show the silvicultural opportunities and operational constraints relevant to ATC in exposed plantations on poorly drained soils, conditions met with by many managers.

Case Study 13 - Devilla, Tentsmuir and Cardrona Forests

This case-study deals with varied ATC experiences, across three Forestry Commission sites in eastern Scotland, when trying to naturally regenerate plantation stands of Scots pine at 50-70 years of age (i.e. rather younger than the traditional shelterwood working in 80-120 year old pine stands discussed in Case Studies 6 & 7 above). At Devilla Forest in Fife, recent work has used a combination of preparatory thinning and small coupe fellings, restocked by planting following a lack of/ delayed natural regeneration. At Tentsmuir Forest, also in Fife, natural regeneration of well-thinned pines has been secured on acid, coastal sands where vegetation competition is limited. By contrast, at Cardrona Forest in the Tweed Valley, it has proved difficult to recruit pine regeneration in p1930's stands where a competitive grass sward was already established. Such experience is valuable if using ATC to naturalise pine plantations.

Case Study 14 - Longleat Estate

Longleat Estate in Wiltshire has, over the past half century, established a reputation as one of Britain's leading exponents of both alternative silvicultural systems and alternative conifer species. High-value crops of Douglas fir, larch, coastal redwood, grand fir and Lawson cypress are managed, using a selection forestry system, to serve identified timber markets. Of particular importance is the record with Douglas fir, grown since the 1960's on an "off the shelf" system such that individual stems can be selected for felling to meet customer specifications, based on detailed knowledge of the head forester. Longleat is also a leading commercial grower of coastal redwood in Britain, a species that is attracting interest at present due to its potential for use on drier lowland sites in place of disease pine or larch. Longleat is also a suitable location to show how ATC demonstration may best be organised.

Case Study 15 - Wyre, Mortimer and Thetford Forests

This case-study looks at three Forestry Commission sites in central and eastern England where high-value "trophy" crops of p1920's Douglas fir are being managed under alternative silvicultural systems, recruiting a mixed natural regeneration of Douglas fir and native hardwoods. This approach is seen as valuable in areas of higher visitor recreation importance and on PAWS sites, where there is a long-term aspiration to revert to native species cover. Douglas fir in these accessible areas is a commercially attractive proposition, and with current disease threats to established pine and larch crops, many growers will be considering whether expansion of Douglas fir is the right way forward. While Wyre and Mortimer have climates considered ideal for Douglas fir, Thetford Forest is in a much drier category. The fact that Douglas fir crops of the right provenance can be grown under ATC even there is promising.

Case Study 16 - Craigvinean, Ae and Fearnoch Forests

This case-study looks at experiences of operating alternative silvicultural systems in semi-mature Norway spruce on Forestry Commission land in Scotland, a species which it is desirable to retain for reasons of amenity, crop diversity and red squirrel habitat/ forage. Heavy thinning of Norway spruce stands at 60-70 years of age has, in some situations, promoted competitive ground vegetation on more fertile sites, with limited or delayed Norway spruce natural regeneration. Where more shade-tolerant conifers such as *Abies* firs or western hemlock are present, these often produce earlier advance regeneration within Norway spruce stands. Norway spruce regeneration is fairly light demanding but seed production may not be adequate until 70-80 years crop age, hence preparatory thinning must be well timed. Managers may need to consider underplanting stands with Norway spruce and other conifers.

Case Study 17 - Glen Branter, West Loch Eck, Pucks Glen and Benmore

This case-study deals with applications of alternative silvicultural systems in a set of Forestry Commission holdings on the Cowal peninsula in western Scotland. These are older than many other Scottish plantations, with significant elements of the crop dating from the period 1880-1940, and with a wider range of conifers used, including some more shade-tolerant species. Mature stands are of high importance for visitor amenity and for silvicultural/ botanical demonstration value near the Younger Botanic Garden, Benmore. Good natural regeneration has been secured under mature Sitka spruce, noble fir, western hemlock and Douglas fir crops. In some areas with poorly thinned crops of Norway spruce and larch, natural regeneration is dominated by western hemlock, and a planned programme of thinning interventions will be aimed to diversify the structure of these stands and regenerating species.

Case Study 18 - Dunster and Tavistock Estates, with Dartington Hall, SW England

This case-study deals with three estates in south-west England where alternative silvicultural systems are employed to manage productive and valuable crops of Douglas fir, western red cedar, western hemlock and coastal redwood (together with larch and hardwoods at Dartington Hall). Tavistock Estate and Dartington Hall became famous in the 1950's for using innovative group selection forestry methods in mixed conifer stands. The influence of enthusiastic owners (Lord Bradford at Tavistock) and head foresters (P.A. Hutt at Tavistock and W.E. Hiley at Dartington Hall) was significant in this. Both Tavistock and Dartington Hall originally used relatively sophisticated versions of the group selection approach which have since been simplified, but with ATC and natural regeneration remaining predominant. Dunster Estate has more recently implemented less formal variants of ATC in similar crops.

Case Study 19 - Bowhill and Eildon Estates

This case-study deals with two of the longest-established examples of ATC adoption in private woodlands in Scotland, both being located on Buccleuch Estates properties in the central Borders. A variety of largely group-based silvicultural approaches have been employed in these woodlands since the 1920's, with single-tree selection working close to the main Estate houses. Crops include a wide range of tree species including Douglas fir, larch, Scots pine, grand fir, noble fir, western hemlock, beech, sycamore, ash and oak. The twin emphases of management in these areas are estate landscape amenity and the production of quality timber. These woodlands had and continue to have, considerable potential for the

demonstration of ATC in Scotland. Other estate woodland areas in less prominent locations are managed for economic timber production using conventional regular silvicultural systems.

Case Study 20 - Sherwood and Thetford Forests (with Thoresby Park Estate)

These examples deal with the relatively recent/ early-stage adoption of alternative silvicultural systems within lowland pine and larch plantations on former sandy heathlands, mainly owned and managed by the Forestry Commission. Where not being restored to open habitats under current policy programmes, such plantations face challenges from *Dothistroma* in the pines and *Phytophthora* in the larches and need to be actively diversified. ATC offers a variety of approaches to this including (a) recruitment of a self-sown native hardwood understorey, (b) heavy thinning of the pine canopy to reduce *Dothistroma* impacts and promote natural pine regeneration under a shelterwood and (c) active enrichment under-planting with more shade tolerant conifers such as Douglas fir and western red cedar that may form a valuable future crop, managed together with pine and hardwood species under selection systems.

Case Study 21 - Dalmeny and Dalkeith Estates

These case-studies deal with two traditional lowland private estates near Edinburgh using alternative silvicultural systems for management of quality hardwood stands (dominated by oak, ash, beech and sycamore). A proportion of the standing hardwood crops are mature or over-mature. Objectives of management at these sites embrace sustainable timber and woodfuel production, estate landscape amenity and, in the case of Dalmeny, sport shooting. A key aim is to preserve continuous woodland cover within valued historic designed landscapes while producing some income and securing regeneration for the future. The main silvicultural approach employed is small group selection felling, with replanting and natural regeneration. Replanting is the dominant technique at Dalmeny with more natural regeneration at Dalkeith. Challenges include grey squirrel and deer pressure and the new threat of disease in ash crops.

Case Study 22 - Hooke Park

This example gives an opportunity to follow adoption of alternative silvicultural systems from the outset in diverse woodlands, with even-aged crops established between 1950 and 1970. Stand types include areas of pure beech, together with oak-Norway spruce nursing mixtures, Douglas fir, western red cedar, larch and some younger mixed broadleaved plantings. The woodlands are owned by the Architectural Association and form the setting for its rural architecture training. There is a commitment to use the site for demonstration of sustainable woodland management and innovative timber utilisation. Main silvicultural approaches for the foreseeable future will concentrate on selective thinning Norway spruce from nursing mixtures with oak and introducing a selection system into semi-mature beech stands. Douglas fir, western red cedar and quality hardwoods will all be fostered for the future under ATC.

Case Study 23 - Cotswold Beechwoods

The semi-natural beechwoods of the Gloucestershire Cotswolds have a heritage of selection forestry dating back to before the Second World War. A particular influence was the Workman family (local hardwood sawmillers and estate owners). Single tree and group selection management was employed in their various woodland holdings to produce high quality beech timber (with some ash) and to promote natural regeneration. Most of these woodlands have now passed into conservation ownership (National Trust and Gloucestershire

Wildlife Trust) while the Kingscote Woods are under new private owners. Those woodlands managed primarily for conservation tend to be less actively tended than in the past, with an accumulation of dense natural beech regeneration in the understorey. It is hoped that tending may increase in coming years with the improved beech woodfuel market. Grey squirrel and drought are key factors. The Kingscote Woods are managed by group-felling and replanting.

Case Study 24 - Chiltern Beechwoods

The Chiltern beechwoods have a more varied silvicultural history with traditional selection working for the furniture trade being abandoned in the early 1900's with some woodlands left under-managed while others were felled during and after the war and replanted with conifers. This case-study highlights a range of alternative silvicultural approaches in the Chilterns including long-standing mixed shade-tolerant conifer-hardwood selection working at Ipsden, more recent implementation of ATC in post-war hardwood stands at Ramscoat and a sixty year record of Forestry Commission field research into beechwood regeneration at Queen and College Wood. Many of these sites have an atypical record of detailed quantitative enumeration, partly due to their proximity to the academic forestry centre at Oxford. Current challenges include severe grey squirrel impacts, drought effects on beech and ash die-back.

Case Study 25 - Wilderness Wood

This small private woodland in Sussex presents an unusual, ready-made example of detailed and carefully-recorded adoption of alternative systems, by an enthusiastic owner-manager. The family owners use their woodland as an economic resource, both for production and on-site marketing of timber and woodfuel and as a context for a rural visitor and outdoor education business. For these reasons, preservation of continuous woodland cover was strongly desired. Stands originally comprised stored sweet-chestnut coppice, combined with mixed plantings of beech and Scots pine from the 1960's, thinned in the late 1970's. Management has been inspired by the approach at Tavistock Estate (see Case Study 18) where small group selection fellings are replanted with several species, which have included Douglas fir, western red cedar and hardwoods for timber/ woodfuel and Norway spruce for Christmas trees. The 1987 gale caused damage and drought/ poor soils affect species choice.

Case Study 26 - Whittingehame and Abbey St. Bathans Estates

This case-study continues the theme of recent adoption of alternative silvicultural systems on smaller private estates - here both in south-east Scotland. A common factor here is the ability to process timber products "in house" for either sawn products or woodfuel, favouring a "constant offtake" mode of forest production under ATC. Avoidance of major disturbance to the estate landscape and associated sporting values is also a factor at both locations. Resources vary, but include a major element of post-war coniferous stock that has a limited previous thinning record, resulting in compromised stability. Both estates also have hardwood resources - semi-natural oak at Abbey St Bathans and ash-sycamore at Whittingehame. The availability of a wider range of small and medium-scale harvesting, forwarding and wood processing equipment, often of Continental manufacture, is facilitating ATC adoption on smaller estates, although there remain complications on safety certification of light machines.

Case Study 27 - Coed Preseli, Nant yr Eira and Bryn Arau Duon

This example deals with three privately-owned upland commercial spruce forests in Wales that are under management by SelectFor agents. In each case, there is an overall ambition to convert even-aged spruce from the 1960's and 1970's to permanently irregular structures, relying to a greater extent on natural regeneration. This can be challenging where past thinning has been insufficient on exposed upland sites with limited rooting depth. The initial approach centres on installation of improved roading access to facilitate more frequent silvicultural interventions, combined with variable-intensity mechanised thinning. Assisted by low deer populations, enrichment under-planting with desirable tolerant conifers such as Douglas fir, Norway spruce and western red cedar is being employed to diversify stands for the next rotation, along with the expected natural regeneration of the main Sitka spruce crop.

Case Study 28 - Wyre Forest and Forest of Dean

This case-study deals with the relatively limited experience in Britain of successful natural regeneration of oak using classic seed-tree / uniform shelterwood systems along French lines. Many attempts at these methods have been confounded by infrequent oak mast years, over-competitive ground vegetation on fertile sites and high rates of seedling predation. In the Dean there has been a tradition of using these methods for over a century and experimental work during the 1970's and 1980's under John Everard achieved some notable successes on suitable sites. At the Wyre, more recent work has involved removal of dense shade-conifers in aid of PAWS restoration, and subsequent profuse seedling regeneration of oak on bare soil. Young oak regrowth can be thinned to establish oak high forest stands or re-coppiced to produce small-diameter material for charcoal / woodfuel products with biodiversity benefits.

Case Study 29 - Salcey Forest and Bradfield Woods

This case-study deals with active management of oak-dominated woodlands under the traditional coppice-with-standards system. This produces a combination of valuable oak timber from standard trees on a 100-120 year rotation together with coppice products from ash, hazel, field maple, aspen etc on shorter rotations, ranging from 10 to 25 years. While many such examples had fallen out of management over recent decades, rising demand for woodfuel and an aspiration to native woodland restoration are favouring their resumption. Bradfield Woods in Suffolk is a county wildlife trust reserve where this form of management has been consistently pursued over many centuries, whereas work at the Forestry Commission's Salcey Forest is seeking to restore active coppice-with-standards management to high forest oak stands ranging from perhaps 50-150 years in age. This involves group selective thinning of over-dense oak canopies and re-cutting of surviving coppice stools.

Case Study 30 - Weasenham, Sennowe and Fulmodeston Woods

The final case-study features a set of three private estates near Fakenham in north Norfolk which have an unusual record of selection forestry in diverse conifer plantations. This owes inspiration to forestry work by the Earls of Leicester in the late 1800's and early 1900's, establishing the Weasenham Woods on open heathland and restocking the Fulmodeston site. Weasenham in particular has a unique record of managing a wide range of naturally-regenerating conifer species in intimate mixture under single-tree selection to produce valuable individual stems. Silviculture at Sennowe and Fulmodeston Severals aims to maintain and enhance tree species and structural diversity using both planting and natural

regeneration. All of these sites currently benefit from attention of interested and expert owner-managers. The range of species and the management system applied are likely to be of considerable interest to forest owners and managers in lowland England, seeking to diversify spruce, pine and larch crops that are potentially challenged by climate and disease factors.

Examples covered at a lower level of detail within the project

In addition to those 65 individual examples of alternative silviculture adoption dealt with within the 30 reported case-studies summarised above, shorter-form commentaries are provided on a further 49 ATC adoption examples selected from the database register, where there have been recent reports on their development prior to commencement of the present study. These include (a) 24 examples which have been the subject of recent published reports following research work or organised field visits and (b) 25 examples that were the subject of illustrated case-study reports within the present author's previous reported studies on adoption of minor conifers and silvicultural PAWS restoration working. These commentaries are included in a digital archive appendix to the present report as further illustration. Finally, 43 other examples are recorded, but only as single-line entries within the locational database.

A spreadsheet appendix captures additional aggregated areas on the National Forest Estate in England, Scotland and Wales where Forestry Commission records suggest that alternative silvicultural systems are being (or are planned to be) adopted. These areas will mostly be in ***developmental categories 3, 4 or 5*** (transformation at early or preliminary stages or planned, but not yet commenced) and are included here to give an estimate of overall ATC extent.

Potential adoption examples not captured by the project

It is accepted that there will also be some further examples of alternative silvicultural systems application on private and charitable forest holdings that have not been captured by the locational database. Again, these areas will mostly be in ***developmental categories 3, 4 or 5*** (transformation at early or preliminary stages or planned but not yet commenced). There is no comprehensive spatial register of silvicultural systems on the private forests to compare with that referred to above for the National Forest Estate, so the project coverage can only be based on examples known to the author, noted from the literature review or actively notified. There are likely to be few significant unrecorded examples of more advanced/ developed ATC.

It is thought that the majority of unrecorded examples will have the following characteristics:-

- concentration in southern, western and central England, and possibly mid-Wales.
- location on smaller private estate and farm properties without a head forester.
- concentration in lowland broadleaved and mixed broadleaved-conifer woodlands.
- dominant correspondence with adoption scenarios 2, 12 and 15 as detailed above.
- recent and largely informal adoptions, often as part of management resumption.
- objectives of woodfuel and small-scale quality hardwood timber production.
- limited previous engagement with organised forestry society and CCFG visits.

It is suggested that the project database could be held open to incorporate future notifications of additional ATC sites that become known, or more prominent, during the next decade.

The forthcoming National Forest Inventory (NFI) should provide a statistical estimate of the total extent of adoption of alternative silviculture systems adoption within private woodlands.

Summary insights arising from field study of ATC adoption examples

Insights gained from the programme of field visits conducted for the present study in large part re-confirmed those obtained from the desk review phase but adding texture and detail:-

- Most of the "core body" of longer-established examples reported by Cyril Hart in Bulletin 115 continue under essentially similar ATC regimes to those described at that time. There has been very little "deliberate" abandonment or cessation of ATC management once it is actively implemented, although some cases have seen "de-intensification" or "de-formalisation" of the more intricate forms of selection forestry management previously practiced, locally merging into "policy woodland" regimes. Some sites where this had happened earlier, such as Corrour Estate, are now seeing ATC rejuvenation under changed ownership and management with new priorities.

- A number of woodland holdings across all ownerships have initiated forms of ATC in the intervening period by non-standard thinning of mid-rotation crops with the intention of later adoption of either a shelterwood or a selection forestry system (in many cases the decision between these will not be made until later). In many of these cases the triggers for a change in silvicultural outlook is the first emergence of natural regeneration, coupled with improved woodfuel markets for small diameter thinnings.

- A significant factor in the expansion of ATC adoption in private woodlands is the rejuvenation of active management on traditional private estates, either under existing head foresters or at the point of transfer of management to an enthusiastic retained agent. On smaller properties a new generation of active owner/ managers is emerging. In both these situations, estate amenity remains an important consideration but there is an increased emphasis being placed on "making the woods pay" by taking advantage of improved markets for woodfuel and specialist, large-diameter softwoods/ hardwoods for premium applications. There is also an increasing trend to seek to secure autonomy from grant regimes, associated bureaucracy/ PAWS regulations etc. The latter is more readily achieved where the clearfell/ restock operation is avoided.

- It remains possible to interview two experienced private sector forestry agents within 50 miles of each other, one of whom will say that ATC is simply too complex and expensive and that the owner won't carry the costs of adoption, whereas the second forester will argue that re-stocking following clearfell is simply too expensive and the the owner won't carry the cost of that. Differences between these perspectives has a relationship with the age of the forester, with older foresters being more sceptical of ATC on the whole, although with some experienced individuals highly enthusiastic. Managers of more diverse lowland forestry tend to be more ready to consider ATC as compared with those dealing with monospecific even-aged plantations on upland sites. Managers of woodlands whose owners are able to supply "up-front capital" to resource the transformation process are more likely to consider ATC, whereas those managing woodlands where capital-release and income are vital, tend to avoid it.

- Interestingly, certification under UKWAS or equivalent schemes is most frequently cited as a major rationale for ATC adoption by the Forestry Commission, although other benefits of its willing adoption are tending to come to the fore. Some private owners are dropping out of UKWAS because of a perceived lack of commercial benefit and perceived regulatory burden, even although most of these owners are in fact managing their woodlands broadly in compliance with certification standards.

- There is a significant element of adoption of ATC/ CCF "on principle" or "for its own sake" in private woodlands, which runs somewhat counter to published FC guidance emphasising ATC/ CCF as a "means to a management end". This is especially true of new small woodland owners for whom perpetuation is often the primary forestry aim. These novel private adopters often have a surprisingly high technical awareness level. A similar situation pertains in community-managed woodlands, where preservation of amenity is often foremost, but with more emphasis on economic returns in Scotland.

- On the charitable woodland holdings, landscape or ecological restoration from plantation forestry is the primary aim for widespread "ATC equivalent" adoption. In the case of the Woodland Trust and county wildlife trusts, this is usually gradual silvicultural restoration of PAWS sites acquired from the Forestry Commission or private estates. In some cases restoration of coppice-with-standards working is an aim. The National Trust has been more involved with ATC as an approach to preservation of estate landscape amenity on properties with long-established policy plantings.

- An increasing proportion of the more recently-adopted ATC practice is informal, adaptively responding to patterns of natural regeneration and not espousing adherence to any particular silvicultural system. Future development often remains uncertain. Use of periodic quantitative inventory and monitoring methods is confined to a small proportion of what might be termed "elite adopters" across all ownership sectors, and is largely self-funded. Even the simpler relascopic and tariff methods are not frequent. There are a range of emergent silvicultural problems arising from this - either the periodic harvest is too heavy, decapitalising the stand, or too light, risking shading-off of natural regeneration. Both become more pronounced if interventions are infrequent.

- Many managers using ATC systems have an increasing intuitive understanding of light requirements for natural regeneration of different species and target/ critical basal areas. This is a very important step forward in British ATC practice over the past two decades, but should often be supported by relascopic/ tariff measurement of basal area.

- ATC is being adopted in a wide variety of silvicultural and species contexts (categorised using the "adoption scenario" scheme in this work). Success varies markedly by principle species, largely reflecting issues with natural regeneration. Examples involving shade tolerant conifers (red cedar, *Abies* firs, western hemlock), Douglas fir, Sitka spruce, ash, beech and sycamore are generally progressing rather well, due to their relatively prolific, early and medium or shade-tolerant natural regeneration. Examples involving Scots pine are often successful where the canopy is sufficiently opened to promote natural regeneration, but Corsican pine appears more reluctant. Work involving larch often fails to recruit a successor crop of larch due to retained shade and ground vegetation competition, with most succeeding to medium or shade-tolerant conifers where a seed-source is present or otherwise to intruded mixed hardwoods. Norway spruce is a "problem conifer" for ATC adoption, with many examples repeatedly thinned to promote regeneration, only for weed competition to swamp the site. Current FC guidance tends to encourage expectation of regeneration too early - I believe it should not be seriously sought until stands reach 70-80 years. Oak remains a relatively difficult species to naturally regenerate in British forests, although a number of successful examples of shelterwood-style working were recorded within the present study. Examples using other species remain uncommon.

- Skills availability clearly remains an issue for the expansion of ATC adoption in British forestry, although there are a number of counter-veiling trends. Clearly, many of the examples developed as case-studies within the current project are atypical in that they involve highly-expert ATC management input. However this is not typical of the context in which ATC is normally considered. In terms of the national and charitable forest holdings, the former "beat forester" system where an individual remained responsible for a relatively small area of forestry over a long period is tending to be replaced by an approach based on functional specialism. Even where a single individual remains responsible for all aspects of management, the area under charge is typically larger than before. Staff turnover in any single area can be high. Whereas experienced retiring staff typically were forestry graduates or had trained in the former "forestry schools" and gained field experience, younger staff are recruited from a wider range of business and scientific backgrounds. These trends imply that agency forest managers have to devote more of their time to desk-based planning and administrative work and to rely more on third-party silvicultural support. This does not create a favourable adoption environment for detailed, site-specific management of the kind that is required for successful ATC adoption. Rather, there is a preference for standardised management approaches that require only intermittent site intervention. It is very noticeable that on the National Forest Estate, despite a high degree of organisational direction, ATC adoption is often driven by atypically independent-minded beat foresters or district forest managers with a stronger "appetite for innovation". One of the strengths of the Forestry Commission system is its continued willingness to allow scope for this kind of pioneering activity, within reason. Retirement of traditional head foresters from the private estates is often followed by part-time replacement by a "retained agent" covering several properties, although some of these new managers are highly expert in, and enthusiasts for, ATC adoption. Similarly the trend to small estate and woodland purchase by innovative individuals from other fields of business is creating a new cohort of "self-taught" ATC adopters.

- Operational and logistical implications of ATC adoption present a mixed picture. There is no doubt that there are challenges in securing the necessary machinery and motor-manual operators for ATC adoption in some parts of the country where the post-war tradition has been of extensive even-aged spruce and pine crops harvested at 30-50cm dbh for large-scale industrial processors. Retirement of owner-operators of chainsaws, skidders and cablecranes narrows the options available to forest managers. In some situations, the combination of vulnerable soils, heavy machinery and a lack of brash during early ATC interventions makes for significant difficulties and risks. The difficulty in selling spruce above 50-60cm dbh to major mills is a key obstacle. By contrast more lowland, mixed woodland areas have seen more innovation in small-scale harvesting and forwarding machinery suitable for ATC implementation and the retention/ rejuvenation of the small and medium scale sawmilling sector. The presence of a more diverse growing stock with higher individual stem value is more favourable for ATC adoption. The price-size curve for Douglas fir, larch, oak and ash is essentially continuous, avoiding the "upper dbh limit" observed for upland spruce. Innovation in portable and bespoke sawmilling is also more common in such areas. While some insights have been obtained for younger spruce crops from the FC demonstration site network and the single Trallwm PhD study, ATC economics, and economic comparisons with conventional working are critically under-researched. Other than on AFI study sites, the emphasis tends to be on short-run operational costs (either incurred or avoided by ATC adoption), rather than long-run crop valuation.

Opportunities for continued expansion of ATC adoption - summary

The work conducted during this project has identified five main contextual opportunities for continued ATC adoption over the next 20 years. Two of these, relating to quality timber production and estate landscape amenity are of long standing, while the other three relating to nature conservation/ PAWS restoration, sustainable woodfuel production and climate/ pest and disease resilience have risen (or returned) to prominence over the past two decades:-

1. Quality timber production remains a key rationale and context for wider ATC adoption, particularly where this involves the "desirable conifers" such as Douglas fir, western red cedar and larch and the quality broadleaves such as oak, beech, sycamore and ash. ATC offers continuity of forest micro-climate within which these species can be successfully regenerated to produce a valuable final crop of larger-dimension growing stock. Silvicultural interest and curiosity of the owner and forester should not be overlooked. Timber production using ATC in upland spruce and pine plantations offers considerable opportunities in terms of scale, but perhaps more moderate benefits in terms of value.

2. Estate landscape amenity is also an enduring rationale for wider ATC adoption across all ownership categories, with increased public awareness of, and interest in, the development of attractive forest landscapes. The forester's "mandate to manage" is dependent to a large degree on public approval and ATC can be a valuable tool in securing and retaining it. ATC is particularly relevant in areas of upland plantation forestry in visually sensitive areas along valley bottoms and lower slopes with high recreation and amenity value. It is also increasingly seen as a cornerstone of active management and rejuvenation in designed landscapes in both upland and lowland areas where amenity and sport are aims.

3. Nature conservation/ PAWS restoration work has expanded considerably over the past 15 years as contexts for ATC application. Gradual silvicultural approaches to the restoration and enhancement of PAWS sites are now preferred over clearfell/ regenerate methods by many commentators, helping to realise standing timber value, protect the forest micro-climate, control growth of invasive weeds and recruit native tree regeneration. There remain some contexts were more rapid PAWS restoration methods are to be preferred. Active management of semi-natural woodland stands to produce timber and woodfuel are increasingly seen as consistent with conservation aims where ATC approaches are used.

4. Woodfuel production is once again a major objective of management in many situations and has a particular relevance to small woodlands on farms and smaller private estates which may have been under-managed in the past. These often have significant importance for property amenity, landscape and sporting purposes and clearfelling is not favoured. Existing owners of such woodlands, augmented by a new cohort of recent woodland purchasers with a combination of ethical, economic and amenity objectives are involved. The extent of small under-managed woodlands is considerable and these offer great scope for ATC expansion if the right package of promotion, advice and finance are put in place.

5. Climatic, pest and disease resilience are areas of significant concern in British forestry at present, with a central response strategy centring on diversification of stands in terms both of their species composition and structure to reduce the risks of catastrophic loss of value and possibly to reduce the actual impacts of drought or pathogens. ATC offers an obvious "toolkit" to address these challenges, with current emphasis on spruce stands in drier districts, lowland pine and larch plantations and hardwood stands containing much ash.

Constraints on continued expansion of ATC adoption - summary

From the work conducted within this project as a whole, the following six major constraints have emerged on the rate and scale of continued ATC adoption within the next 20 years:-

1. Unfamiliarity with ATC adoption and associated practical techniques among a significant proportion of forest owners and managers, across all ownership sectors. While awareness of the concept of ATC has risen significantly over the past 20 years since publication of Bulletin 115, expressed confidence in application of practical techniques has seen a much more equivocal pattern of development - increasing in some areas and declining in others.

2. Biophysical constraints on a major proportion of the sites used for plantation forestry in Britain - particularly wind exposure, poorly drained soils and difficulty of repeat entry. While there have been important developments in scientific understanding of wind-stability properties of regular and irregular stands, many professional foresters continue to see ATC as a portfolio of techniques that can only be applied under favourable conditions.

3. Skill shortages covering both the availability of (i) professional/ supervising foresters with pre-service training and subsequent experience in application of ATC techniques and (ii) experienced forestry technical operatives with experience of application of relevant thinning and tending techniques in stands managed under ATC, especially in the uplands. While there are some promising developments, dependence on late-career staff remains. In-service training opportunities are improving, but university-based pre-service training opportunities remain in a critical condition with widespread expectation of further decline.

4. Machinery availability remains limiting on the application of ATC techniques in many situations. The key equipment includes chainsaw/ directional felling, light-weight harvesters and harvester-forwarders with steep ground capability, light-weight forwarders with tractor, quad-bike and horse haulage, skidders, cablecrane and skyline assemblies. While relevant equipment is now much more widely available on the market, and has been tested/ demonstrated by FC-TDB, many contractors remain equipped with a fleet of heavy harvesting and forwarding equipment that is ill-suited to sustainable ATC working. British industrial sawmills are not suitably equipped to accept and process two key timber categories from ATC (i) spruce logs >55cm dbh, (ii) all sizes of *Abies* firs and hemlock.

5. Quantification and demonstration of ATC adoption practice is very poorly developed as compared with the Continental position and many relevant opportunities are unable to be exploited due to a lack of financial and staff resources and weak co-ordination. This has the consequences that ATC-relevant silvicultural research and modelling are impeded, practical in-service training and knowledge exchange opportunities are restricted and comparative understandings of silvicultural, economic and operational implications of ATC are unable to be effectively investigated, hence growers cannot assess ATC progress.

6. Promotion of ATC adoption to the forestry sector and wider interested public has lacked the sense of "official drive" that accompanies native woodland conservation and PAWS restoration. There remains a strong dependency on advocacy by charitable bodies and self-funded silvicultural enthusiasts in the private sector. While the Forestry Commission has produced much valuable ATC adoption guidance and FSC/ UKWAS protocols indicate a wish to see increased ATC adoption, there remains a sense of "official reserve" among policy-makers with the Forestry Commission reluctant to "policy mainstream" ATC.

Enabling requirements for continued expansion of alternative silviculture

From the work conducted within this project as a whole, the following five major enabling requirements have been identified for continued ATC expansion, over the next 20 years. These inform the set of detailed recommendations to be presented below:-

1. Increased promotional activity to encourage adoption of ATC as the normal mode of management in British forestry, rather than as an exceptional mode of management for application under atypical circumstances. This promotional drive needs to engage the efforts of the Forestry Commission, private sector forestry bodies such as ConFor, professional bodies such as the ICF and voluntary advocacy bodies such as CCFG. A range of promotional techniques need to be adopted including published/ online literature, conferences, workshops and seminars and more flexible and accessible grant-aid regimes.

2. Improved information exchange/ training opportunities to continue to develop the potential of the existing body of professional forest managers, owner-managers and forest operatives in Britain. The aim should be to develop the technical knowledge and standards applied in British ATC management towards those of the Continent over the next 20 year period, no longer accepting a lower standard as "just the way we do things here". Again a range of public, private, academic and voluntary sector participants need to become engaged in provision of such opportunities, but reducing dependence on voluntary work.

3. Quantified inventory and monitoring/ demonstration stands need to be installed in a much wider range of British woodland being managed under or transformed towards ATC. This is a requirement both to support the improved provision for information exchange and training opportunities and to provide individual woodland/ owners managers with more information to inform and evaluate their progress with ATC adoption practice. There are a range of options (set out overleaf) to develop a network of quantified ATC demonstration sites, but whichever is adopted, this will require a considerable ongoing commitment of time and resources by public, private, academic and voluntary sector participants.

4. Machinery and processing capacity in the British forestry and sawmilling sectors need to be developed to accept the more diverse produce from ATC management as the norm. The current model of industrial dependence on a narrow range of tree species and size classes of timber is inconsistent with a national ambition to develop a forest resource managed largely under ATC systems and is also unsustainable in an environment where extensive mono-specific plantations are under climatic, pest and disease challenge. A major directed investment programme in new, more flexible forestry machinery and sawmilling capacity, informed by ATC modelling/ production forecasting, is desirable. Continued technical development work on relevant machinery will also remain vital.

5. Academic forestry education and research in support of ATC adoption in British forestry needs first to be secured and under-pinned by increased investment and then expanded during the next two decades. To some extent, this represents a reversal of declines that have taken place in these spheres of activity since the 1960's, but accelerating during the last decade. A balance needs to be struck here between (a) securing existing critical mass in silvicultural work, especially within Forest Research and (b) protecting and fostering the expansion of research and forestry teaching in academic institutions. There is also a role for private and voluntary activity, especially in the applied research sphere. Securing a viable base for degree-level training in forestry and silviculture is an absolute priority.

Options for the development of an improved British ATC demonstration site network

Forestry Commission demonstration sites

The existing network of eleven ATC demonstration sites on the National Forest Estate represent a valuable but under-exploited opportunity, largely through a lack of resources deployed and competing management priorities at the Forest District level. These sites are not all monitored using a consistent quantitative protocol, despite being under single ownership. The results of inventory and monitoring work that has been conducted at these sites has not been sufficiently well publicised or openly disseminated to the wider forestry sector. Valuable experience has been reported from these sites in terms of operational guidance and economic analyses - while this is theoretically available to the forestry sector through the Forestry Commission website, that is not sufficiently straight-forward and has not been particularly widely promulgated. Casual visitors to these "low profile" open demonstration sites are not provided with significant on-site interpretation or information (other than at Glentress) and even their exact map location within forestry blocks takes some enquiry to discover in most cases. There is little evidence that they are used for informal self-guided training visits by the wider "forestry public", although they have served a valuable training function through organised visits by FC staff groups and pre-arranged CCFG, ICF and royal forestry society excursions. There is no explicit plan for accession of additional ATC stands on the National Forest Estate to this network of demonstration sites, although this project has identified many potentially suitable examples, some "on a par" with those already included (for example at Wyre Forest). To these can be added a handful of sites on the National Forest Estate which do not form part of the formal FC demonstration network but are enumerated by academic researchers from regional universities (University of Aberdeen, working at Faskally Wood and Bangor University, working at Artist's Wood, Gwydyr). There is therefore considerable potential to use a combination of existing and innovative/ collaborative approaches to increase the benefit of this existing network of sites (with relevant additions) to the sector. This would, however, require an increase in FC manpower and financial resources devoted to the task of ATC demonstration and possibly its more dedicated, "command driven" management. Some working examples, such as that at Sherwood Forest, may refer to a distributed mosaic of sites where it would be more difficult to promote unannounced or self-guided visitor activity.

Private sector demonstration sites

At present there are a rather small number of private, charitable and community woodland sites that have existing potential to act as formal ATC demonstration sites, in that they are already subject to regular quantitative enumeration, inventory and monitoring. These include a small number of private estates in south-west England and Wales where the AFI protocols have been implemented. The Stourhead Western Estate AFI activity also includes a "Martelloscope" thinning "trainer stand" which has now been used for several ATC adoption training days. Involvement of these sites in future ATC demonstration activities remains at the discretion of their owners and managers, with a preference for occasional organised visits.

This project has also identified a wider cohort of other private woodland ATC adoption sites, reported as illustrated case-studies, which certainly have latent potential as demonstration sites but which are not currently subject to full quantitative monitoring or inventory work. Some of these sites do have a certain amount of previous compartment-level data collection based on relascopic or intermittent plot-based tariff surveys, which is handed out at forestry society visits etc. Helen Whitney McIver had collated this type of information for many of the sites that she reported upon in 1991, but there is a sense that collection and retention of such

information has declined since that time with the demise of the estate "wood book" system. Many potential private woodland ATC demonstration sites therefore have little quantitative data available, although they may already serve an informal function as qualitative working exemplars. In order to bring these examples into play as quantified demonstration sites, considerable investment would be required to install enumeration and the owners would need to be agreeable to that being pursued on their land and to the selected sites being open for visits subsequently. In many of these cases owners have previously agreed to forestry society visits and CPD activity which is suggestive of willingness to fulfil a demonstration function, but most would have serious reservations about any commitment to unannounced access.

It should be noted that the Woodland Trust have designated a small number of sites for demonstration of gradual silvicultural PAWS restoration - notably Robson's Spring, Wentwood and Bovey Valley Woodlands, where some quantified research plots were formerly maintained by the Oxford Forestry Institute. The Natural England area within Wyre Forest, dealing with oak shelterwood, can also be considered in this distinct category of ATC sites where conservation objectives are paramount. The AFI in France are currently exploring how their ATC monitoring protocol can be reconciled with that applied on nature reserves. Most native woodland conservation sites in Britain now have only periodic qualitative monitoring under the "habitat condition survey" system, but there is a large body of older data collected since the 1960's, which records semi-quantitative details of stand composition.

Resourcing and co-ordination of any private-sector demonstration site network

In order to realise the potential of additional private woodland ATC sites to serve as future demonstration examples, a combination of greater resources and better coordination would be required. Most of those private woodland owners who are willing to undertake enumeration work on a "self-proposed and self-funded" basis are likely to be already doing so, although there may be some others who could be persuaded to begin such work autonomously with the right kind of approach to the landowner or head forester. These are mainly the larger traditional estates, including the Duchy of Cornwall and the Crown Estates. In many other cases, private owners might agree to such measurement work being undertaken on their land, but would expect it to be paid for from other sources (e.g. government grant, charitable foundations etc) and to be carried out by visiting specialist surveyors from the Forestry Commission or the universities. Many owners and managers spoken to during this project expressed the view that they (or their client) could not justify the costs of such work in terms of management benefit and that they could not spare the time to carry it out personally or identify anyone within their established professional circle would could do so reliably. It remains seen by many as "something of interest mainly to the boffins" which may have wider forestry sectoral benefits and therefore should be paid for and carried out more centrally.

It seems certain that if greater activity in terms of quantitative inventory, monitoring and demonstration is to be promoted on British private ATC adoption sites, some form of co-ordination would be required and that this might make it easier to "leverage in" additional financial resources and more effectively deploy the limited body of ATC survey expertise. There are essentially three alternative approaches to delivering greater activity/ coordination:-

1. Forestry Commission led working. Under this model Forest Research could be given additional financial resources by the Forestry Commission to upgrade the work that it is currently carrying out out at the 11 ATC demonstration sites on the National Forest Estate and to extend this working, using the FCIN45 protocol, to additional private-sector sites, with the agreement of the landowners. Forest Research staff (or perhaps

subcontractors) would make contact with the woodland owners involved, travel to those sites and make the necessary measurements on a regular cycle, analyse and publish the results on their website, in FR print-media and in journal articles. The advantages of this model are that it could make relatively rapid initial progress, would draw upon and reinforce existing, proven scientific expertise and take advantage of established and reliable mechanisms for data custody, assurance and dissemination. The disadvantages of this model are that it would have rather high unit costs (possibly limiting total activity), would probably require an increase in the FR complement against current public-spending restrictions, and might not be particularly effective in securing and developing private owner engagement - it could be seen as a rather remote, disconnected research study without particular benefits to the landowners. There might be issues with timely dissemination of results through the FR processes.

2. Landowner/ forestry agent led working. Under this model private woodland owners and/or their professional forestry agents would establish or operate an independent network of ATC demonstration sites, on the model of, or by extension of, the French AFI network. Woodland owners would either pay for the work themselves or perhaps claim grant-in-aid under WIG equivalents. The work would be carried out to a standard agreed protocol such as that from FCIN45, the AFI, or some adaptive variant upon these. There would need to be some degree of formalisation in terms of agreement on data custody and dissemination. Actual measurement could be by the owner, the agent or contracted surveyors. The advantages of this model are that it would have relatively low costs to the public purse and would, by self-selection, involve only those owners and agents with a "self-starting" spontaneous interest in ATC adoption and a likelihood of persistence. The disadvantages of this model are that it would be likely to make a much slower start as mutual arrangements were put in place and participating owners and agents were persuaded to join in. As the scale of the network increased it might become more difficult to retain a co-ordinated approach, although the AFI network has done so. Arrangements would be required to deal with ownership changes and withdrawal, and access rights to individual sites. It is likely that a degree of proprietary/ commercial activity would be involved with charges for advice, inventory work or an expectation of retained consultancy. There might also be constraints in terms of available survey skills and data assurance.

3. Academic/ voluntary led working. Under this model, the work would assume the nature of an ongoing research project. An independent network of ATC demonstration sites might be established and operated by a consortium of university forestry departments, independent researchers, interested landowners and voluntary forestry bodies such as the Continuous-Cover Forestry Group, ICF and royal forestry societies. A relevant model is the Future Trees Trust/ BIHIP hardwood breeding programme. The AFI in France is also a relevant example as it makes extensive use of "in kind" research and administrative support from the university forestry departments. Any consortium would need to persuade private owners to join the network and reach some form of agreement with them as to access, data custody and dissemination. The work would be carried out to a standard agreed protocol such as that from FCIN45, the AFI, or some adaptive variant upon these. Work could be carried out by a combination of academic researchers, PhD students, citizen science volunteers and contractors. While some work might be carried out on a semi-voluntary or studentship basis, it is likely that the consortium would need to apply for research grants or philanthropic aid. The advantages of this model are that it would foster the development of critical mass in

the British alternative forestry research provision sector, act as a "neutral arbiter" of data collection methods and standards and engage a wider audience for the work. Costs to the public purse would probably be intermediate between the FC-led and owner/agent-led models. Unit costs would almost certainly be lower than for the FC-led model, alleviating constraints on total activity level, but there would probably be a somewhat lower rate of initial progress and a need for research grant assurance. The disadvantages of this model centre on the capacity or otherwise of the bodies engaged in the collaborative/ consortium to establish and sustain the level of activity sought. Most are smaller and organisationally weaker than their Continental equivalents and have very limited recent experience of long-term contractual commitments. Changes in staffing levels and resources might place the central co-ordination in jeopardy. A key requirement would be for a stable and well-understood constitutional basis to be in place at the outset - the unincorporated association/ cooperative model is vulnerable.

Selection of recording and quantified assessment protocols

It is not the place of this study to recommend any particular existing ATC inventory and monitoring protocols for adoption at demonstration sites. A range of options currently exist and are available for use either singly or in combination. These include the long-established *Methode du Contrôle* and Biollet "Check method", the Forestry Commission FCIN45 protocol, the AFI research protocol and its proposed variants and the system described for use within the Tyfiant Coed research programme at Bangor. There seem no strong case at present to resource an attempt to produce a novel protocol or to significantly revise existing protocols.

It is important that all demonstration sites within any network should be monitored using one or more consistent protocols selected from those available. The opportunity for rigorous research comparison of the outcomes of application of different protocols to the same demonstration sites (e.g. FCIN45 and AFI) should not be overlooked. It is essential that the inventory and monitoring protocols selected for use should command the understanding and support of the owners and managers involved and should supply the desired information. In particular, it is believed to be important that, when taken together with volume determination of removals by species, the selected protocols should allow for reliable increment assessment. The potential value of spatially-specific individual tree data for stand modelling work (e.g. using MOSES) should also be taken into consideration in the planning of any such work. The present author's view is that these factors push one in the direction of permanent plot work. In selecting methods, practicality of consistent application and training need must be considered. Serious consideration should also be given to recording other valuable types of information at ATC demonstration sites, such as (i) economic, operational and management cost data, (ii) soil physical and chemical parameters, (iii) habitat quality and biodiversity indices, (iv) priority species records and (v) recreational usage and public perception survey data etc.

Quantitative working on ATC adoption sites below demonstration level

There is also a need to encourage owners and managers of ATC adoption sites, not considered for inclusion in any demonstration site network, to carry out more basic types of quantitative enumeration of their growing stocks and increment. This applies equally to all ownership categories. Standard relascopic and temporary plot enumeration approaches are relevant. Such work is essential in ensuring the sustainable adoption of ATC methods and setting the allowable harvest. A combination of promotion, training and grant-in-aid will be required.

Recommendations

The central recommendations emerging from the work conducted in this project are:-

Promotional activity and published guidance

There is a need for enhanced promotional efforts by the Forestry Commission, university forestry departments, voluntary forestry groups and professional advisers to encourage a greater proportion of forest managers to adopt alternative silvicultural systems (ATC) for the full range of benefits identified earlier in this report. Over time, ATC would come to be seen as the normal or "default" mode of forest management, with the clearfell/ restock regime being regarded as an exceptional treatment for which a specific argument needs to be made in each case. It would be beneficial if this was to be made an article of government forest policy in the same way as the Broadleaves Policy (1985) or post-Rio (1992) biodiversity policies.

To that end, relevant existing published ATC guidance material from Forestry Commission, Forest Research, CCFG and other sources could be more actively promoted, and if necessary, made available in alternative and additional formats. The outcomes of the current review project should be disseminated through seminar events, alongside print-media and on-line publication of reporting materials by the sponsoring and other bodies if appropriate. If necessary, a "popular version" of the outputs of the current project could be prepared to address the non-professional audiences, such as farm forestry/ small woodland owners. That exercise would need to involve staffs with specific expertise in training and interpretation.

The potential role of voluntary bodies such as Reforesting Scotland, Small Woods Association and the Community Woodlands Association and of farm woodland extension providers such as the Scottish Agricultural College and Heartwoods would be valuable here.

Demonstration and quantification activity

The various options discussed above for wider quantification and demonstration of alternative silvicultural systems (ATC) adoption should be considered and adopted as appropriate. A balance needs to be struck between (a) centralisation/ co-ordination of demonstration activity and (b) fostering a diversity of autonomous "bottom up" activity by owners and academics.

At the entry level, more woodland managers need to be encouraged and incentivised to collect basic repeat quantitative information about their stands and ATC management progress, using traditional relascopic or temporary tariff plot approaches. This will require a combination of promotion/ awareness-raising activity, on site demonstration/ training and grant assistance. FCIN45 provides much relevant information on suitable methods for plot based assessment, but an entry level short-form guide, including the relascopic methods, might be considered. ATC adoption sites with such basic inventory/ monitoring in place have initial informal demonstration potential in terms of both self-guided and owner/manager-accompanied visits.

The existing network of formal ATC demonstration sites on the National Forest Estate could be subjected to more consistent inventory/ monitoring using the protocols described in FCIN45 and other supplementary methods as appropriate. There may be a case for these sites to be supervised by a central "ATC implementation and demonstration unit" with greater resources available to them in terms of finance and specialist expertise than the current forest district management. These sites would become much more high profile, with a public-facing presence on the Forestry Commission web-site and innovative arrangements for self-guided training using either conventional laminated signage on site or hand-held multimedia/ internet

tools. The data arising from regular re-enumerations would be available on an open-source basis. Consideration should be given to adding additional sites on the National Forest Estate to this suite, placing more emphasis on those in more diverse, lowland mixed woodland. It is recommended that Forest Research should concentrate their efforts in this field on those demonstration sites on the National Forest Estate, at least until these aspirations are realised. Financial implications of that activity would be dependent on FR internal costing structures.

The small number of existing *de-facto* demonstration sites in private woodlands, using the AFI and similar methodologies, should be encouraged to expand by inclusion of additional suitable sites, many of which have been identified during the current project. Clearly this will require the consent of individual landowners, and that may only be forthcoming with suitable grant incentives. It is thought unlikely that private estate examples can be made available for self-guided visiting, with pre-arranged organisational visits remaining the preferred mode. It may be valuable to use some or all of these private demonstration sites to compare the results from application of different monitoring protocols, such the Biollet "Check method", the AFI methodology and the FCIN45 protocol. A suitable framework should ideally be established for recording, collating and disseminating details of the results obtained from private demonstration sites. It is recommended that this should involve the Continuous-Cover Forestry Group, together with the university forestry departments and networks of private forestry advisors such as SelectFor (essentially adopting my third option above). The Forestry Commission could consider "establishment financing" for such a network, preferably in the form of a capital endowment to avoid the need for annual fund-raising work. Initial installation of a network of 30 private ATC demonstration sites can be expected to have a capital cost of the order £100-150k, including survey work and overheads for central coordination. Subsequent periodic re-measurement, analysis and dissemination work based on the network might have annualised costs of £20-30k, again making allowance for "core funding". The Forestry Commission might need to defray the bulk of these costs at the outset, but contributions from private owners, philanthropists and grant-awarding bodies may be expected to develop as the network achieves critical mass and the value of results crystallizes.

Grants and incentives

The current regimes of RDP forestry grants are not seen as particularly supportive of ongoing management of existing woodlands using alternative silvicultural systems. Previously available Annual Management Grants and Woodland Improvement Grants relevant to these approaches have either been discontinued or are very complex and time-consuming to access in relation to the level of grant available. As a result, some private woodland owners actually view adoption of ATC as a route to reducing their exposure to the grant scheme bureaucracy!

A new area-based "single forest management payment" could be considered for woodlands managed under alternative silvicultural systems by an owner or retained forester with "earned recognition". This grant could have an entry level for informal ATC management, with two levels of supplements for (a) adoption of basic quantitative inventory work and (b) serving as a fully quantified ATC demonstration site. Ideally such a grant scheme would revert to a simple, paper-based administration system and would be freed from influence of the EU Rural Development Regulation (by 100% home funding). In support of this measure, each FC Conservancy or equivalent management unit might appoint a specialist ATC promotional officer, along the lines that have previously been implemented for woodfuel promotion work.

Research and development

In support of wider adoption of alternative silvicultural systems, there should be continued support for both national and regional-scale research and development work. A balance here needs to be struck between retaining the critical mass of the national-scale silvicultural research effort concentrated in Forest Research and encouraging the development of activity at the regional and local scales, provided by the university forestry departments and networks of private and voluntary sector actors. The latter is important in being better able to provide the ongoing "hand holding" extension service for potential ATC adopters that is currently critically lacking due to the over-stretched FC private woodland officer network. Fostering a greater role for the university forestry departments would also underpin their teaching role and, in time provide a more robust environment for "Continental standard" ATC training.

The focus of future research and development work in the field of ATC, while not neglecting fundamental scientific and modelling work, would place most emphasis on the applied operational and economic aspects of most immediate relevance to potential ATC adopters. The major part of that activity would be through the networks of demonstration sites above.

Machinery provision, availability and processing capacity

The work carried out within this project has identified the availability of suitable types of flexible, lighter weight forestry machinery as a constraint on wider ATC adoption, especially in some upland forestry areas. The key resources are chainsaw/ directional felling, light-weight steep ground harvesting machines, "county" skidders, light-weight forwarders (self-propelled, tractor-drawn, quad-bike and horse-drawn), cableways and skylines. Recent initiatives in terms of technical development and proving work on small forest machinery by FC-TDB at Ae has been of considerable value in addressing this, as has the advent of regional "agricultural machinery rings" including farm forestry equipment, for example in the Grampian and Scottish Borders regions. Grant-aid available under SRDP and other RDP schemes has also facilitated the gradual expansion/ diversification of on and off-farm rural businesses operating such new machinery, although much contracting activity remains self-capitalised by enthusiastic owners and forestry entrepreneurs. Support for continued development activity in these areas needs to be maintained across the spectrum of mechanisms described, preferably trying to foster a more inclusive rural-diversification adoption environment with reduced dependence on availability of private start-up capital. The Forestry Commission might consider partially re-equipping their own direct production force with a suite of alternative machinery more suitable for ATC implementation, either at the forest district level or on a regional touring basis, and delivering necessary staff training. Surplus FC machinery and staff time could then be contributed to regional machinery rings.

A critical component of successful ATC adoption is the ability to market timbers of a wide variety of tree species and diameter classes. Prices for small-diameter roundwood thinnings of most species and lower-grade hardwood logs are now supported by the healthy woodfuel and biomass markets. Currently there are few difficulties with larger diameter sawlog stock of the desirable hardwoods and conifers such as Douglas fir, fine larch and western red cedar. Standard sizes of spruce, pine, Douglas fir and larch arising from ATC stands enter industrial markets. However selling larger diameter classes of spruce (>55cm dbh) and all size classes of the *Abies* firs and western hemlock is problematic and wider ATC adoption will increase supply of these assortments. There is a need for market development of novel engineered timber products such as cross-laminated timber elements and massive timber construction that can make better use of these products and for the industrial sawmilling fleet to be re-tooled over time with North American and German/ Austrian equipment better suited to the 60-90cm

diameter class in standard spruce and pine. The Forestry Commission and industry bodies such as ConFor have an important role to play in informing sawmillers as to the greater diversity in species and size-class assortments that are now "coming down the line" from ATC adoption. Continued "hankering after" uniform, small-medium diameter industrial spruce stock is less likely to remain a viable future business model based on British-grown material and may not serve the development of the national forest resource and processing sector well. There may be a role for sectoral support/ investment grants in aid of retooling.

In-service and pre-service training

The need for enhanced CPD and in-service training opportunities in ATC adoption will, in large measure, be addressed by the developments and enhancements recommended in the GB demonstration site network. These sites can act as the focus for much of the relevant activity. While some in-service training can be of a self-guided/ self-taught type, some further attention needs to be devoted as to who will deliver the trainer-led component. At present there are effectively three sources available (a) attendance at field events organised by CCFG, ICF and the royal forestry societies, (b) attendance at training courses operated by the Forestry Commission, in the first instance for their own staff and (c) attendance at private-sector operated training such as that offered by SelectFor using the AFI stands at Stourhead. Each of these has an important role to play and should be supported. Consideration might be given to increasing the capacity of the FC training courses operated by Jens Haufe from Ae and making them more readily accessible to private, community and charitable foresters. In particular, developing local suites of demonstration sites would reduce travelling costs to attend. A more active advertising and marketing campaign might draw in more attendees.

The British forestry sector as a whole needs to urgently address the current fragile status of forestry teaching in the university departments. This is of particular importance in the field of ATC adoption, as degree-level training in classical silvicultural systems and associated forest operations was formerly a vital preparation for professional foresters entering service with the Forestry Commission or on the private estates. Arguably, university provision in this area has never really recovered from the loss of the silvicultural opportunities associated with colonial forestry service until the early 1960's. By contrast, the situation in France, Germany and other Continental countries has remained much stronger due to domestic silvicultural emphases. The past 20 years have seen a decline in the number of British universities offering traditional forestry degrees, curtailment of ATC-relevant content within remaining degree programmes (especially longer field excursions and preparation of management plans), reductions in the number of active forestry research academics and significant declines in the numbers matriculating. The latter is usually blamed on the low profile and perceived lack of prospects in forestry careers - traditional salaried forestry employment opportunities have reduced or been opened-up to non-forestry graduates, while the opportunity to enter the profession as a self-employed agent continues to have a strong dependence on private means and contacts. By contrast there has been a rapid rise in interest in forestry-related distance-learning MSc programmes appealing mainly to the mature-student and "career change" market. However the shorter duration of such courses makes it more difficult for them to equip candidates with a sufficient body of knowledge and practical experience to practice as autonomous silvicultural foresters, without reliance on advisory support from an earlier cohort. Without some determined effort to remedy this situation, the more technically-demanding aspects of British forestry practice, such as ATC adoption, are likely to "run out of steam" in future. A central recommendation in this area is that the Forestry Commission, ConFor, ICF, CCFG, royal forestry societies and major private growers/ managers should maintain and strengthen their links with the remaining British forestry universities and work to foster their critical

mass through research commissioning and work experience opportunity programmes . They could also engage in joint endeavours to promote the value of formal pre-service forestry training and operate recruitment policies which give reality to that value upon graduation.

Glossary of technical terms

Silvicultural systems

Alternative silvicultural system to clearfell/ restock (ATC) - a system of forest management where timber is harvested but where stands are regenerated without clearfelling (clearfelling being harvesting all trees in any area larger than a circle of tree-height radius).

Continuous-Cover Forestry (CCF) - similar to ATC above but excluding the uniform shelterwood and coppice-with-standards management systems which involve phases when all or most of the growing stock on any given area is young regeneration or coppice regrowth.

Lower-Impact Silvicultural System (LISS) - similar to ATC above but also including non-intervention and limited intervention management systems where little timber is harvested. This includes nature reserves, long-term biological retentions and policy woodlands/ arboreta.

Shelterwood system - a management system where the mature tree canopy is used to provide shelter for the next generation of trees, usually where natural regeneration is being used. Once the next generation is established the mature trees are harvested in one or more felling phases.

Selection system - a management system where mature trees are harvested when they reach a target diameter for marketing or to release younger trees growing beneath. Regeneration of the forest is therefore a constant process, rather than episodic as with the shelterwood system, and at no time is all of the mature growing stock harvested/ removed over a short time period.

Uniform system - a regime (normally shelterwood) where a whole stand is treated evenly to secure natural regeneration (for example by uniform thinning of the canopy/ overstorey).

Group system - a system (shelterwood or selection) where small groups of mature trees are felled in order to meet market requirements and to allow space for regeneration below. Groups should be less than two tree heights across or this system becomes patch clearfelling.

Irregular system - a system (normally shelterwood) intermediate between uniform and group where a combination of individual large trees and groups of trees are harvested, most often in response to natural regeneration arising from below. This results over time in an **irregular stand structure**, where trees of a range of sizes and ages are present within any given area. Where at least three age/size classes are present, this is also known as a **complex structure**. Where only two classes are present (canopy and seedlings) this remains a **simple structure**.

Coppice-with-standards - a traditional forest management system where an area is stocked with an understorey of coppice stools (often hazel, ash, field maple, lime, chestnut or hornbeam) while a small number of older widely-spaced open-grown trees provide timber (typically oak, ash or beech). Where the understorey is of seedlings this tends to shelterwood.

Operations/ descriptive terms

Natural regeneration - any tree regeneration that is arising from seed, without planting.

Advance natural regeneration - natural regeneration which occurs while at least some of the mature overstorey trees remain in place above, rather than only after the overstorey is felled.

Shade tolerance - typically of natural regeneration. How much light seedlings of a particular tree species require to grow and develop. **Shade tolerant** species such as western hemlock, grand fir, western red cedar and beech require little light, whereas **light demanding** or shade intolerant species such as pine, larch and oak require much more light. Other species such as ash, sycamore, Sitka spruce and Douglas fir are intermediate or **medium tolerant**. Some species such as ash, become less shade-tolerant as they get older and grow into the canopy.

Critical basal area - the standing basal area in m^2 per hectare below which natural regeneration of a species will normally survive and grow, rather than being shade suppressed. Hence shade tolerant species have a high critical basal area (35-40 m^2/ha) whereas light demanding species have a low critical basal area (20-25 m^2/ha). Critical basal area is often used to set the appropriate thinning intensity (see below) to promote and recruit regeneration.

Thinning - harvesting a proportion of trees to allow others (including natural regeneration) to grow on to larger sizes while meeting demands for small-diameter produce.

Crown thinning - a thinning operation where the emphasis is on the overstorey, removing some trees to allow the crowns of others to expand, promoting more rapid growth. This is often used as part of the process of developing more diverse structure within ATC systems.

Low thinning - a thinning operation where the emphasis is below the overstorey, removing small trees which are suppressed by competition and will not reach their full potential. This is the conventional mode of thinning very often used within clearfell/ replant systems.

Frame-tree thinning - a thinning operation which seeks to favour a set of the larger, more windfirm trees in a stand that are expected to form the final crop under an ATC system. This approach is of particular significance where ATC is being adopted in more wind-prone areas.

Variable-intensity thinning - a thinning operation where the proportion of trees removed varies across a stand, normally in response to advance natural regeneration from below. This is the typical thinning strategy adopted in irregular shelterwood and group selection systems.

Target diameter felling - felling mature trees as they reach an optimum size for the market. Some species, such as Douglas fir, get more valuable as they get bigger essentially without limit, whereas others, such as Sitka spruce, have an optimum harvesting size for the sawmills.

Under-planting - planting of young trees under the shelter of a mature canopy. This technique can be used where natural regeneration fails to occur or where there is a wish to change species (for example to produce more valuable timber or avoid a climate/ disease risk)

Enrichment planting - planting of trees under or among an existing crop to increase the number of species growing on the area or to change the balance between species. This is very often carried out by means of underplanting - for example of red cedar under pine or larch.

Naturalisation - changing the structure and species composition of a stand to make it more like that which would occur naturally on a given site. For example **PAWS restoration** from a stand of introduced conifers to native broadleaves is an example of naturalisation, as is **restructuring** an even-aged pure plantation stand of native trees such as Scots pine or oak.

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