DEVELOPMENT OF BROADLEAVED WOODLAND ON COLLIERY AND OPEN PIT COAL MINES IN THE UNITED KINGDOM[1]

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Abstract: Broadleaved woodland is an important land use and vegetation type in the United Kingdom (UK), and potentially the most effective landscape and restoration treatment for colliery waste tips and open pit coal sites.

A field-based national survey of collieries in England and Wales in 1986 and 1987 showed that establishment was satisfactory in only half of the schemes, and growth was deemed satisfactory in less than one-fifth. Also, the majority of the plantations had little affinity with woodland types found locally or regionally. The main causes of poor establishment were poor stock viability, and competition with herbaceous ground cover vegetation for available soil water in the immediate post planting period. The poor growth was due to competition for water with herbaceous vegetation and low inherent available water capacity of the soil profiles.

There are standard forestry practices whereby stock quality can be assured, and herbaceous vegetation controlled or eliminated by the use of herbicides. During the restoration of the site, depending on choice of species, adequate soil water can be provided by the selection of appropriate soil types and thicknesses, and adoption of appropriate soil handling and decompaction practices. The low affinity of the plantations with local and regional types was partly due to the planting of non native species and partly due to the failure to match species with site and soil characteristics. There is no reason why woodlands of a local and regional character cannot be established by planting the associated species. A matrix of fast-growing tree and/or shrub species should be used to promote early woodland development. These would be removed during normal management which is essential for the ultimate success of the woodland. Planting schemes should also incorporate woodland structural elements and understorey and ground flora species.

Provided that these measures are fully implemented, significant improvements in establishment, growth, and woodland development on restored sites should be achieved.

Additional Key Words: broadleaved woodlands, establishment, growth, species composition, colliery tip restoration.

Broadleaved Woodlands

Broadleaved woodland is an important land use and vegetation type in the United Kingdom (Peterken 1981, Evans 1984, Rodwell 1991). Potentially, the planting of broadleaved woodland on restored colliery sites and open pit coal mines is often the most effective landscape and restoration treatment. It also provides important wildlife habitats, a source of home-grown timber products, and a means of supporting and diversifying rural economies, as well as environmental benefits such as assisting the redevelopment of soil structure and improving the water quality of catchments.

With recent changes in the emphasis of land use policy in the UK, from agricultural production to environmental quality and community recreation, woodland will become more prominent in restoration schemes than hitherto. There has also been a change over the last 20 yrs in the type of woodland planted, from coniferous plantations for timber production to predominantly broadleaved types for landscape and nature conservation. This is

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already manifest by the number of major initiatives to create large-scale wooded landscapes in lowland England. These include the new National Forest, covering some 50,000 ha in an area of 200 square miles, and a number of other extensive community woodlands.

The British Coal Corporation is involved to a significant extent in several of these projects, including the new National Forest and the Forest of Mercia in the Midlands, the South Yorkshire Forest, the Great North Forest in County Durham, and the Red Rose Community Forest in Greater Manchester. The new woodlands are to include a number of open pit coal mines and colliery sites. Indeed, the industrial heritage of coal and mineral workings was one reason why the location of the National Forest was chosen (Anon 1993). With the demise of the local coal industry, the Forest was seen as an opportunity for improving the local landscape, encouraging economic revival, and providing a focus for leisure activity and access. Elsewhere, on a local scale, the amount of broadleaved woodland to be planted on restored collieries and open pit sites is likely to continue to increase for the same reasons.

The purpose of this paper is to communicate the lessons learned from planting schemes implemented over the last 10 yrs on collieries and open pit sites in the UK, and to recommend measures that could be beneficially adopted in the current and future schemes.

Past Achievements

Historically, the methods of preparation and establishment, and the composition of woodland planted on restored colliery waste tips and open pit coal sites followed the advice of the local planning authorities and the statutory advisory body, the Forestry Commission. However, the results have often been disappointing and much criticized by both the general public and the planning authority.

In 1986 Humphries Rowell Associates was commissioned by British Coal's Headquarters Technical Department to undertake a national field-based assessment. The study included 16 newly planted and 54 existing schemes at 27 collieries in England and 7 collieries in Wales. In 1987, 21 planting schemes at 5 of the collieries in England and 3 in Wales were closely observed during implementation. The investigation was carried out using the approach we had previously developed to assess colliery tip restoration practices (Humphries et al. 1984).

The rationale behind the approach was that field surveys formed the basis of objective assessment of past and current achievement, using appropriate tests and measurements. Other methodologies, such as literature and document reviews and experimentation, need only be implemented when achievement and standard forestry practices have been shown to be unsatisfactory. From previous assessments, we have demonstrated that poor achievement is generally due to the failure to implement current recommended practices or failure to implement them properly. For this reason practices used during planting and management were also observed in this study.

Establishment

The field survey indicated that establishment was satisfactory in only half of the schemes. A quarter had establishment of less than 50% (table 1). It appeared that most of the mortalities had occurred in the first year following planting.

Table 1. Overall percentage establishment achieved in tree planting schemes on colliery wastes prior to 1988.

	Very unsatisfactory <50	Unsatisfactory 50-70	Satisfactory 70-90	Very satisfactory >90
Percentage of schemes surveyed.....	24	30	36	10

There was no evidence in the field that mineral nutrition, acidity or compaction were factors (Humphries and Benyon 1988). Neither was there evidence that poor establishment was associated with a particular planting practice or the competence of the contractor. Also, low establishment was not confined to any particular species, although the establishment success of birch (*Betula* spp.), pine species (*Pinus* spp.), larches (*Larix* spp.), and alders (*Alnus glutinosa* and *A. incana*) was particularly variable (table 2). Most of the unsatisfactory establishment was recorded in the schemes without a soil cover over the colliery shale, or where the cover was less than 20 cm deep. However, soil cover and depth did not account for all instances of unsatisfactory establishment. In three of the schemes planted in 1986-87, it was due to poor-quality work where the use of a clayey subsoil to cover the spoil had made it difficult to plant the trees properly.

During 1987, a distinct pattern to the failures was observed: i.e., early-season mortality in May and late-season mortality between May and September (table 3). Early season mortality generally accounted for a small proportion of the first-year total, and was confined either to certain species or to isolated areas on the tips. The latter was associated with persistent local waterlogged conditions, mainly at the "break" of slopes and at the "toe" of the tip. The species-specific mortality (birch and alder in England and larch in South Wales) was associated with poor transportation and handling practice, where the roots of these desiccation-sensitive species had been allowed to dry out prior to planting. The late-season mortalities generally accounted for most of the first-year losses, and were largely confined to the species alder, birch, larch, and willows (*Salix* spp.). This was attributed to physiological drought induced by the presence of a moderate to high herbaceous ground cover vegetation around the trees, the affected species being notoriously sensitive to drought. The symptoms included progressive "leaf-burn" and shoot dieback from May onwards. The herbaceous ground cover occurs as volunteer vegetation colonising the spoil and soil or from seed mixtures sown to control surface erosion and run-off.

Other, but only occasional, causes of poor establishment included browsing by rabbits or sheep, diseased stock supplied by the nursery, or extremely alkaline conditions on cement-stabilized tailings.

Table 2. Percentage establishment rates for commonly planted species at end of first year.

	1986			1987		
Species	Range	Median	n[1]	Range	Median	n
Pine	0-73	42	6	77-100	94	13
Birch	26-100	56	8	51-100	77	6
Common alder	34-100	69	5	35-100	72	15
Grey alder	17-100	63	6	70-100	93	4
Swedish whitebeam	91-100	97	3	NA	100	4
Field maple	NA[2]	100	2	NA	100	8
Sycamore	86-100	95	3	NA	100	7
Ash	29-100	82	6	NA	100	8
Oak	NA	80	2	85-100	96	10
Rowan	67-100	90	4	80-100	97	8

[1] n = Number of schemes surveyed.

[2] NA = Not applicable.

Growth

As part of the above surveys in 1986 and 1987 the growth performance of the plantations was assessed (table 4). This indicated that only 19% of the schemes older than 3 to 4 yrs were considered to have achieved satisfactory growth (i.e., >1.5m tall), and 39% were particularly poor (i.e., <0.9m tall).

In some of the unsatisfactory schemes, poor growth was not confined to any particular species, whereas in others birch, pine species, common alder (*Alnus glutinosa*), hawthorn (*Crataegus monogyna*), and field maple (*Acer campestre*) notably achieved greater height and spread than other species. There was no evidence in the field that mineral nutrition, acidity or any other site or soil physical characteristic, such as compaction, was a factor.

Table 3. Percentage mortality of newly planted trees in May and September 1987.

Colliery	May	September
Harworth.............	2.5	26.0
Rufford................	3.0	17.0
Welbeck..............	1.5	31.5
Thoresby.............	10.8	24.4
Sherwood............	2.0	51.0
Markham Main.....	0	3.0
South Kirkby........	0.7	6.7
Oakdale...............	1.0	12.0
Cynheidre............	3.0	10.5
Wernos................	5.0	20.0
Mean...................	2.9	20.6

On closer inspection of the data, it became evident that two components were contributing to the variation of tree heights between schemes; these were the amount of extension growth and dieback of shoots. Both are related to the amount of available soil water, and this was partly determined by the amount of herbaceous ground cover around the trees. Hence, competition with herbaceous ground cover vegetation for water was identified as the principal cause of poor growth (Humphries and Benyon 1988).

Woodland Composition and Structure

From the surveys it was also possible to determine the types of woodland planted. The majority (60%) of the broadleaved plantations had little affinity with the types found locally or regionally, and in particular with the oak (*Quercus* spp.) woodland types expected for most of the sites (Humphries and Benyon 1988). Also, most of the schemes (89%) would have been expected to be a species-poor variant of oak woodland associated with shallow base-poor soils, the prevailing conditions on many of the tips (table 5).

Most of the non oak woodland types were dominated by species regarded as introduced non native species (e.g., grey alder (*Alnus incana*), false acacia (*Robinia pseudoacacia*), red oak (*Quercus rubra*), white poplar (*Populus alba*), Swedish whitebeam (*Sorbus intermedia* agg.), Japanese larch (*Larix kaempferi*), Corsican pine (*Pinus nigra* ssp. *laricio*), lodgepole pine (*Pinus contorta*)), or species alien to the expected woodland type (e.g., field maple, ash (*Fraxinus excelsior*), sycamore (*Acer pseudoplatanus*)). However, the non native species have been used widely in the reclamation of colliery spoil in the UK (Jobling and Stevens 1980) because of their perceived better performance, although there is no evidence from our surveys to indicate they perform any better than native species.

Table 4. Median maximum tree heights (m) in plantations of different ages.

	Pre-1981	1981-1983	1983-1985	1985-1986
Median........................	1.00	1.10	0.84	0.76
Upper quartile.............	1.80	1.23	1.00	0.92
Lower quartile.............	0.81	0.85	0.76	0.65
Range..........................	0.66-1.89	0.67-1.71	0.49-2.30	0.58-1.30
Number of schemes.....	9	19	27	16

Table 5. The number of woodland types expected to be planted for soil characteristics and the number actually planted.

	Oak woodland types[1]						Other woodland types	Total number of schemes
	Base-poor soils				Base-rich soils			
	Species-poor		Species-rich					
Operational Areas	E[2]	P[3]	E	P	E	P	P	
Nottinghamshire.....	18	0	0	2	0	6	13	21
South Wales...........	14	0	0	4	0	1	9	14
North Yorkshire.....	14	0	0	4	0	1	10	14
South Yorkshire.....	7	0	0	3	0	3	4	10
Western................	3	0	0	0	0	2	1	3
Total.....................	56	0	0	13	0	13	27	63

[1] Hopkinson 1927, Jones 1959.
[2] E = Expected
[3] P = Planted

The woodlands surveyed were typically plantation like in nature, with trees being of an even age, and they often had a regular pattern of species distribution, or were planted in blocks of single species or simple mixtures of species. They also lacked the basic elements that may give rise to structural development in the future. There were no "edge" and "core" structural and composition elements, nor understorey and ground flora components.

Consequences

A major consequence of the low rates of establishment in some of the schemes and the universally poor growth rates was an ineffective landscape treatment, albeit in the short term. Effective landscape treatment of collieries and open pits is often the main concern of the local public. They generally expect a woodland landscape to develop quickly, i.e., within a 5 to 10 yr time frame, and are disappointed when it does not. The results achieved within this time frame have been typically scrub like in appearance with little closure of the canopy (fig. 1).

Other important consequences are the result of the species planted. Sites planted with the non native species in particular are usually neither satisfactory from a landscape point of view nor suited to exploitation for timber products and have dubious benefits for wildlife, although they may be satisfactory for recreational use.

Improved Practice

It was clear from the literature and current guidelines that provisions should have been made at planting and in the post planting maintenance period to ensure that stock was viable and that competition from herbaceous vegetation was controlled. Similarly, provisions should have been made to counter the other causes of poor establishment and growth. The field survey indicated that in many cases either no provisions had been made, or if they had, they were either ineffective or not fully implemented (Humphries and Benyon 1988).

Also at the design stage, often no provisions had been made either for local woodland types and woodland structure or for appropriate soils and soil profiles to provide sufficient soil water for normal growth.

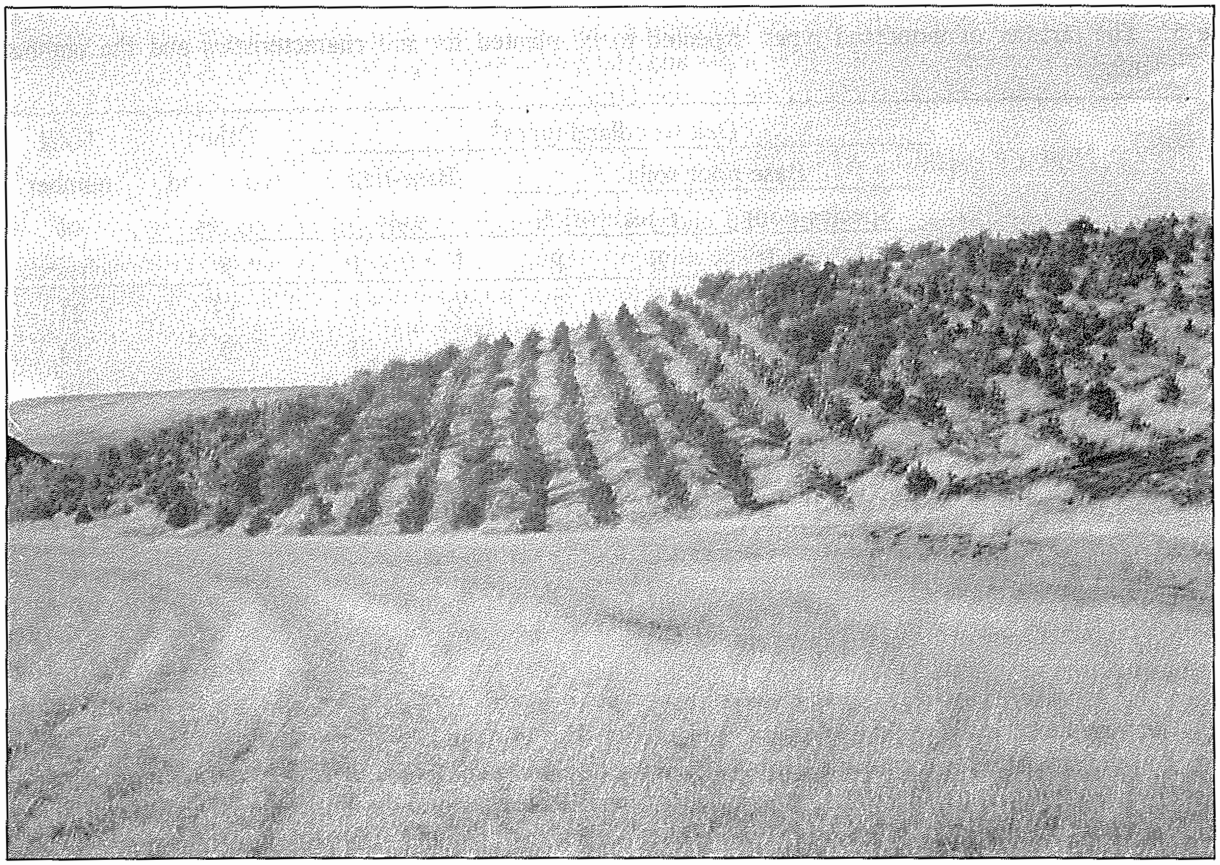

Figure 1. A typical plantation on a colliery waste tip in the Midlands, showing an incomplete tree canopy cover after almost 10 yrs and consisting of a high proportion of non native species.

Establishment

There are proven standard forestry practices that, if properly implemented, can ensure stock viability and control of ground cover vegetation at the planting stage (Evans 1984, Committee for Plant Supply and Establishment 1985, Sale et al. 1986, Davies 1987). Stock viability can be maintained if the roots of the trees and shrubs are protected from drying during handling at the nursery, during transit, and on site at planting. Herbaceous competition can be effectively controlled by the use of approved herbicides, but control must be complete prior to planting and maintained as such throughout the critical first year. Similarly, there are standard measures whereby animal damage can be controlled, such as fencing, individual tree guards, and vermin extermination programs. In the case of waterlogged areas there are a range of measures, including avoidance at planting, a policy of not replanting failures, planting with tolerant species, and drainage.

Growth

Herbicides are also the proven standard forestry practice to deal with competition from herbaceous ground cover vegetation in the post planting period (Davies 1987, Sale et al. 1986). The control around the trees and shrubs must be complete and should be maintained for the second and third year after planting, and longer if necessary.

In addition the thickness and physical characteristics of the soil profile (textural and structural) affect the amount of soil water available to the trees and shrubs and hence growth rates and dieback. Growth can be improved and dieback minimized through the selection of appropriate soil physical and chemical types and thicknesses, and soil handling and decompaction practices (Humphries and McQuire 1994). Both should be addressed in the formulation of site restoration proposals and detailing of the planting scheme.

Woodland Composition and Structure

Species Composition. The surveys in 1986 and 1987 demonstrated that native tree and shrub species could be established successfully on colliery sites, and the same is true for open pit sites. The evidence suggests that there is no reason why species associated with local and regional semi natural broadleaved woodland types, described recently by Rodwell (1991), cannot be established, provided that the site and soil conditions are appropriate. Hence, there is no need to use non native so-called reclamation species.

Structure. Woodland structure is and will be partly dependent on species composition and planting pattern, but ultimately it will be dependent on management and time.

Planting schemes, where appropriate, should incorporate woodland edge and core mixtures. The former should typically be co-dominated by shrub species and species of the understorey layer. There is no reason why both woodland understorey and ground flora species cannot be planted as part of the schemes.

An important element is the development of the vertical structure of the woodland. This can be accelerated in the early years by the use of fast-growing tree and/or shrub species when planted as a matrix with the other species.

In the UK fast-growing broadleaved and conifer tree species have been used as nurse crops to promote plantation development (Evans, 1984). While such species, in conjunction with slower growing woodland trees and shrubs, were often used in reclamation schemes in the UK from the mid-1960's through the 1970's (Jobling and Stevens 1980), the practice has rarely been accepted since. Recently, the practice has been successfully re-adopted at ARC's Huntley Wood sand quarry in the Midlands. Here oak was planted at 4 m centers in a matrix of common alder at 2 m centers on a former silt lagoon. A "closed" canopy developed within 3 to 4 yrs and, after 5 yrs, the oaks were typically 3 m in height and the alders 5 m. Both externally and internally, the plantation has a woodland appearance (fig. 2).

There are many benefits to planting a matrix of fast growing trees and shrubs. These are largely due to the achievement of a rapid canopy cover which provides a visual effect in the shortest time possible. The matrix usually induces more rapid growth of the other woody species, largely through shelter, but also by providing appropriate light conditions to promote the etiolation of certain species such as oak and beech (*Fagus sylvatica*).

The more rapid closure of the canopy is also necessary for the establishment of woodland ground flora, through reducing competitive ability of aggressive species and creating appropriate light conditions (Finegan et al. 1983, Buckley and Knight 1989, Street and Mond 1992). The more rapid closure of the canopy can also be beneficial by reducing the amount of effort required to control ground cover vegetation competing with the trees and shrubs. Other benefits include the earlier provision of cover, which is beneficial for birds and other wildlife.

Suitable matrix species for the UK are those typical of primary colonization of impoverished soils and early successional vegetation (Whyte and Sisam 1949, Finegan et al. 1983, Humphries and Guarino 1987). These include native birches, alders, and willows, and shrubs such as buddleia (*Buddleja davidii*). For more sheltered sites and fertile soils, where conditions are more synonymous with secondary succession, suitable species include the shrubs hawthorn and blackthorn (*Prunus spinosa*). If the matrix species used are alien to the proposed woodland type, they should be totally removed during subsequent management.

Figure 2. Inside a plantation on a former slurry lagoon in the Midlands, showing complete canopy closure within 5 yrs and the development of woodland conditions. The woodland consists only of native species.

Woodland management is probably the most critical aspect of woodland development, and the one that has been most neglected. It is particularly important where a matrix of faster growing species is planted. A thinning program must be implemented. In the first 20 yrs two thinnings would normally be expected: between years 6 and 10 and between years 11 and 20 (Woolhouse personal communication).

The thinning has several benefits as well as promoting the continued development of the woodland. From a timber point of view it enables the selection of the "best" trees and provides a source of material for fencing and other products such as wood chips, and hence a potential income which can be offset against the management costs. Alternatively the material can be left within the wood as a source of organic matter, which can promote soil development and habitat diversification. Thinning must be carefully planned, however, if the aim is to promote the development of the ground flora and increase its value as wildlife habitat.

Conclusions

Provided that the measures recommended above are fully implemented, along with other good standard forestry and site restoration practices (Evans 1984, Bacon and Humphries 1987, Humphries and McQuire 1994), significant improvements in establishment growth and development of woodland schemes on colliery wastes and restored open pit sites should be achieved. This, together with the use of fast-growing tree and shrub species as a matrix should ensure that both visually and functionally woodland development is accelerated, at least in the short term.

There need be no inhibition about establishing woodlands with local and regional characteristics, in terms of composition and structure. The determining factors are site and soil conditions and management practice. This should also result in a more satisfactory landscape treatment and be more satisfactory from a wildlife point of view.

Guidelines for Broadleaved Woodlands

To achieve more successful and cost-effective restoration, along with the associated environmental, landscape, wildlife, and community benefits, broadleaved woodlands of a local and regional character should be established wherever possible and appropriate.

The choice of woodland composition and structure, both for the area of woodland generally and locally within it, must be related to site and soil conditions, and the proposed management regime and use (e.g., source of wood products, amenity or wildlife). The former is to be determined by appropriate desk and field assessments, and the latter through liaison with the intended users and administrators.

There is no need to use non native species. The use of matrix species to promote woodland development is strongly recommended. Where it is necessary to use species alien to the woodland type as the matrix, they must eventually be removed during later management.

The planting plan should include the fundamental structural elements of core and edges, understorey and field layer. Additional structural characteristics and diversity (i.e., glades and rides) should be introduced during management in the longer term.

It is essential that current recommended forestry and reclamation practices be fully implemented. Viable stock must be supplied and planted; this will need to be specified and checked. During the establishment phase, it is essential that any herbaceous ground cover around the newly planted trees be completely controlled for the first 3 yrs. Where a ground cover is not required to control soil erosion and a woodland flora is not planted, the whole area may be kept bare. There needs to be provision to control animal damage by fencing, the use of guards, and/or extermination methods.

Finally, there needs to be a detailed planting plan that gives all the necessary details of which plants are to be planted where, and what amelioration work, etc., is required. The plan should also include a detailed management plan for at least the first 20 yrs, which should be constantly reviewed on a 3 to 5 yr basis. Ultimately the success of the woodland depends on post planting management, whether it be replacements or thinnings.

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