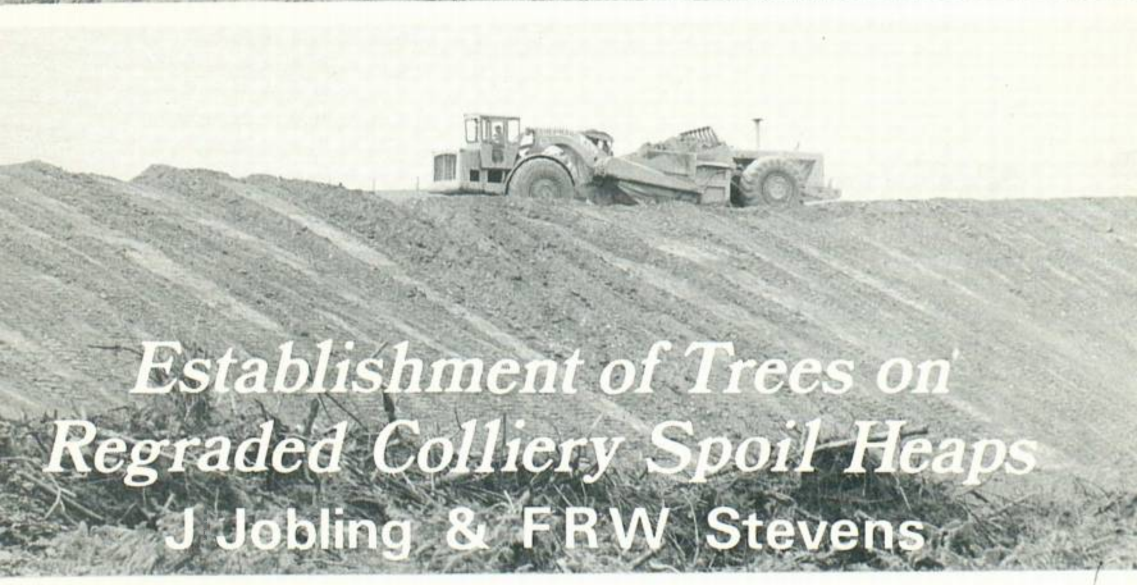
Establishment of Trees on Regraded Colliery Spoil Heaps



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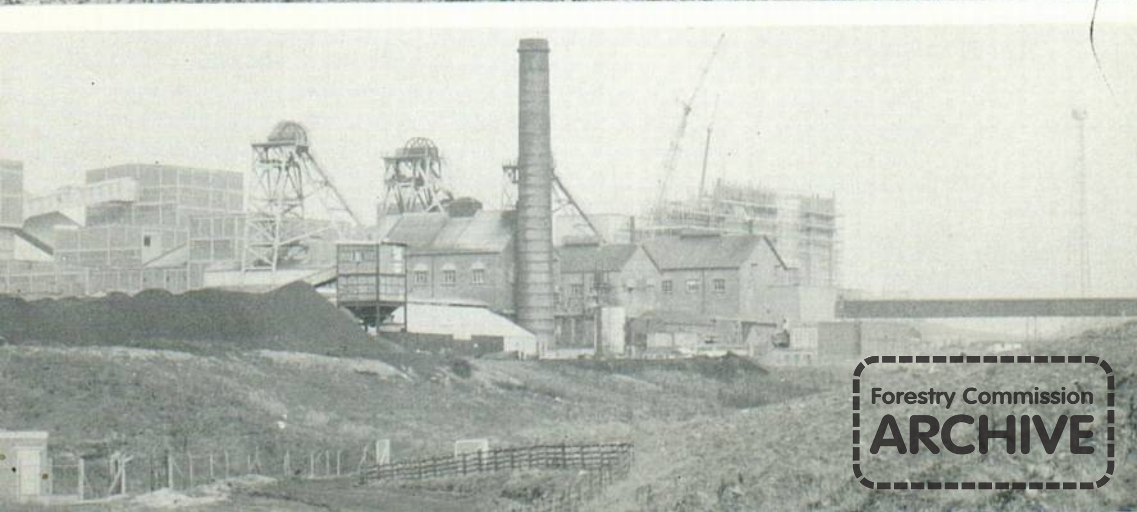

ESTABLISHMENT OF TREES ON REGRADED COLLIERY SPOIL HEAPS

A review of problems and practice

by

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INTRODUCTION

Between October 1976 and September 1977, a critical appraisal was conducted by the Forestry Commission Research and Development Division into the problems of the establishment and management of trees and other woody plants on regraded colliery spoil heaps. Further supporting evidence has since been collected.

The research was carried out under contract to the Department of the Environment and was made possible by the encouragement and valuable help provided by the Standing Local Authority Officers' Panel on the Reclamation of Derelict Land - Vegetation and After Management Sub-Group, Forestry Working Party. Most of the information on engineering and cultural practices on reclaimed land was obtained from local authority officers, and the reclamation schemes selected for field study had been initiated and managed largely by local authority staff.

Data were also collected on a small number of reclamation schemes carried through by the Forestry Commission. Services and advice were provided by Forestry Commission officers at the Forest Research Station, Alice Holt Lodge.

Information and assistance were also obtained from University research workers past and present, and a large number of papers recording details and results of research conducted by University departments were useful sources of information.

This report attempts to summarise the evidence accumulated on tree growth on regraded colliery spoil heaps. For the benefit of workers unfamiliar with colliery wastes special attention is paid to the problems influencing early tree performance on regraded spoil heaps and to the cultural methods used to establish trees on reclaimed land. Species choice and succession, and factors affecting the long-term maintenance of woodland areas on regraded spoil heaps, are briefly discussed.

Guidance on aspects of tree establishment is included for the benefit of foresters and others directly concerned with the revegetation of reclaimed derelict land. However, the temptation to include firm recommendations on cultural practices has been avoided, since it is generally recognised that a good deal more work, including formal experimentation, is required before firm conclusions can be reached on the most effective methods of establishing and maintaining tree crops on regraded colliery spoil heaps.

REVIEW OF TREE PLANTING ON COLLIERY SPOIL HEAPS

Trees have been planted regularly on colliery spoil heaps since the turn of the century. Until the 1950s planting was nearly always carried out as a cosmetic treatment to improve the appearance of the heap, and little if any regrading of the tip slopes was undertaken. Often the whole heap was afforested. By the mid-1950s more than 100 ungraded heaps scattered through all the coalfields in both town and country had been planted, most of them successfully.

The heaps were usually very old, with well-weathered spoil at the surface, and many already supported some naturally colonised herbaceous or woody plants at the time of planting. A very wide range of trees was used and several broadleaved, so called pioneer, species proved to have high survival and growth rates in a large variety of spoil and climatic conditions. An acceptable woodland environment has formed in many instances and the heaps now blend attractively into the landscape. The older plantings are yielding utilisable wood, and are highly valued as leisure and recreation areas as well as habitats for wildlife.

These early plantings on ungraded spoil heaps have been amply surveyed, and information on comparative species behaviour and on factors affecting tree survival and vigour have been well documented (Wood and Thirgood, 1955; Casson and King, 1960; King, 1967; Richardson *et al.* 1971).

Since the 1950s increasing numbers of colliery spoil heaps have been regraded, and both the spoil heaps and the adjacent industrial wasteland have been reclaimed to obtain the maximum local amenity and most beneficial land use. By removing old colliery buildings, abandoned works and disused railway track; by filling in flashes and other dangerous and unsightly holes with the waste materials, and by regrading the heaps to blend them into the surrounding landscape and to permit easy movement of agricultural and forestry machinery, new land has been effectively created from the dereliction.

Tree planting has featured prominently in many reclamation schemes, in blocks to form woodlands, in belts to shelter farmland and playing fields and to screen industrial development, or singly and in small groups solely for visual amenity. Broadleaved species have tended to predominate. In a few instances, where the colliery and spoil heaps were located close to or within existing managed woodland, the whole site has been afforested after regrading with the intention of producing merchantable timber. In these schemes conifers have been extensively planted.

In towns, where public open space has been created out of the dereliction, trees have been planted primarily for ornamental purposes, and to improve outdoor leisure and recreation activities. Where it has been possible to establish small areas of woodland, sometimes nature trails have been laid down through the trees. Towards the outskirts of towns and in the country, where precedence has been given to farming, woodland has been planted to provide shelter for stock and crops. Even so, amenity has been taken into account, so that tree planting has tended to be at the roadside and close to housing development and public footpaths.

It has also been generally recognised that on regraded spoil heaps trees have other important functions. They provide invaluable habitats for wildlife, and largely due to annual leaf fall leading to a build-up of litter, they improve prospects of soil formation. On the steeper slopes of the heaps their roots help to stabilise the surface spoil.

The valuable and differing roles played by trees on reclaimed spoil have been widely accepted. Recently, attention has been drawn to the long-term benefits of planting on spoil heaps and to the tolerance of tree crops to difficult colliery wastes, in contrast to the early onset of management problems following restoration to agriculture. Hardly surprisingly pleas have been made for an extension of the rate of tree planting on reclaimed land (Cornwall, 1974; Buckley, 1978).

Sustained programmes of derelict land clearance by local authorities commenced in the late 1960s and most have only gathered momentum since 1970. Even so, immense progress has been made, and in England alone more than 70 major reclamation schemes incorporating some tree planting have been completed in the last decade. However, more than two-thirds of all the plantings on regraded colliery spoil heaps are still in the establishment or immediate post-establishment phase. Few plantings are showing signs of general canopy closure or appear to be in need of thinning. Consequently, reliable data on growth rates and on comparative species behaviour for the widely differing conditions occurring within and between sites are inevitably scanty, while predictions on future tree dimensions and on crop performance after the onset of thinning are difficult to make.

FACTORS AFFECTING TREE SURVIVAL AND VIGOUR ON REGRADED COLLIERY SPOIL HEAPS

Local authority records of tree planting on regraded spoil heaps often reveal that serious losses occurred and extensive tree replacement had to be undertaken in the early life of the crop. To maintain prescribed stockings, tree replacement had sometimes to be continued into the fifth and sixth seasons. Frequently, growth was slow for several years and crop establishment was inevitably prolonged.

Tree survival was probably poorest in the 1960s and early 1970s, in what might be termed the pioneer days before many problems had been identified and solutions found. Since then, the introduction of improved engineering and cultural practices has ensured better survival figures. Nevertheless, even during the past few years, more dead trees have had to be replaced at some sites than might have been expected.

In contrast, some tree crops have been quickly established with comparatively few losses. However, the reason for the improved survival in these instances and not at other sites where conditions appear to be similar, has not always been obvious. Sometimes, the absence of planting records and of details of site factors influencing survival has lessened the likelihood of any valid conclusions being reached.

Often large groups of trees have died locally while survival has been high on other parts of the reclamation site. The heterogeneity of colliery spoil, which is known to account for sharp changes in naturalised plant communities and in tree behaviour on ungraded tips, is clearly responsible in some cases for such wide variations in survival. It is also apparent that certain reclamation practices, which are discussed on later pages, may have led to marked differences in early tree performance and, on some sites, to a high failure rate. The problems ordinarily encountered in forestry have contributed to or been the direct cause of tree failure in a large number of cases. Frequently the factors responsible have been clearly recognisable, though varying markedly from place to place and from one year to another.

Vandalism and damage by animals

Vandalism has remained a major problem in many areas. Ornamental trees in car parks and close to roads and footpaths have probably suffered the worst damage, and young forest trees in well-fenced blocks the least. Unfortunately, vandalism has persisted at several sites after crop establishment and year after year a succession of well-formed, rapidly growing trees have been seriously injured or killed.

Sometimes forest gates have been broken and fences deliberately cut, and sheep, cattle and horses encouraged to feed in the woodland areas. These animals, together with hares, rabbits and voles, have hindered tree establishment on many regraded tips. Horse riding and motor-bike scrambling are not commonplace but where they have been practised locally trees have been injured or killed.

Fire has also destroyed young crops on a substantial scale. Thick dry grass, usually dominated by Red fescue *(Festuca rubra* subsp. *rubra)* and its variants, appears to have helped the blaze to spread in most instances, but burning spoil, perhaps not surprisingly, has occasionally contributed to the problem.

Silvicultural practices

The extent to which the death or slow growth of newly planted trees has been primarily the result of poor silviculture is much more difficult to define. This is partly because sub-standard work may be difficult to detect or, where suspicions have actually been aroused, the effects of the poor work may not be observable until some time afterwards. The understandable reluctance by nurserymen and forestry contractors to accept responsibility for low grade work may have ensured its continuation and inhibited solutions being found.

Local authority experience suggests, however, that certain practices do occasionally fall short of desirable standards and lead to tree failure in the early years. The use of poor planting stock, especially trees whose roots have been allowed to dry out, and low standards of planting, appear to be the most common problems. The importance of adopting sound silvicultural methods is discussed in the section following, page 24.

The site conditions peculiar to reclaimed spoil heaps are also considered to have a marked influence on tree survival and growth, though extreme conditions likely to seriously hinder establishment are now more easily recognised and the adoption of ameliorative measures to overcome them has become commonplace. The conditions are so much a feature of reclaimed land generally and of regraded colliery spoil heaps in particular, and give rise to so many problems encouraging both research and speculation that they deserve special mention here. Five particular conditions characteristic of regraded heaps are discussed; they are spoil water holding capacity, spoil compaction, spoil acidity, soiling after spoil regrading, and the presence of a grass mixture ground cover. They are believed to be important in the context of tree establishment; other workers may disagree with this assessment and with the sequence in which they are treated in this paper.

Spoil water-holding capacity

More often than not, spoil at the surface of regraded heaps has a low water-holding capacity. As a result, there is a progressive and usually rapid drying-out of the surface wastes in dry weather. Moreover, as its moisture content falls, spoil hardens and becomes increasingly difficult to penetrate. The driest conditions invariably arise during rain-free periods in the growing season when root extension is taking place. The survival and vigour of young swards and recently planted trees can then be adversely affected. Even established trees may suffer a serious reduction in growth rate, and in extreme cases exhibit crown die-back in dry weather. Conversely, high survival and growth rates are associated with frequent rain fall during the spring and summer.

Spoil compaction

Major land reclamation can only be undertaken effectively if large, fast, box scrapers and other heavy earth-moving machines are employed. Compaction is inevitable, as the machines pass continually and systematically over the site moving materials from one place to another, and firming them layer over layer. Long-distance shifting is done by huge scrapers, many of which are able to cut and carry 50 tonnes at a time. Heavy graders flatten the materials where they drop.

Colliery spoil heaps are generally large and obtrusive, and are regraded amongst other reasons to make them more attractive, to make them safer and to create a topography permitting ready access by tractors and farm equipment. Regrading compacts the spoil, but compaction is an engineering requisite since surface stability is improved and, because air spaces are reduced, the risk of spontaneous combustion is lessened. Compaction also hinders percolation of moisture and encourages its run-off.

Spoil containing mudstones, shales and siltstones undergoes the greatest compaction, manifested by surface water logging after heavy rain. As the spoil dries out it can assume the characteristics of concrete, when the surface of the regraded heap becomes hard and very resistant to penetration. Spoil in a concreted state is sometimes associated with the presence of gypsum (hydrated calcium sulphate). If present, washery waste, which contains a high proportion of silt, also contributes to this difficult physical state. Regrading when spoil conditions are unsuitable aggravates compaction.

Unless compacted spoils are cultivated, attempts to revegetate them with grasses and other herbaceous flora are usually erratic and prolonged and trees and other woody plants may prove difficult to establish.

Tree survival and growth may be poor simply because the planting was badly done in the first place. Compacted spoils are difficult to penetrate with a spade, so that the hole or notch may not be sufficiently deep to accommodate a tree's roots. As a consequence the roots may become bent or may even curl up into a ball. They may dry out because they are partly exposed or at best are only in the surface layers of the spoil. To overcome the problem, mattock planting has often been adopted since the practice usually leads to the preparation of deeper and wider holes. In any event, the timing of planting assumes considerable importance since the preparation of the holes is made considerably easier if the spoil is moist. Therefore planting is often arranged to follow a period of heavy rainfall.

Even if reasonable standards of planting can be achieved in compacted spoil, root development is likely to be restricted for a few years and survival may remain in the balance. Shoot growth may be slow, and leaf size and colour will probably be poor. The plantation will thus have little visual impact for some time.

That the successful revegetation of regraded spoil heaps depends on the employment of intensive cultivation practices to relieve the compaction has become increasingly obvious over the past few years. Indeed, since the early 1970s the reclamation specifications drawn up by local authorities have included clear directives on the different types of cultivation to be undertaken prior to sowing grass mixtures, whether for pasture or woodland ground cover. These practices are briefly considered in the section following on page 18.

In the majority of reclamation schemes tree planting is carried out some months after sowing when the surface spoil, for various reasons, has become compacted again. Local authority officers have shown increasing concern with the problem and effects of tree planting in compacted spoil, and during the past few years ameliorative measures based on techniques used commonly in forestry have been introduced on a widening scale on reclaimed land. Ripping or subsoiling along the planting lines before planting is due has become the most prominent method of relieving spoil compaction. The practice is discussed further on p. 18.

A good deal is known about the physical characteristics of colliery spoil and of the physical factors causing compaction (Rimmer and Colbourn, 1978). However, up to the present, relatively little work has been done on regraded heaps to devise simple methods of assessing compaction, to determine the most effective systems of cultivation or to enable predictions to be made of the behaviour of different forms of vegetation. Experiments are required to compare the effects of different intensities of spoil cultivation on the establishment and management of grass mixtures and on tree survival and vigour, and to test different methods of compaction relief before tree planting. Research is also needed to undertake a thorough appraisal of all the factors influencing root development on regraded heaps.

Spoil acidity and salinity

Most fresh colliery wastes tend to be neutral (pH = 7.0) or alkaline (pH $>$ 7.0). Sometimes their pH value may be higher than 8.0. On exposure to air and moisture the spoil weathers at the surface of the tip, acid production takes place and the pH value of the spoil falls.

The factors controlling acid generation have been recently reviewed (Chadwick, 1973a; Richardson, 1976; Gemmell, 1977a), and only a summary of the main chemical reactions, and of the consequences of acid generation, need be included here.

Acid production is primarily due to the presence of iron pyrites in the spoil which, on coming into contact with air and moisture, oxidises, leading to the production of ferrous sulphate and sulphuric acid

$$2FeS_2 + 7O_2 + 2H_2O \rightarrow 2FeSO_4 + 2H_2SO_4$$

Further oxidation occurs, associated with leaching of sulphuric acid, and ferric sulphate is produced

$$4FeSO_4 + O_2 + 2H_2SO_4 \rightarrow 2Fe_2(SO_4)_3 + 2H_2O$$

Ferric sulphate then hydrolyzes, and sulphuric acid and ferric hydroxide are formed

$$Fe_2(SO_4)_3 + 6H_2O \rightarrow 2Fe(OH)_3 + 3H_2SO_4$$

The chemical changes are complicated and are not fully understood; some of the reactions depend on bacterial activity (Le Roux, 1969).

Several factors control the rate of oxidation and hydrolysis of iron pyrites and of acid production. The forms of iron pyrites in the spoil, since some are more resistant to oxidation than other, the rate at which the spoil containing iron pyrites weathers, and the quantity of neutralizing agents (carbonate minerals) in the spoil able to neutralize the acids produced, are thought to be the more important. Wastes rich in carbonates may remain neutral or become only slightly acid. Sometimes an equilibrium is achieved, but in general neutralizing minerals are eventually exhausted so that from a reasonably balanced state, acid production rapidly increases.

Acid production may be quite small, and the pH of the spoil may become stable at a value close to 7.0. In contrast, intensely acid spoil may be produced (pH $<$ 3.0), with the pH of some types of spoil falling below 2.0. However, most spoil on weathering becomes slightly acid (pH 5.0 to 6.0) to moderately acid (pH 3.0 to 5.0). The spoil comprising a tip may vary considerably in pH value, and different tips, even in the same locality, may display a wide variety of acidic conditions.

When a spoil heap is regraded, unweathered wastes are brought to the surface and are exposed to the processes causing acid production. The rate of acid generation varies enormously, and while the chemical composition of the fresh spoil may change rapidly and a stable pH be reached in a matter of months, acid production may last for scores or hundreds of years before a stable condition is attained. Since there are no certain ways at the present time of determining potential acidity, the chemical amendment of spoil at the surface of newly reclaimed tips cannot be undertaken confidently. The problem is considered further in the sections on *Liming* and *Fertilisation*. (pp. 21 and 22).

Acid generation cannot usually take place in burnt spoil as oxidation of the pyrite occurs on combustion and sulphur dioxide is released. However, in some cases combustion may not be complete, so that part of the pyrite remains in the spoil as a potential source of acidity (Arnold, 1979).

As spoil acidity increases plant growth worsens, until the high concentration of hydrogen ions causes roots to die. Toxic conditions may also arise because of the release from minerals contained in the spoil of large quantities of aluminium and manganese into solution. Acid generation also increases fixation of phosphate, a nutrient which is only present in spoil, in any case, in low proportions.

The problems of revegetating acid spoil have received a good deal of attention during the past few years, and empiric solutions have been found to improve prospects of successful reclamation. Research carried out on highly acid spoil heaps such as Mitchell Main, South Yorkshire, to resolve fundamental chemical questions and to find acceptable methods of amending acid spoil has yielded helpful results (Chadwick, 1973b; Williams and Chadwick, 1977). Work largely devoted to an appraisal of cultural practices undertaken during reclamation and to the selection of grasses, trees and shrubs for colliery spoil has proved of particular interest to practitioners. These studies have been reviewed in two recently published papers, the second containing valuable information on species choice for acid spoil (Richardson, 1976; 1977).

The most common method of amending acid spoil is by application of limestone The amount of limestone required to neutralize a well-weathered spoil can be reasonably calculated from its pH value using recommendations for farmland made by the Agricultural Development and Advisory Service of the Ministry of Agriculture, Fisheries and Food. However, the pH value of freshly exposed spoil at the surface of a newly regraded tip will give little or no indication of its lime requirement because of the latent ability of the unweathered spoil to produce acid. Nevertheless, while pH values give no indication of the presence of reactive pyrite, research into methods of determining the potential acidity of colliery wastes may reveal effective practical solutions to the problem. Ideally, measurements of the amount of iron pyrites capable of oxidation and hydrolysis, and of the amount of carbonate minerals able to neutralize the acids produced, with assessments of the initial acidity of the spoil, should give an indication of the maximum potential acidity and provide an estimate of the limestone dressing required for permanent control of acidity (Gemmell, 1977b).

On some reclamation sites believed to have high potential acidity, very heavy dressings of limestone, sometimes in the region of 100 tonnes per ha, have been made after regrading. On other potentially very acid heaps, such high application rates have been avoided. Instead, after applying a much smaller quantiy of limestone, the site has been soiled. A limestone dressing of 50 tonnes per ha and a soil depth of at least 300 mm have recently been recommended (Doubleday and Jones, 1977). The possibility of the soil covering acting as a seal and preventing or slowing down the rate of oxidation of the pyrite has been considered. The treatment has analogies with clay seals built over tipped domestic refuse to keep out rain water.

Many of the tree species which have been planted on regraded colliery spoil heaps during the past decade or so appear to be tolerant of a wide range of acidity. There is encouraging evidence that some of them are able to thrive in moderately acid spoil with a pH value as low as 3.5. Indeed, at Mitchell Main, healthy, live rootlets of Common alder *(Alnus glutinosa)*, Silver birch *(Betula pendula)* and False acacia *(Robinia pseudoacacia)* have been found extending into and growing through spoil with a pH value of 2.8.

The behaviour of trees on spoil of varying acidity, as well as on heavily limed spoil and on soiled sites, requires special study so that species selection for different types of site can be made more readily in the future. On acid spoil, the tree roots are usually placed at planting in the spoil zone of greatest acidity (100 to 220 mm), and attention should be given to the possibility that root extension as a result might be inhibited for a year or two. The performance of several selected species should be monitored to determine their inherent acidity tolerance on regraded tips.

Regrading may expose slightly to moderately saline spoil. Weathering of the spoil may then quickly lead to the release of salts which, during dry weather, are carried to the surface of the heap. This situation arises when evaporation of moisture from the heap into the atmosphere exceeds rainfall. As the salts increase proportionately at the ground surface severe salinity problems may arise. Salinity is normally estimated by measuring electrical conductivity of a saturated moisture extract of surface spoil samples (Doubleday and Jones, 1977).

As severe salinity may limit the establishment of a grass sward, a period of leaching by rainwater is required before sowing grass seeds mixtures. It is also possible that where high electrical conductivity values are noted, the survival and vigour of newly planted trees may be adversely affected. There is little guidance available to the practitioner on the tolerance of different tree species to saline spoil, however. Salinity problems are a feature of heaps in the coalfields of north-east England.

Soiling

A large number of regraded spoil heaps have been wholly or partly soiled. Where reclamation has been carried out to bring the land into agricultural use, soiling has generally been considered an essential phase of the scheme. However, largely because soil of suitable quality has been difficult to find or because soiling has been considered prohibitively expensive, the treatment has not always been undertaken. Gemmell (1973) has summarised the revegetation techniques for unsoiled sites.

The type and amount of soil used on tips has been determined partly by what has been available in the locality during the latter stages of reclamation, and by what could be obtained from peripheral parts of the site before regrading started. It has been policy where soil has not been plentiful to confine soiling to areas being reclaimed for farming at the expense of areas designated for tree planting. However, there has been a considerable amount of planting on soiled areas, with contrasting results.

In a small number of cases there is evidence to suggest that planting in soil led to improved rates of survival and early growth. At Waleswood, South Yorkshire, for example, it appears that while very few trees have died in the original planting carried out in 1969 on a soiled site, there have been large numbers of deaths and substantial tree replacement over several years in a nearby planting on spoil. Comparisons of this type can, of course, be misleading since other factors may have contributed to these differing results. In this instance, however, recent radial and height increases of species common to both areas have been appreciably greater on the soiled part of the site than on the unsoiled portion, suggesting benefits associated with soiling. Perhaps this is not surprising since the soil is a fertile clay loam, with a depth in places of 450 mm. On some soiled sites in Derbyshire, such as Church Gresley, it is probable that the behaviour of several tree species has been better in the early years due to soiling than would have been the case had planting been carried out directly into the spoil.

Yet at other sites there are indications that soiling may have had a harmful effect on tree survival and vigour. Sometimes the reasons have not been clear, but generally the soil has contained a high proportion of low-quality material such as heavy intractable clay or, inadvertently, a high stone or building rubble content from local demolition work. It is reasonable to conclude that it would have been preferable at these sites to have left the woodland areas unsoiled. Similarly, there seems to have been little point in spreading only a thin cover of soil at some sites, since at planting the tree roots were actually placed in the underlying spoil.

There is some evidence to indicate that tree roots may not extend readily from a fertile soil horizon into the colliery spoil beneath, especially if this is at all compacted. If the practice of soiling is to continue, therefore, the best means of encouraging root development into the underlying spoil might have to be studied.

It also seems probable that soiling has increased the weeding problem in some young woodland areas. This is partly because of the more vigorous growth of the sown ground cover and partly as a result of the introduction of weed seeds in the soil increasing the rate of natural colonisation. To compensate, the development of a richer flora has perhaps been encouraged.

Woodland ground cover

Colliery spoil heaps reclaimed by local authorities are sown with grass seeds mixtures as soon as possible after the completion of the physical and chemical amendment operations that follow regrading. This is done primarily to give the site an attractive appearance in the shortest possible time and to stabilise the surface spoil to prevent erosion. It is also hoped that a grass sward will improve spoil structure, encourage the development of soil fauna and flora populations, and enhance the prospects of soil formation.

Grass seeds mixtures are usually sown in the periods March to April and July to September. Areas reserved for tree planting are sown at the same time as other parts of the site. Tree planting always takes place some months after sowing, in some cases the difference may be 18 months, and the sward by then can be well established. In the main the sowing rate on woodland sites varies from 25 to 45 kg per hectare.

The deleterious effects on tree growth of a competitive ground flora are well known in forestry; a dense grass cover is commonly believed to be the most harmful type. On regraded spoil heaps there is extreme competition for moisture and nutrients, and trees planted in a grass sward can be killed unless weeding is thorough (Richardson, 1977). Also, small trees may be overgrown and suppressed by tall growing grasses. For a few years after planting, therefore, generally until the trees are growing vigorously, weeding is considered to be an essential practice on reclaimed land.

The composition of grass seeds mixtures chosen for woodland areas is governed by several factors. In the first place the species and strains used should be tolerant of acid colliery spoil and have a low nutrient requirement; second, they should be easy and quick to establish because of amenity and erosion considerations. However, the fire risk, a problem inevitably associated with grasses in woodland, and the competitive nature of grasses have to be taken into account. These contrasting requirements, and perhaps uncertainties about the behaviour of some components of the sward, have led to the use of many different types of mixtures and a large number of species and strains overall. Because of their nitrogen-fixing properties and tolerance of difficult soils, and because they are less inflammable than grasses, clovers have figured prominently in most seed mixtures. Other legumes have sometimes been used.

Information on grasses and legumes used on some 33 reclamation sites planted between 1967 and 1976 is given in Appendix I. The statement shows that Red or Creeping Fescue *(Festuca rubra rubra)*, notably strain 'S59', and Common Bent-grass *(Agrostis tenuis)* were used on the majority of sites, and that Wild White clover *(Trifolium repens)* and the White clover strains 'S100' and S184' were the commonest legumes used. Red Fescue has proved to be a vigorous, easily established grass on most woodland areas, but it is competitive and can swamp out small trees if weeding is neglected. It is regarded as a serious fire hazard, especially during late winter and early spring. Consequently there has been some interest in other fescues and at a few recently planted sites it has been replaced by Chewing's fescue *(F. rubra* subsp. *commutata)* or Sheep's fescue *(F. ovina)*. Lowland pasture grasses such as Perennial rye grass *(Lolium perenne)* have sometimes been included in seeds mixtures, but they tend to be weak and to die-back. Rye grass strain 'S23' has been the most commonly used. The potential value of rye grass strains in seeds mixtures merits further attention, since they might have a useful temporary role, particularly on slopes where there is a risk of erosion, while long-lived though slow to establish species like Sheep's fescue form a sward. Westerwolds rye grass, because it can be rapidly established and may be relatively short-lived on colliery spoil, is probably well suited to this purpose.

The value of nitrogen-fixing legumes in woodland ground cover also requires study. Although it is known that vigorous, upright growing species are capable of swamping small trees if weeding is neglected, the benefits they provide, and the proportions in which they should be used in well-managed crops, have not been assessed. Several species deserve attention. The introduction of other broad-leaved herbs on to woodland sites, by including them in grass seeds mixtures, might also be usefully studied.

AMENDMENT OF REGRADED COLLIERY SPOIL HEAPS BEFORE TREE PLANTING

The revegetation of reclaimed colliery spoil can only be effected satisfactorily by amending the difficult physical and chemical conditions before sowing and tree planting are undertaken. Two considerations are pre-eminent. First, in order to improve prospects of rapid crop establishment and longevity, compaction must be relieved at the surface of the heap to encourage root development. Second, to counteract acidity and to compensate for nutrient deficiencies, adequate supplies of limestone and inorganic fertilisers must be deeply incorporated into the spoil.

Various factors influence the selection of amendment operations, and there are remarkable variations in the type, number and sequence, and in specifications, from scheme to scheme. The diversity of methods of compaction relief is briefly reviewed in the next section. Chemical amendment practices are discussed in the later sections on *Liming* and *Fertilisation*. The best amendment operations and specifications are determined after careful assessment of the physical and chemical attributes of the spoil, and of special characteristics such as slope, the occurrence of soiled areas, and climatic influences such as rainfall. Land use and management objectives are also taken into account.

Areas selected for tree planting are given the same physical and chemical amendment prior to sowing grass seeds mixtures as potential farmland and public open space. But as the surface of prospective woodland can be left in a comparatively rough condition some operations, which are ordinarily undertaken on reclaimed land to obtain a smooth covering, could be omitted. This is reasonable, as if ripping or ploughing is carried out just before tree planting, a disturbed woodland floor will be produced in any case.

To illustrate the diversity and sequence of operations undertaken during the amendment stages of reclamation, details of engineering and cultural work carried out at North Beechburn, County Durham, are given in Table 1 opposite. The spoil heap at North Beechburn was regraded in 1976 and amended in time for sowing in mid-summer 1977. Several woodland areas are being established adjacent to public open space and pasture. Three stages of work are identified, namely earthworks, seeding, and maintenance during the 12-month period following sowing. These reflect the contract arrangements agreed before regrading started and Table 1 is not intended to be a generally applicable procedural model.

Cultivation

In the earliest reclamation schemes, cultivation after regrading - to relieve compaction and to incorporate limestone and fertilisers - was seldom deeper than 150 mm. Often the work was done by agricultural tractors and equipment incapable of reaching greater depths. During the past decade, however, cultivation has been increasingly intensified, and nowadays depths greatly in excess of 150 mm are readily reached, and two deep cultivations prior to seed-bed preparation may be undertaken.

The first operation to amend spoil compaction after regrading is usually called rooting or engineering ripping. Rooting is normally to a depth of 450 to 600 mm using a large tracked vehicle such as a Caterpillar D8 or D9 drawing a single tine or a multi-tined ripper. With a single tine complete spoil disturbance to this depth is achieved by ripping at intervals of 450 mm; with a multi-tined ripper, with the tines set 600 mm or 1.0 m apart, more than one pass is made over the ground.

Rooting is undertaken to reveal large, solid objects in the spoil that are likely to interfere with future cultivation. Generally all hard debris larger than 150 mm in any dimension, including brick rubble, clinker and stones, and

(contd. p.20)

TABLE 1

RECLAMATION SCHEMES : NORTH BEECHBURN, COUNTY DURHAM

Sequence of Operations

Earthworks

1. Regrade spoil heap.
2. *Root to 600 mm depth at 600 mm centres.
3. Remove all stones, bricks, wood, wire etc down to 150 mm diameter.
4. ≠Scrub with rolled steel joists (RSJs).
5. Remove all stones, etc.

Seeding

6. Spread ground limestone at rate not exceeding 10 tonnes per ha.
7. Chisel plough in two directions to 150 mm depth at 120 mm centres.
8. Remove all stones etc.
9. Chain harrow and Cambridge roll.
10. Scrub with rolled steel joists.
11. Spread fertiliser at rate not exceeding 0.5 tonne per ha in two operations.
12. Sow grass seeds mixture (broadcast at 35 kg per ha).
13. Flat roll twice.
14. Remove remaining stones etc.

12-months maintenance

15. Cambridge roll.
16. Cut grass three times.
17. Spread fertiliser.
18. Remove all stones etc.

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*Root. Term used in land reclamation to describe an operation carried out on completion of regrading to expose cable or wire, large stones and pieces of metal, rubble or wood which might hinder later cultivation or drainage and agricultural work. Though the term is probably misleading in a report concerned with tree growth and root extension, it is used here on account of its general acceptance by reclamation practitioners.

≠Scrub. Term used in agriculture and engineering to describe an operation undertaken to smooth the soil (or spoil) surface after cultivation or the removal of large objects exposed, for example, by rooting.

pieces of metal and wood, together with lengths of wire rope, are removed and either buried or taken off the site. Because rooting disrupts the spoil, and the subsequent removal of large articles leaves holes, the heap is invariably lightly graded or scrubbed before chemical amendment and the next stages of cultivation are undertaken.

Further deep cultivation is then carried out, partly to incorporate limestone and phosphate fertiliser such as basic slag, and partly to initiate seed-bed preparation. Most authorities chisel plough at this stage, usually to a depth of not less than 150 mm. After further stone removal a fine tilth and firm seed-bed are obtained, generally with a chain harrow and roller. Finally a balanced fertiliser may be applied and lightly worked into the spoil surface just before the grass seeds mixtures are sown.

Sometimes, to obtain a greater depth of cultivation prior to seed-bed preparation, subsoiling follows rooting and scrubbing. At Ellis Laithe, West Yorkshire, for example, where a Caterpillar D4 tractor was employed to draw a ripper fitted with two tines, the depth of subsoiling was 450 mm and, by making two passes, the rips were set 600 mm apart. This operation followed rooting to a depth of 600 mm with the rips 450 mm apart.

At Higher Folds, Greater Manchester, reclamation started in 1977 of nearly 200 ha of derelict land, mainly covered by colliery spoil. At this site, rooting and subsoiling were combined. Instead of incorporating limestone after rooting and scrubbing, as is general practice, the neutralising material (in this case an industrial lime-waste by-product) was applied to the compacted spoil surface on the completion of regrading. Cultivation was then undertaken to a depth of about 600 mm with the tines of a five-tined ripper set 600 mm apart. Thorough relief of compaction was achieved by making four passes, the second two at right angles to the first.

On the face of it deep cultivation should improve prospects of tree establishment and, where limestone has been deeply incorporated, the likelihood of acceptable growth rates being achieved after establishment should be increased. However, as colliery spoil contains no organic matter other than coal particles and is invariably structureless, the wastes tend to settle after cultivation and serious compaction can re-occur below the surface. Moreover, the spoil surface may, over a comparatively short period, quickly harden into something like its former impenetrable state. The repeated movement over the site of agricultural vehicles and equipment appears to contribute to the problem.

By the time tree planting takes place, in some instances 18 months after sowing, the surface spoil has become very hard again and the planter has difficulty in making holes for the trees' roots. Thus planting might be badly carried out and, in any event, tree root development might be seriously impeded. Spoil compaction and its amendment before tree planting are discussed in the section on *Planting methods* (p. 28). There is also a possibility that a worsening physical condition below the surface may hinder root extension downwards, and help to create a shallow rooting zone posing stability problems later. It seems clear that the relationship between spoil cultivation and tree root development should be closely studied, to determine the best combination of operations for woodland areas and to assess the physical factors limiting tree survival at and after planting. The benefits, if any, of deeper ripping, and the employment of winged tines to disrupt a larger spoil mass than achieved by conventional tining should probably be taken into consideration.

The special problem of cultivating steep slopes also merits attention. While it is generally recognised that cultivation must be carried out whilst the spoil is dry, the risk of erosion following rooting or subsoiling is always present. Indeed in high rainfall areas the operations may be prohibited altogether on steep slopes because of this danger. It would seem therefore that research is required on sites with erosion potential to devise safe amendment practices which are also culturally acceptable.

Liming

The causes and artificial amendment of acidity in colliery spoil, the problems of determining the maximum potential acidity of the wastes and the amount of limestone required for permanent control of acidity are reviewed in the section on *Spoil acidity* (p. 11).

Lime requirements are generally based on the pH value of the surface spoil after the completion of regrading. Application rates are derived from liming recommendations issued by the Agricultural Development and Advisory Service (ADAS) for agricultural soils, to raise the pH of acid soils to 6.5. Where the colliery spoil is found to have a pH below 3.5, a doubling of the ADAS liming is advised.

The problems of sampling reclamation sites, of collecting and analysing spoil samples, and of interpreting pH values were appraised in the early 1970s by the Standing Local Authority Officers' Panel on Land Reclamation: Vegetation and After Management Sub-Group. The report prepared by the Panel (Anon, 1973) provides guidance on different aspects of liming reclaimed land, and describes procedures for monitoring changes in acidity during and after reclamation. The adoption of standard systems by reclamation authorities and the employment of ADAS analytical and advisory resources are particularly stressed.

Local authority officers unfamiliar with sampling and analytical methods and with pH data and their interpretation, and organisations newly embarking on colliery spoil reclamation, should approach their ADAS Regional Office for technical guidance and information on the facilities which are available. A list of Regional Offices in the coalfields is given in Appendix IV.

Sites on regraded heaps which have been selected for tree planting are given the same limestone dressing as those intended for farmland and public open space. This is partly because the acid tolerance and lime requirement of the large number of species used on reclaimed land are far from understood. In practice, several of the commonly used trees, notably Common and Grey alder, Silver birch and False acacia, are thriving on notoriously acid heaps, and it may be argued that ADAS recommendations, which are made for agricultural soils, are perhaps generous for some tree crops. Certainly it seems curious that tree roots can remain healthy and vigorous whilst extending into, and through spoil with a pH as low as 2.6, as at Bowburn, County Durham. Also, it is difficult to explain why the appearance and vigour of young trees on reclaimed colliery spoil hardly ever reflect the spoil pH. Investigations on a substantial scale would be needed to resolve these anomalies and to reach conclusions of practical relevance on the lime requirements for all types of woodland. The general use of mixtures, which often include demanding species, and interest in the development of climax woodland containing species such as ash and oak, which grow best on deep, fertile loams, suggest that regardless of the acid tolerance of certain pioneer trees, limestone dressings might remain at the present levels. Nonetheless, the use of demanding species on regraded colliery spoil should be undertaken with care since many factors affect their performance.

Fertilisation

Colliery spoils are nitrogen deficient, often seriously so, and suffer from phosphate deficiency and fixation. They are usually adequately supplied with potassium and magnesium. Heavy dressings of fertilisers containing a high proportion of nitrogen and phosphate are therefore made to reclaimed sites prior to sowing grass seeds mixtures. The fertilisers are worked into the spoil surface usually after limestone has been incorporated by subsoiling or chisel ploughing. Woodland areas receive the same dressings prior to sowing, as do farmland and public open space. Fertilisers are less commonly applied to trees at or after planting.

Advice on types of fertiliser and application rates is normally obtained from ADAS Regional Offices (See Appendix IV). Details of sampling procedures and ADAS analytical facilities are discussed in the section on *Liming* on pages 21 to 22. Doubleday (1971) has reviewed the nutrient status and chemical amendment of spoil at length.

Various types of phosphate fertiliser and widely differing application rates have been used on reclaimed land. Examples of the range are given in Appendix I. Basic slag, superphosphate and triple superphosphate are the commonly used phosphate fertilisers, though basic slag - which has been widely used in large amounts - is not as effective in neutral spoil as the other two. On acid spoil and in high rainfall areas, rock phosphate has certain advantages but it has not been generally applied. It is cheaper than the other forms and its slow solubility is of benefit to perennial plants such as trees. It is the preferred form in commercial forestry on acid soils.

Nitrogen is commonly applied as a component of a balanced fertiliser containing other nutrients. Many different types and application rates have been employed; examples are given in Appendix I. The higher rates generally indicate a low nitrogen content. Sometimes a low rate appears to have been chosen because of the inclusion of clover in the grass seeds mixture.

Nitrogen is only beneficial after application of a phosphate fertiliser. However, increasing the rate of nitrogen may not necessarily increase yield since it is the balance between nitrogen and phosphate that determines the effect of the application (Chadwick, 1978).

While fertilisers are commonly applied to reclaimed spoil before sowing grass seeds mixtures, they are not often applied to trees at time of planting and hardly ever to trees after planting. Details of materials and rates at some 33 sites planted between 1967 and 1976 are given in Appendix I. Since 1976 the use of fertilisers at and after tree planting may have increased. The commonly used materials have been bonemeal, incorporated into the planting medium, and basic slag, magnesium ammonium phosphate and ground mineral phosphate (Gafsa), applied as surface dressings after the trees had been firmed-in. Technical literature is not helpful on the subject of fertilising trees on reclaimed spoil and little experimental work has been done to test different forms of fertiliser or methods of application.

There is some evidence to suggest that fertilisers applied to regraded heaps during the cultivation stage of reclamation meet the nutrient requirements of the later planted trees. Indeed, trees whose roots having extended from the planting hole into the surrounding spoil which was fertilised only before sowing grass seeds mixtures, rarely show any nutrient deficiency. Further, the evidence seems to indicate that tree survival and vigour during the early years of the planting are much less dependent on spoil nutrition than on other growth limiting factors such as spoil compaction, spoil moisture and rainfall, plant quality and method of planting. However, quite simple experiments would quickly reveal whether fertilisers applied at or in the first year or two after planting benefited tree performance, and it would be an easy matter to compare the effects on tree growth of different forms and methods of application. The role of soluble fertilisers applied during the growing season, and the efficiency of ammonium fertilisers in particular probably merit special attention.

There are no grounds yet for believing that fertiliser dressings may be required once the trees are established, and only preliminary studies in carefully selected crops, leading to the collection of leaf samples for foliar analysis, appear to be needed at this stage. Though the work has obvious links with other services provided by ADAS, it is probably too early to consider routine monitoring and recording of nutrient uptake by tree crops on reclaimed spoil.

The related topics of mycorrhizal associations in colliery spoil and the use of organic wastes to improve spoil structure merit further research, particularly to determine their relative value in a practical context.

METHODS OF TREE ESTABLISHMENT

This section reviews silvicultural practice on regraded colliery spoil heaps. Attention is focussed on plant type and quality, methods of planting and on the likelihood of research in these fields leading to widespread improvements in tree survival and growth rates. It is not the purpose of the review to examine the consequences of planting and maintenance undertaken by different workers, nor is it intended to question the policy and the administrative decisions taken by local authorities on revegetation practices.

Much of the tree planting on reclaimed spoil is carried out by different forestry contractors, some of whom operate nationally while others only carry out work locally. In the circumstances, variations in early tree performance from one site to another have been attributed to differing standards of work.

When account is taken of planting done by local authority labour, by Job Creation gangs and by Forestry Commission staff on an agency basis, albeit to commonly agreed specifications, further variation in both standards and results may be anticipated. The supply of planting stock from many sources also contributes to differences in establishment rates on reclaimed spoil. Perhaps more pertinent, there is increasing evidence that low-quality stock and poor planting techniques alone may be responsible for the death or prolonged slow growth of large numbers of young trees. Clearly there is a responsibility for all concerned with reclamation to ensure that tree establishment work is carried out to high standards. It is tempting to add that foresters should be increasingly involved in the planning and implementation of planting on reclaimed spoil.

Type and quality of planting stock

Bare-rooted forest trees have been used almost exclusively in woodland plantings on regraded tips. Unrooted cuttings of poplar and willow, and container and bare-rooted plants of both conifer and broadleaved species have been included in trials laid down to compare species behaviour and type of stock. Trees have also been established on reclaimed spoil using hydroseeding and other direct sowing techniques.

In general, bare-rooted stock has not been especially raised for planting on colliery spoil, but a few local authorities have developed nurseries in which a small proportion of the requirements for reclamation sites is now raised. Since plant production in these instances is under the direct control of the authority, and stock, in theory, can be transferred quickly from the nursery bed to the planting site as required with the minimum of handling, production in local nurseries should provide cultural advantages. Where opportunities have arisen for comparing on the same site the behaviour of locally raised stock with that obtained from normal commercial sources, the locally grown trees have displayed the better growth in the early years. This is hardly surprising if the imported trees were not properly cared for after lifting from the nursery bed. Quite short periods of exposure to drying winds or storage in a warm environment, leading to water losses in root and shoot systems, can adversely affect survival and growth rates even after careful planting on a well-prepared site. Current Forestry Commission research should provide guidance on the amount of water loss and period of exposure that lead to the death of the commonly used species.

Rigorous quantitative specifications for forest trees have been laid down by the Standing Local Authority Officers' Panel on Land Reclamation : Vegetation and After Management Sub-Group, and so far as possible stock reaching these specifications are sought for reclamation sites. The specifications, listed in Table 2, show a greater stem diameter at root collar for a given height than the minimum standards published by the British Standards Institution (British Standard 3936, Part 5, 1966). That is to say, a sturdier tree than is generally used in forestry is believed to be desirable for reclaimed spoil heaps.

TABLE 2

MINIMUM DIAMETER SPECIFICATIONS FOR TREES PLANTED ON REGRADED COLLIERY SPOIL HEAPS

	Minimum stem diameter at root collar for 4 height classes (mm)			
	Height classes (mm)			
Species	*200*	*300*	*450*	*600*
Acer species			9.0	12.0
Alders			10.5	14.0
Ash			9.0	11.0
Birch			7.0	9.0
Blackthorn			8.0	11.0
False acacia			7.0	10.0
Larch		5.0	7.0	
Common oak		6.5	8.5	
Red oak		6.5	8.5	
Pines	5.0	7.0		
White poplar			9.0	12.0
Swedish whitebeam			9.5	13.0
Common thorn			6.5	9.0
White willow			7.0	11.0

In practice, such sturdy trees as these are difficult to obtain and stock that fail to reach the specifications in Table 2 are usually planted. However, in stress situations such as occur when dry conditions follow planting or when weed control is neglected during the growing season, it is probable that the thinner trees are the first to suffer. It is also difficult to determine a relationship between stem height and early performance. It has been found that small plants can be physically swamped by heavy weed growth, especially Red fescue, and tall trees may become very unstable, particularly in exposed situations. In both cases death may occur or, at best, the establishment period may be prolonged. Precise guidelines on minimum and maximum specifications for stem height are almost impossible to define because of the large number of factors to be taken into account, but there is some agreement that broadleaved forest stock shorter than 300 mm or taller than 600 mm should be avoided. In the case of most pine species a height range of 100 mm to 200 mm is acceptable.

In trials laid down to examine different types of planting stock, container and ball-rooted plants have generally survived well and grown faster in the early years than bare-rooted stock. The results have been sufficiently encouraging to suppose that prospects of tree establishment might be appreciably improved on reclaimed spoil if well-grown container trees could be widely used. However, containerised trees are more difficult and costly to produce, transport and plant than bare-rooted stock, and so results on reclaimed land would have to be commensurately better to justify their use. In any event, further experimentation is still needed to test different sorts of containers and sizes of plant. Species such as birch, sycamore *(Acer pseudoplatanus)* and Corsican pine *(Pinus nigra* var *maritima)*, which often survive badly or grow slowly for several years after planting on reclaimed spoil probably merit special attention.

In public open space, whips, feathered trees and standard trees planted for amenity are exposed in general to the same growth limiting factors as forest trees in woodland areas. Further, to ensure the successful establishment and continuing satisfactory growth of these larger types of tree, the same amendment operations as those practised on other parts of the reclamation site to improve the chemical and physical characteristics of the wastes are carried out prior to planting.

However, in public open space, cultural problems are encountered that are not ordinarily met with in woodland areas. Some of them arise, regrettably, simply because of the risk or local incidence of vandalism. Special arboricultural techniques are therefore undertaken to establish and maintain amenity trees, and it is beyond the scope of this paper to draw attention to them separately. Details of the more important aspects of amenity tree planting, including plant supply, planting methods,staking, protection, weeding and irrigation and choice of species have been well documented in recent arboricultural and horticultural literature. The more important publications are listed on p.41.

Hydroseeding techniques have been used on a trial basis to establish vegetation on regraded colliery spoil heaps, and have been sufficiently successful to support the view that, should the need arise, practical systems could be developed to revegetate whole sites. But the introduction of tree seed into a ground flora seeds mixture causes cultural problems. First the trees are distributed irregularly over the sown area and, second, the presence of more than one tree species in the mixture leads to management difficulties due to growth differences and competition. Also, tree species with large seed are not, at the moment, well suited to the technique, though seed pre-treatment and the use of a more suitable medium might increase the chances of success. Research and development are being carried out in many parts of the world.

Planting methods

Despite intensive cultivation after regrading to relieve compaction, to incorporate fertilisers and limestone, and to provide a spoil surface suitable for sowing grass seeds mixtures, difficult physical conditions usually prevail at time of tree planting. These are largely due to the recompaction of the upper spoil horizon, which becomes very hard and relatively impenetrable again, and the occurrence of stones and other solid materials close to the surface. Consequently the preparation of holes to accommodate the trees' roots invariably proves arduous, and the planting may be badly carried out. Usually the hole is not made sufficiently deep to take the whole root system, which then grows slowly and mis-shapenly for some years. Shallow planting also encourages the roots to dry out because they are partly exposed, and increases the risk of the trees becoming unstable.

That the quality of tree planting on reclaimed spoil may have a greater and more direct influence on early tree behaviour than any other factor has hardly ever been disputed. Thus local authority officers concerned about poor survival and growth rates have shown increasing interest in recent years in the introduction of improved planting methods. Until the early 1970s direct notch planting was commonly practised for establishing forest trees, using a spade driven through the grass sward into the hard spoil to make a narrow hole. Sometimes small pits were dug, and a mattock was preferred to a spade. Pit planting has since become commonplace, leading to the introduction into the holes of ameliorative materials such as turves and loam (Richardson, 1977). Mechanical soil augers have been employed to make the holes, so improving planting rates without adversely affecting survival and vigour. Robust augers appear to be needed, however, for prolonged operation on most sites. Because of the larger size of their root systems, amenity trees in public open space have generally been pit planted.

Perhaps the most significant development, however, has been the introduction during the past six or seven years of cultivation operations just before planting. To begin with, ploughing was carried out at a few sites but for various reasons the practice was not commonly accepted. It was superseded by ripping or sub-soiling, a technique which is now being widely adopted. Both operations are intended to relieve compaction in order to make planting easier and to encourage faster and better root extension in the early years.

Ploughing was limited to reclamation sites in Northumberland (one is now in Tyne and Wear following local authority reorganisation in 1974) and to spoil heaps in Forestry Commission woodland. Shallow, contour ploughing was carried out along the intended direction of planting at the proposed tree spacing of 1.5 to 2m. The trees were planted on or to the side of the ridge. Ploughing appears to be advantageous since the trees are planted in substantially weed-free spoil, but the visual appearance of the site is worsened for a few years until the grass sward is re-established on the ridge. Ploughing is believed to increase the risk of erosion on slopes, and tree stability problems are thought likely to arise in later years where linear development of roots has occurred along the plough ridges with little or no development into the furrows.

Ripping, with a single tine along the planting lines, to a maximum depth of 600 to 750 mm, usually promotes excellent physical conditions for planting and disturbs a considerable amount of spoil below the surface without seriously impairing the look of the site. The risk of erosion is not considered to be affected by ripping other than on very steep slopes. In West Yorkshire the practice has been further developed by ripping twice over the site, the second run being at right angles to the first, and then planting at the intersections of the slots. Other advances are likely, though experiments are required to examine the effects on tree survival and growth under different treatments. The use of a winged tine to disrupt a larger spoil mass along the planting lines or of a multi-tined ripper to relieve compaction between the planting lines are other potential developments requiring study.

It would also be proper to assess the effects of different planting methods on early root development, by examining whole root systems of selected trees. While there is evidence of widespread root extension laterally after the establishment phase, little is known about the downward growth of tree roots on reclaimed spoil. The behaviour of tree roots on ploughed and ripped spoil, and in pits prepared by soil auger is of particular interest.

Regardless of practice, however, all trees are well firmed after planting to lessen the risk of rocking or socketing. Holes in the spoil made by the tree's movements are difficult to close later, and serious damage may be done to the stem and root near the collar due to rubbing against sharp-edged wastes. The motion of the tree may also inhibit root development. Unfortunately, careful planting cannot wholly prevent socketing in some situations. Pines are especially prone to socket in almost any position. There is little or no evidence to suggest that the condition of the spoil at planting influences socketing. Planting in wet spoil, favoured because preparation of the holes is made easier, is not considered a contributory factor.

Weed control and other early maintenance

Trials on reclaimed spoil have shown that the survival rate of newly planted trees may be significantly reduced by the competitive effects of the grass sward (Doubleday and Jones, 1977). Local authority officers in general have recognized the seriousness of the problem, and on a large proportion of woodland sites weeding is regularly carried out in the early years of the planting. On some sites weeding is prolonged because of continuing tree replacement and the slow establishment of the crop. The measures adopted and the degree of weed control achieved have varied considerably from site to site.

Advances in the development and use of herbicides have led in the past two decades to greatly improved weed control in young plantations. Hand weeding, which is expensive, has therefore been greatly reduced or eliminated. A large number of materials and methods of application have been used in practice to suit individual preferences and varying conditions, and fresh materials are constantly coming into use. The recent development of new formulations has greatly improved the ease and accuracy of application, and given more effective control of weeds. Summary guidance on the use of herbicides is given in Appendix III. Detailed information on weed control measures in young plantations is contained in several publications listed on page 42.

Herbicides are applied usually as a spot treatment at the planting position, to provide a weed-free condition around the tree to a radius of about 250 mm. On some sites, for instance where the grass sward is not well established, weeding may not be needed everywhere. Rigorous weed control measures that kill patches of surface vegetation over the whole site are bound to alter its visual appearance for a few years; but there is some agreement that temporary loss of amenity is preferable to the death of trees and slow establishment of the plantation due to weed competition. Among local authorities, there is a belief that in high rainfall areas or on steep slopes, intensive weed control may lead to surface erosion and that, in some circumstances, no weeding should be carried out at all. In newly planted crops, however, it is neither necessary nor desirable to remove all unwanted vegetation, and only weeds which compete for moisture, nutrients or light and those that are likely to smother the young trees need be controlled (Crowther, 1978). One possible solution on erodable slopes lies in selective weed control and in the inclusion in the grass seeds mixture of a herbicide-resistant component which is minimally competitive.

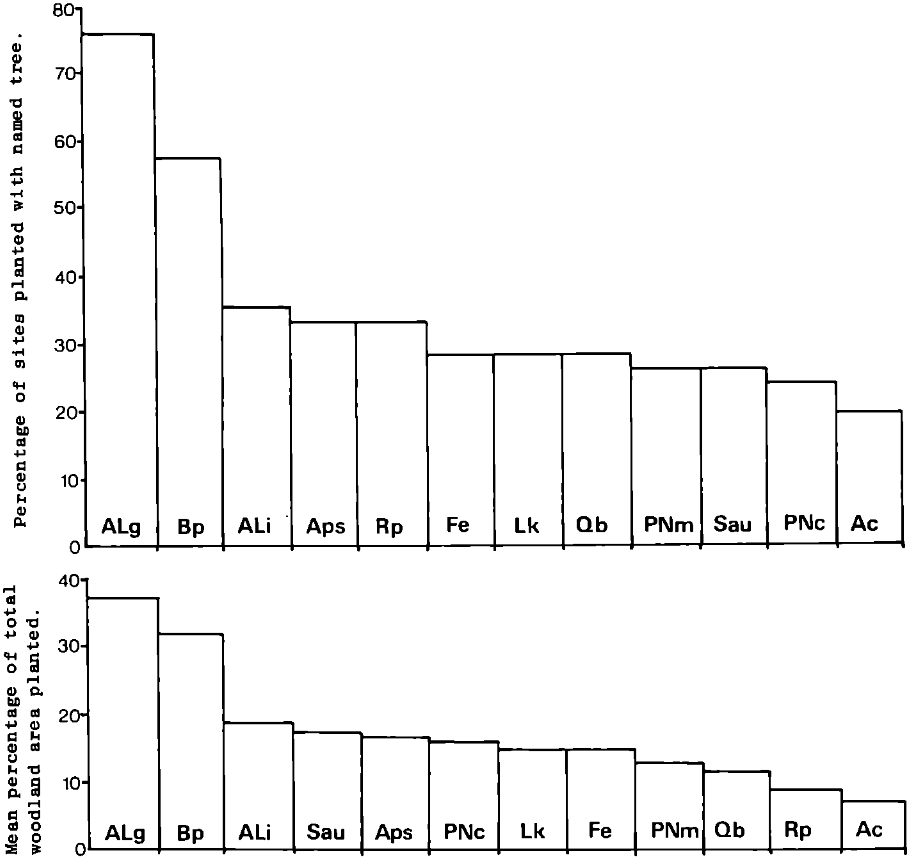
Herbicides are safe to use so long as they are properly handled and applied. Local authority officers or forestry contractors should ensure that all safety rules are carefully observed, in order to avoid potential damage to human beings, stock and fish, and wildlife generally, as well as to the trees themselves.

Other work undertaken on reclaimed land during the crop establishment phase has included the repair of fences and gates to limit the entry of animals into plantations and to lessen prospects of vandalism. Also, where trees have started to socket, attempts have generally been made to firm the spoil again to prevent further movement of stem and root.

CHOICE OF SPECIES

Considerable reliance has been placed by local authorities on a small number of pioneer trees known to be tolerant of colliery spoil, other industrial wastes and infertile mineral soil. Only 12 species have been widely used, and these account for a very large proportion of all the planting on regraded pit heaps during the past decade. One species, Common alder, predominates; it has been planted on the majority of sites, and has often been used as a matrix in which other species have been planted only on a small scale. About 15 other, relatively tolerant, trees and a small number of demanding species make up the remaining proportion. Usually, these have been planted in small groups or in single lines in mixed crops composed largely of pioneer species. Sometimes, however, they have been used in quite large blocks, often to replace pioneer trees which failed in the initial planting. An indication of the range of species and their relative use on selected sites planted between 1967 and 1976 are given in Appendix I. The extent of the use of the 12 commonly used species is shown in Figure 1 page 32.

Some widely planted pioneer trees have proved to be difficult to establish on some sites. Silver birch, for example, has survived badly in several plantations, and sycamore (*Acer pseudoplatanus*) has grown very slowly to begin with on most sites. In contrast, False acacia, and Common and Grey alder, have generally survived well and grown vigorously in most crops after the first two or



KEY

ALg - *Alnus glutinosa*
Common alder

Bp - *Betula pendula*
Silver birch

ALi - *Alnus incana*
Grey alder

Aps - *Acer pseudoplatanus*
Sycamore

Rp - *Robinia pseudacacia*
False acacia

Fe - *Fraxinus excelsior*
Ash

Lk - *Larix kaempferi*
Japanese larch

Qb - *Quercus borealis*
Red oak

PNM - *Pinus nigra* var. *maritima*
Corsican pine

Sau - *Sorbus aucuparia*
Rowan

PNc - *Pinus contorta*
Lodgepole pine

Ac - *Acer campestre*
Field maple

Figure 1. Use of the 12 major species on 33 regraded colliery spoil heaps, 1967-76.

three years. Nevertheless, it would be unwise to make too many generalisations about long-term species behaviour on the basis of early tree performance on reclaimed spoil, and the comments that follow under *Commonly used trees* are intended to provide a balanced judgement. That a cautious approach may be expedient is illustrated by the behaviour of two frequently planted trees, False acacia and Silver birch. On the one hand, False acacia usually survives well, grows vigorously after only two or three years and quickly makes a visual impact; however, it prefers a sheltered situation and often assumes a poor, shrub-like shape with little increase in height. Silver birch, on the other hand, often has a low survival rate and its growth is slow for some years, but once established it becomes relatively vigorous, thrives in a wide range of conditions and appears on most sites to be a potentially valuable component of woodland.

A small number of species are listed separately under *Species trials*. These are little-used trees on reclaimed spoil, or trees which have not been planted at all so far as is known, and are deserving of attention because of their satisfactory performance on other difficult sites. They merit inclusion in small scale trials on selected colliery wastes.

The proposed field trials of clonal stocks raised at the Institute of Terrestrial Ecology from selected trees found to be growing well on reclaimed spoil are also worthy of comment. In the longer term the behaviour of progenies produced from seed collected in stands on both ungraded and regraded heaps may claim attention as well.

Commonly used trees

1. Sycamore *(Acer pseudoplatanus)* - widely used pioneer tree in every coalfield, survives well but grows very slowly and has a poor foliage for several years after planting. Once established, its growth rate greatly improves and, on most sites, it is likely to be a valuable long-term component of mixed woodland. It is one of the better trees for exposed heaps. However, it has little attraction for wildlife and eventually casts dense shade.

2. Common alder *(Alnus glutinosa)* - the most widely planted and, overall, the easiest to establish species. It is often the most vigorous tree on the site and where it predominates in the crop the visual impact is early and striking. It tolerates moderate to intensely acid spoil. Annual height increases of 900 mm are common on wetter spoil but its shape tends to deteriorate with increase in exposure and, in dry seasons, serious crown die-back may occur. If the winter and growing season are wet it can recover strongly. While in many respects an excellent, and perhaps the best, choice for reclaimed spoil

its long-term value actually remains to be determined. Common alder is a site improver and first rotation stands may quickly provide suitable conditions for the successful establishment - by interplanting - of climax species.

3. Grey alder *(A. incana)* - a widely planted pioneer tree which is easily established and usually quick growing. It tolerates a wide range of site conditions including acid spoil, and may be a better choice than Common alder for drier wastes. Like this species it may have an important role as a site improver and as a nurse for less tolerant trees. Sucker growth develops from surface roots from an early age.

4. Silver birch *(Betula pendula)* - an important pioneer species which has proved relatively difficult to establish on regraded spoil heaps. But if it can be successfully established, it then maintains satisfactory growth rates and is likely to be a valuable component of mixed woodland from the amenity and wildlife viewpoints. It tolerates acid and dry spoil, and considerable exposure, and in some situations it will outgrow Common and Grey alder.

5. Hawthorn *(Crataegus monogyna)* - wherever planted on reclaimed spoil it has tended to thrive, sometimes in exposed situations, and appears to merit much wider use. It is very tough and hardy and provides an excellent habitat for wildlife. It is a vandal deterrent and could be used to protect more valuable and sensitive species.

6. Beech *(Fagus sylvatica)* - a little-used species on regraded colliery spoil heaps, its value remains doubtful. It proves quite difficult to establish and its growth rate remains slow for some years. The reasons for its comparatively poor behaviour are not clearly understood, since on some regraded pit heaps it is growing surprisingly well. It is a tree known to dislike excess moisture and will not root into poorly drained horizons; it seldom does well on heavy spoils or in damp hollows. It has a number of draw-backs later in life, including proneness to disease and decay.

7. Ash *(Fraxinus excelsior)* - a potentially valuable tree because of its generally good survival and rapid early growth rate on several sites as well as in exposed situations. Where establishment has been slow, plant quality or planting method may have been more to blame than the spoil. It is a species which merits wider use.

8. White poplar *(Populus alba)* - frequently included in trials, this species has grown well in sheltered localities and appears to be among the easiest trees to establish. It has an attractive bark and foliage, and its ability to sucker may be an advantage in some situations. However, the related Grey poplar *(P. canescens)* has greater merit and should be preferred, especially for planting in woodland.

9. Red oak *(Quercus borealis)* - it is much more quickly established and grows considerably faster than English oak *(Q. robur)*. In some situations, on colliery waste it is only slightly less vigorous than Common and Grey alder. Since it tolerates light, dry and acid soils it may be well suited to most types of spoil.

10. English oak *(Q. robur)* - usually planted in small groups and as single trees in an alder or pine matrix, this species is usually very slow to establish, and some eight years may elapse after planting before acceptable growth rates are attained. Its survival rate is quite moderate and research is required primarily to see if improvements in vigour can be achieved in the first few seasons. For several reasons it ranks as an important tree and planting on a wider scale, assuming establishment can be improved, appears to be a justifiable objective. There is some evidence that Sessile oak *(Q. petraea)* may be successful on some sites.

11. False acacia *(Robinia pseudoacacia)* - a much planted tree on reclaimed colliery spoil, it is usually fast growing in the early years and generally survives better than most species. It is most successful, however, on sheltered sites and may die-back or become misshapen on exposed slopes. It tends to become bushy and may not reach a large stature other than in favoured positions. It is badly damaged by hare and rabbits and has a brittle wood. Like the alders it has a value as a nitrogen fixer.

12. Willow *(Salix* spp. and cvs.) - only White willow *(S. alba)* and Goat willow *(S. caprea)* have been widely used, but never in large numbers on any site. Other species and a small number of cultivars have been included in trials. Generally, the willows have been successful, especially in wetter spoil at the base of the heaps, and merit further planting. There is a strong case for investigating direct cutting insertion techniques and for extending some species, including Goat willow, on to more acid spoil.

13. Rowan *(Sorbus aucuparia)* - a pioneer tree on many reclaimed spoil heaps, it tolerates a wide range of conditions, and is very hardy and resistant to exposure. It is attractive for much of the growing season. However,

sometimes it starts very slowly and may lack vigour, remaining thin-crowned for many years. Its chief role is probably as a minor component in mixed broadleaved woodland or as an amenity tree at the perimeter of conifer plantations.

14. Swedish whitebeam *(S. intermedia)* - planted recently in large groups on reclaimed spoil in the north of England, where it has survived well and grown quickly after only a year or two. It appears to tolerate a wide range of environmental conditions including acid spoil. It is highly decorative for the whole of the growing season and probably has a higher amenity value than either rowan or whitebeam *(S. aria)*. Its long-term role and management in pure blocks on regraded spoil needs to be assessed.

15. Japanese larch *(Larix kaempferi)* - this species has been used on a small scale in earlier plantings on reclaimed spoil, usually in small groups or in single lines in a broadleaved matrix, and on the best sites it has survived and grown well, though less spectacularly than the broadleaved component. A species that will not tolerate shade, bad drainage and heavy soil, it appears on the face of it to be one of the least useful trees for reclaimed spoil. However, its relatively vigorous growth and good shape in a number of quite exposed localities suggest that planting should continue.

16. Lodgepole pine *(Pinus contorta)* - A few large blocks have been planted in the north-east of England for timber production. It appears to be much less difficult to establish on reclaimed spoil than Corsican pine *(P. nigra* var *maritima)* and it sometimes grows quickly from the second or third year onwards. South of the Tyne, however, its rate of both height and radial growth on colliery spoil is a good deal less than that of Corsican pine.

17. Corsican pine *(P. nigra* var *maritima)* - long recognised as one of the best trees for planting on colliery spoil, it often survives poorly on regraded heaps and may take two or three years to grow vigorously. It tolerates dry spoil better than many species and is a sound choice for large-scale planting on heaps in Yorkshire and southwards. Containerisation of planting stock may improve survival rates.

18. Scots pine *(P. sylvestris)* - this species has been widely planted on colliery spoil for several decades, though on regraded heaps it has been less used than Corsican and Lodgepole pine. However, it is being planted on reclaimed spoil in County Durham, where it has grown well on pit heaps, as a nurse matrix for oak, sycamore and other broadleaved species.

Species trials

Several tree species have been planted in trials on colliery spoil and have survived and grown exceptionally well. Their use on a wider scale or in larger numbers locally cannot easily be evaluated, however, and it is probable that further trials to examine their general potential should now be laid down. They are listed here without comment. A small number of species not hitherto planted on reclaimed spoil, but perhaps meriting inclusion in the trials because of their excellent behaviour on infertile soils and other difficult industrial wastes, are included.

Field maple *(Acer campestre)*; Norway maple *(A. platanoides)*;
Common horse-chestnut *(Aesculus hippocastanum)*; Italian alder *(Alnus cordata)*;
Sweet chestnut *(Castanea sativa)*; Hybrid cockspur thorn *(Crataegus lavallei)*;
Lawson cypress *(Chamaecyparis lawsoniana)*; Crab apple *(Malus sylvestris)*;
Common hazel *(Corylus avellana)*; Turkish hazel *(C. colurna)*;
Common holly *(Ilex aquifolium)*; Grey poplar *(Populus canescens)*;
Black cottonwood *(P. trichocarpa)*; Aspen *(P. tremula)*;
Roble beech *(Nothofagus obliqua)*; Raoli *(Nothofagus procera)*;
Pin oak *(Quercus palustris)*; Turkey oak *(Q. cerris)*; Whitebeam *(Sorbus aria)*;
Hybrid larch *(Larix x eurolepis)*; Japanese larch *(Larix kaempferi)*;
Willow *(Salix* spp and cultivars*)*.

Use of shrubs

Shrubs have been planted on reclaimed spoil with ornamental trees in car parks, picnic sites and close to footpaths. They have seldom been included in woodland plantings other than in small quantity for amenity at the perimeters of the blocks. But it is well known that shrubs have an important amenity and wildlife role in woodland, and make a significant contribution to the development of the ecosystem. They are widely used as pioneers, as ground cover under high forest canopy, and as shelter for establishing exacting species.

Shrubs have been included in some species trials planted on colliery spoil by university departments. They have also been planted by local authorities on a small scale. The list that follows is based on the known good behaviour of shrubs in these plantings. Shrubs that tolerate acidity, dry soils, exposure and other extreme growth limiting factors,that have not been widely seen or encountered at all on colliery spoil are included. Many different objectives appear to influence choice of shrub species, and comments on individual species in the list have therefore been avoided on the grounds that practitioners are likely to have specific reasons for choosing shrubs that cannot be covered in this type of publication. There is a wealth of information on shrubs in botanical and horticultural literature.

Buddleia *(Buddleia davidii);* Dogwood *(Cornus stolonifera);*
Cotoneaster *(Cotoneaster simonsii);* Broom *(Cytisus scoparius) - (Sarothamnus);*
Common ivy *(Hedera helix);* Sea buckthorn *(Hippophae rhamnoides);*
St. John's wort (Rose of Sharon) *(Hypericum calycinum);* Dog rose *(Rosa canina);*
Privet *(Ligustrum vulgare);* Tree lupin *(Lupinus arboreus);*
Bird cherry *(Prunus padus);* Blackthorn *(Prunus spinosa);* Gorse *(Ulex europaeus);*
Rhododendron *(Rhododendron ponticum);* Ramanas rose *(Rosa rugosa);*
Bramble *(Rubus fruticosus);* Common elder *(Sambucus nigra);*
Red-berried elder *(Sambucus racemosa);* Goat willow *(Salix caprea);*
Grey sallow *(Salix cinerea);* Purple osier *(Salix purpurea);*
Common osier *(Salix viminalis);* Guelder rose *(Viburnum opulus).*

MAINTENANCE AFTER CROP ESTABLISHMENT

The behaviour of young trees and the establishment of woodland on reclaimed colliery spoil have been considered at some length in other parts of this publication. The poor survival and slow growth of newly planted trees and the prolonged establishment of plantations have received special attention.

In general in forestry, plantations are considered to be established when some 2,000 to 2,500 trees per hectare have attained a height of 1.5 to 2 m, and are healthy and vigorous more or less. Whether this principle should be strictly applied by local authorities to all plantings on reclaimed land is a moot point, since the special problems of revegetating regraded colliery spoil, the widely different objectives of planting and the marked heterogeneity of the wastes must be taken into account. Nevertheless, the provision of a yard-stick of this sort, while perhaps subject to different interpretations, may be seen as a helpful guide, especially by officers unfamiliar with woodland management.

There are no over-riding reasons for devising management objectives for woodlands on reclaimed colliery spoil different from those adopted in general for small woods on other types of land. Thus gates and fences will have to be maintained to keep out farm animals, cleaning will have to be undertaken to control competitive woody weed growth, and brashing will have to be arranged to improve access through plantations. Most importantly, thinning will have to be carried out periodically, starting from the fifteenth to twentieth year, to enhance the development of woodland conditions. The preponderance of broadleaved species, many of which coppice, sucker or produce large quantities of fertile seed, and the layout and composition of some mixtures may give rise to maintenance problems locally.

While there are expectations that merchantable wood will be produced in some, if not all, stands the revenue from early thinnings will be insignificant and some marketing difficulties may be encountered. Thus in the early life of the plantation a substantial sum of money will be spent undertaking work from which there will be little, if any, financial return. It follows that operations must be properly forecast and allowed for in financial estimates, otherwise cultural work may be neglected to the detriment of the crop.

As woodland conditions develop, the successful introduction of demanding tree species, such as ash and oak, may become less difficult. Certainly, it is tempting to consider that crops composed predominantly of broadleaved pioneer species might be enriched in this way. Single trees or small groups of trees might be planted, for exmample, in naturally occurring or artificially created gaps up to about age 25 years. Where planting is contemplated in naturally occurring gaps it will be necessary of course to ensure that spoil conditions will support tree growth. It should also be borne in mind that the risk of surface erosion may inhibit clear felling and the development of conditions suppressing ground flora.

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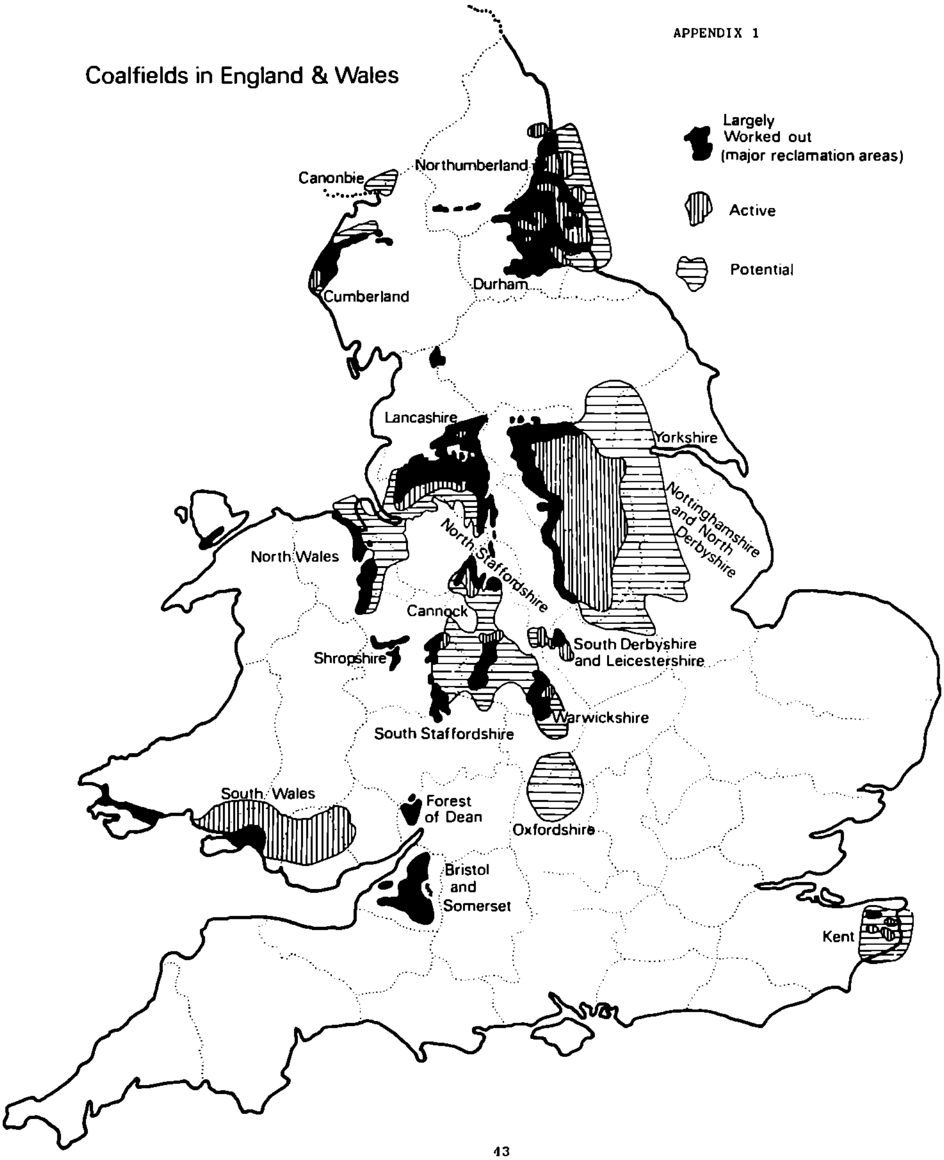
Coalfields in England & Wales
Largely
Worked out
(major reclamation areas)
Active
Potential
Canonbie
Northumberland
Cumberland
Durham
Lancashire
Yorkshire
Nottinghamshire and North Derbyshire
North Wales
North Staffordshire
Cannock
Shropshire
South Derbyshire and Leicestershire
Warwickshire
South Staffordshire
South Wales
Forest of Dean
Oxfordshire
Bristol and Somerset
Kent

APPENDIX 2

Guide to use of herbicides to control grasses and grass/herb mixtures

Information on the use of herbicides to control bracken, heather and woody weeds may be found in Forestry Commission Booklet 40 (HMSO) and the handbook 'The use of chemicals in the Forestry Commission'.

PRE-PLANTING TREATMENT

WEED TYPE	HERBICIDE	TREATMENT	TIME OF APPLICATION (MAY – APRIL)	EQUIPMENT	APLICATION RATES (per treated hectare): RATE ACTIVITY & FORM	DILUENT	TOTAL VOL. OR WEIGHT
grasses and grass/ herb mixtures	atrazine	foliar & ground		K GD CDBA	8-12kg 50% WP 8-12 150% FL 100-150kg 4%G 8-12 150% FL	MV Water - VLV Water	WP 300-500 l FL 200-400 l 100-150kg 20-30 l 1½:1/ Water:FL
	chlor-thlamid, 7½% dichlobenil & dichlo-benil 6¾% + dalapon 10%	ground	leave one month before planting	GD	40-60kg 7½% 6¾%G 6¾% + 10%	-	40-60kg
	glyphosate Use freshly diluted herbicide each day	foliar		CDBA K	1.5 litres 36% L	VLV Water MV Water	10-20 litres 300-500 litres
	propyzamide	ground		K CDBA GD	3kg 50% WP 10 litres 15%FL 40kg-50kg 4% G	MV Water VLV Water -	300-500 litres 20 litres 40-50kg
	paraquat	foliar	molinia only before 1st Sept; not within 3 days of planting	K	5-10 litres 20% L	MV Water	300-500 litres
	"velpar"	foliar and ground		K	2 kg 90% WS	MV Water	200-500 litres
				K	10 litres	MV (Water)	300 litres

POST-PLANTING TREATMENT

WEED TYPE	HERBICIDE	TREATMENT	TIME OF APPLICATION (MAY–APRIL)	EQUIPMENT	APPLICATION RATES (per treated hectare): RATE, ACTIVITY & FORM	DILUENT	TOTAL VOL. OR WEIGHT
grasses and grass/herb mixtures	atrazine	foliar & ground	USE THE LOWER RATE DURING APRIL + MAY FOR EL, NS & WH. ONLY SPRAY HARDWOODS WHILE DORMANT	K GD CDBA	8-12 l 50% WP 8-12kg 50% FL 100-150kg 4% G 8-12 l 50% FL	MV Water - VLV Water	WP 300-500 l FL 200-400 l 100-150kg 20-30 l 1½:1/ Water:FL
	chlor-thiamid 7½% dichlobenil & dichlo-benil 6¾% & dalapon 10%	ground	on LP, CP, SP, SS, NS oak ash, beech & sycamore EVEN DISTRIBUTION OF GRANULES IS ESSENTIAL	GD	40-60kg 7½% 6¾%G 6¾% + 10%	-	40-60kg
	glyphosate Use freshly diluted herbicide each day	foliar	Use a tree guard on all species DO NOT SPRAY LARCHES, WH OR HARDWOODS WITHOUT A TREE GUARD Use a guard	CDBA K (plus guard)	1.5 litres 36% L	VLV Water MV Water	10-20 litres 300-500 litres
	propyzamide	ground		K CD BA GD	3kg 50% FL 10 litres 15% FL 40kg-50kg 4% G	MV Water VLV Water -	300-500 litres 20 litres 40-50kg
	paraquat	foliar	molinia only at this time	K (plus guard)	5-10 litres 20% L	MV Water	300-500 litres
coarse grasses	"velpar"	foliar and ground	Use a guard Use only with CP, LP, SP, NS & SS. Larches and hardwoods are killed.	K (plus guard in May & June)	2kg 90% WS	MV Water	200-500 litres
					10 litres	MV (Water)	300 litres

FULL WIDTH OF SHADING INDICATES TIME OF APPLICATION GIVING A COMBINATION OF BEST KILL & GREATEST SUITABILITY

DIMINISHING WIDTH OF SHADING INDICATES PROGRESSIVELY LESS SUITABLE OR LESS EFFECTIVE TIME OF APPLICATION

CUT OFF INDICATES TREATMENT HAS TO TERMINATE BECAUSE OF PLANTING OR ONSET OF DORMANCY

KEY:
- GD GRANULE DISTRIBUTOR
- K KNAPSACK SPRAYER
- CDBA CONTROLLED DROP BAND APPLICATOR
- WP WETTABLE POWDER
- FL FLOWABLE FORMULATION
- G GRANULE
- L LIQUID
- WS WATER SOLUBLE POWDER

LITRES/HA	
200-700	MV MEDIUM VOLUME
10-49	VLV VERY LOW VOLUME

APPENDIX 3

AGRICULTURAL DEVELOPMENT AND ADVISORY SERVICE (ADAS) OF THE MINISTRY OF AGRICULTURE, FISHERIES AND FOOD. REGIONAL CENTRES AND SUB-CENTRES AT WHICH ANALYTICAL SERVICES ARE AVAILABLE

EASTERN REGION - (Bedfordshire, Cambridgeshire, Essex, Hertfordshire, Norfolk, Suffolk)

Block C, Government Buildings, Brooklands Avenue, Cambridge CB2 2DR
Telephone: 0223 58911

EAST MIDLAND REGION - (Derbyshire, Leicestershire, Lincolnshire, Northamptonshire, Nottinghamshire)

Shardlow Hall, Shardlow, Derby DE7 2GN. Telephone: 0332 792313

NORTHERN REGION - (Cleveland, Cumbria, Durham, Northumberland, North Yorkshire, (Districts - Richmondshire, Hambleton, Rydale, Scarborough), Tyne and Wear).

Government Buildings, Kenton Bar, Newcastle-upon-Tyne NE1 2YA.
Telephone: 0632 869811

SOUTH EASTERN REGION - (Berkshire, Buckinghamshire, East Sussex, Hampshire, Isle of Wight, Kent, Oxfordshire, Surrey, West Sussex)

Block A, Government Offices, Coley Park, Reading RG1 6DT.
Telephone: 0734 581222

Sub-Centre - Olantigh Road, Wye, Ashford, Kent TN15 5EL. Tel. 0233 812761

SOUTH WESTERN REGION - (Avon, Cornwall, Devonshire, Dorset, Gloucestershire, Somerset, Wiltshire)

Block 3, Government Buildings, Burghill Road, Westbury on Trym, Bristol BS10 6NJ
Telephone: 0272 500000

Sub-Centre - Staplake Mount, Starcross, Exeter EX6 8PE. Tel. 062 689481

WEST MIDLAND REGION - (Cheshire, Hereford and Worcester, Shropshire, Staffordshire, Warwickshire, West Midlands M.C.)

Woodthorne, Wolverhampton WV6 8TQ. Tel. 0902 754190

YORKSHIRE AND LANCASHIRE REGION - (Greater Manchester M.C., Humberside, Lancashire, Merseyside M.C., North Yorkshire (Districts - Craven, York, Harrogate, Selby), South Yorkshire, West Yorkshire)

Block 2, Government Buildings, Lawnswood, Leeds LS16 5PY.
Telephone: 0532 674411

WALES - (All Counties)

Trawsgoed, Aberystwyth SY23 4HT. Telephone: 0970 913255

Sub-Centre - Government Buildings, 66 Ty Glas Road, Llanishen, Cardiff CF4 5ZB
Telephone_ 0222 757971

Sub-Centre - Bryn Adda, Penrhos Road, Bangor, Gwynedd LL57 2LJ.
Telephone: 0248 2561

Revegetation Practices on Regraded Colliery Spoil Heaps: 1967 to 1976

Data from selected sites reclaimed by local authorities are listed inside back cover.

Abbreviations used are:

Materials

GL	— Ground limestone (unspecified)
GCL	— Ground calcitic limestone
GML	— Ground magnesium limestone
MAP	— Magnesium ammonium phosphate
O	— no treatment
—	— no information available

Methods

P	— ploughing before planting
R	— ripping before planting
n	— notch planting
p	— pit planting

Grasses + legumes

At	— *Agrostis tenuis* — Common bent (or brown top)
At (Am)	— — American brown top bent
Cc	— *Cynosurus cristatus* — Crested dog's tail
Fo	— *Festuca ovina* — Sheep's fescue
Fp	— *Festuca pratensis* — Meadow fescue
Frc	— *Festuca rubra commutata* — Chewing's fescue
Fr (Can)	— — Canadian red fescue
Fr (Dan)	— — Danish red fescue
Frr	— *Festuca rubra rubra* — Creeping or red fescue
Ft	— *Festuca tenuifolia* — Fine-leaved sheep's fescue
Lm	— *Lolium multiflorum* — Italian rye grass
Lp	— *Lolium perenne* — Perennial rye grass
PHp	— *Phleum pratense* — Timothy grass
POp	— *Poa pratensis* — Smooth meadow grass
POt	— *Poa trivialis* — Rough meadow grass
LOc	— *Lotus corniculatus* — Bird's foot trefoil
Th	— *Trifolium hybridum* — Alsike clover
Tp	— *Trifolium pratense* — Red clover
Tr	— *Trifolium repens* — White clover

(continued p. 48)

Revegetation Practices on Regraded Colliery Spoil Heaps: 1967 to 1976

Trees

Ac — *Acer campestre* — Field maple
Apl — *Acer platanoides* — Norway maple
Aps — *Acer pseudoplatanus* — Sycamore
AEh — *Aesculus hippocastanum* — Horse chestnut
ALc — *Alnus cordata* — Italian alder
ALg — *Alnus glutinosa* — Common alder
ALi — *Alnus incana* — Grey alder
Bp — *Betula pendula* — Silver birch
Ca — *Corylus avellana* — Hazel
CRm — *Crataegus monogyna* — Hawthorn (May)
CRo — *Crataegus oxyacantha* — Midland hawthorn
CSs — *Castanea sativa* — Sweet chestnut
Fe — *Fraxinus excelsior* — Ash
FAs — *Fagus sylvatica* — Beech
Hr — *Hippophae rhamnoides* — Sea buckthorn
Lk — *Larix kaempferi* — Japanese larch
PCo — *Picea omorika* — Serbian spruce
PCs — *Picea sitchensis* — Sitka spruce
PNc — *Pinus contorta* — Lodgepole pine
PNm — *Pinus nigra* var. *maritima* — Corsican pine
PNs — *Pinus sylvestris* — Scots pine
PO — *Populus* spp. — Popular species
POa — *Populus alba* — White poplar
PRs — *Prunus spinosa* — Blackthorn
Qb — *Quercus borealis* — Red oak
Qc — *Quercus cerris* — Turkey oak
Qp — *Quercus petraea* — Sessile oak
Qr — *Quercus robur* — English oak
Rp — *Robinia pseudoacacia* — False acacia
Sar — *Sorbus aria* — Whitebeam
Sau — *Sorbus aucuparia* — Mountain ash (Rowan)
Si — *Sorbus intermedia* — Swedish whitebeam
SA — *Salix* spp. — Willow species
SAa — *Salix alba* — White willow
Tp — *Tilia platyphyllos* — Large leaved lime
XB — Other broadleaf species
XC — Other conifer species

Notes

1. Original planting 1970 failed. Ploughed and replanted 1971.

2,3,4 and 5. These were rooting rippings.

6. Comprises 18 small tree-planting sites.
7. Applied Dec. 1974 as surface treatment. Pyritic patches given 40 tonnes/ha.
8. Part of site only.
9. Original planting 1973-74 destroyed by sheep and cattle.
10. T & W = Tyne and Wear.
11. L/GMC = Lancashire/Greater Manchester Council.

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