PHYSICAL CRITERIA FOR THE DESIGN AND ASSESSMENT OF RESTORATION SCHEMES IN THE UNITED KINGDOM[1]

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Abstract: The restoration of colliery wastes and open pit coal sites in the United Kingdom (UK) is undertaken according to a land use strategy plan and detailed specifications that have been agreed upon with the planning authorities.

For two of the major land uses in the UK, agriculture and forestry, data on physical criteria (climate, site features and soils) are available to assist in the planning and design of land use strategies and specification of restoration treatments. Similar criteria could also be developed for the restoration of semi natural vegetation and habitats for landscape, wildlife, and amenity uses.

Three examples are described illustrating the use of the physical criteria in the design of schemes, the specification of treatments, and the assessment of achievements.

Additional Key Words: restoration strategy, restoration treatments, physical criteria, climate, site features, soils.

Why Criteria?

The restoration of colliery lagoons and spoil heaps, and of open pit coal sites in the UK is undertaken according to a land use strategy plan and detailed specifications. These are usually prepared by the industry in conjunction with consultants. The restoration plan shows the location and types of land use and is accompanied by detailed specifications for all aspects of the treatment and management work to be used to achieve the strategy. Both the strategy and the specifications have to be agreed upon with the local government planning authorities. Usually the strategy is agreed upon during early consultations and the application stage of the process. In long-term developments, the principles of the strategy may be outlined and, by agreement, modified according to changes in local and national land use policies. The details of the specifications may be agreed upon at the same time or delayed until just before restoration commences.

In the recent past, the strategies and specifications formulated have not been based on specific criteria for the land uses and vegetation types, but have been governed largely by land ownership, land use aspirations, and availability and allocation of soil material. While this approach has often been relatively successful for agricultural uses, it has been largely by default, and associated with those sites where the original soil types and thicknesses have been replaced. It has been less successful in the case of other land uses, and woodland in particular, where there has often been an insufficient cover of soil materials. This often occurs at older redundant collieries where, for historic reasons, soils were not recovered prior to development and waste disposal (Humphries 1984). In the past the available soil materials have preferentially been allocated to agricultural uses, with little or no cover material for the other land uses. The reasons for this have been multifarious, but have mainly been based on the misguided assumption that non agricultural land uses and vegetation types are less demanding in terms of "fertility" etc.

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From an operational viewpoint the past approach has generally specified universal treatments irrespective of site constraints, proposed land use type and quality, and the vegetation's requirements. This blanket approach to restoration has tended to result in unnecessary and costly work such as more stone removal, greater thicknesses of soil cover, and additional cultivation, which are not economically justified owing to physical limitations on the potential quality and ability to utilize the land.

Both of the above criticisms have arisen because of the absence of accepted criteria against which strategies can be formulated and tested, and restoration treatments ultimately specified.

The lack of criteria has also made it difficult for others to objectively assess restoration achievements in the past (Humphries et al 1984). This evaluation aspect of restoration has become increasingly significant now that most coal projects in the UK are subject to environmental impact assessments under recent legislation (Department of the Environment 1989a). The ability to restore to specific land uses and qualities has now become a key issue in the planning process in the UK. Hence, there is a need for accepted criteria against which proposals and achievements can be evaluated. Furthermore, the Town and Country Planning (Minerals) Act 1981 (Department of the Environment 1982) requires land to be restored to physical characteristics that are suited to the proposed use, whether it be agriculture, forestry, amenity, or wildlife. However, no guidance on the characteristics to be used or the standards to be achieved is given in the Act, and such guidance is only cursorily referred to in respect of agriculture in more recent literature (Department of the Environment 1989b).

The purpose of this paper is to draw attention to the fact that for two major land uses, agriculture and forestry, physical criteria are available and these can be adapted to other uses. For example, the criteria for forestry are also applicable to semi natural broadleaved woodland for landscape, wildlife, and amenity purposes. Other vegetation types could also be based on the same framework, although there will need to be some development work.

Available Criteria

Published Criteria

There are published physical criteria whereby land in the UK can be assessed for its suitability for agriculture and forestry use (Bibby 1982, Bibby and Futty 1988, MAFF 1988). These methodologies have their roots in the system used in the USA in the 1960's (Klingebiel and Montgomery 1961). According to the criteria, land in the UK can be grouped into broad categories of potential land use and quality for both agriculture and forestry (table 1). The groups represent a gradation of productivity, crops and/or species, and flexibility of utilization from category 1 (no or minor limitations and a wide species range) to 5 (severe limitations and a very restricted species range).

Physical Criteria

Agricultural and forestry productivity and utilization in the UK are largely determined by climate, relief, soils, and their interactions. Hence, climate, site features, and soil characteristics need to be taken into account when designing restoration schemes and specifying treatments.

Table 1. Categories of potential land use and quality.

Category	Suitability for agriculture	Suitability for woodland
1..........	No limitations, very wide range of agricultural and horticultural crops, high yields and low variability.	Very wide range broadleaved + conifers.
2..........	Minor limitations, wide range of agricultural and horticultural crops, high yields but may be variable.	Wide range broadleaved + very wide range conifers.
3(a).......	Moderate limitations, narrow range of arable crops and less demanding horticultural crops, moderate to high yields.	Moderate range broadleaved + wide range conifers.
3(b).......	Moderate limitations, narrow range of arable crops, moderate yields, but high yields of grass.	Moderate range broadleaved + wide range conifers.
4..........	Severe limitations, suited mainly to grass, yields moderate to high.	Restricted range broadleaved + moderate range conifers.
5..........	Severe limitations, suited only to grass.	Very restricted range broadleaved + restricted range conifers.

Climate. Climate has a major influence on the range of agricultural uses (grassland, arable, and horticultural), costs, and levels of production. In many places in the UK, it can be the overriding factor; that is, climatic factors can determine land use irrespective of the nature of the soil profile. Climate is a major consideration for afforestation with broadleaved and conifer species; including determining the species planted and their productivity and form. It is also a major factor in determining other wildlife habitats such as wetland and heathland by influencing species composition and competitive ability. Climate is also of major landscape significance, influencing the type and form of vegetation and rates of development. For amenity use, it is of influence through resilience and recovery from damage to vegetation and soil. The effects of climate are partly direct through rainfall, temperature, and exposure to wind and frost, and partly indirect through soil wetness and droughtiness. In this respect, the duration of winter soil wetness is of particular importance.

The physical criteria for differentiating between categories of land use and quality in the UK on account of climate are given in table 2.

Site. Site features, such as gradient of slopes and general topography, which affects the incidence of flooding and risk of soil erosion, also influence land use and vegetation types. These too can be overriding factors but are usually secondary to climatic limitations.

The incidence of flooding and the risk of soil erosion will decide the choice of agricultural and forestry crops, while slope gradients will determine utilization through the efficient and safe operation of machinery. Similarly, these site features can influence landscape development, wildlife, and amenity use. The risk of windthrow is peculiar to forestry and woodland and is considered to be largely a site factor incorporating wind zones, elevation, relief, and soils.

Some of the physical criteria for differentiating land use and quality in the UK on account of site are given in table 3.

Table 2. Climatic requirements for potential land uses and qualities.

	Agriculture			Woodland	
Category	ATO[1]	AAR[2]	ZSMD[3]	ATO	AAR
1..........	>1,250	<1,350	>225	>1,240	<1,350
2..........	>1,150	<1,600	Not limiting	>1,100	<1,600
3(a).......	>1,100	<1,750	Not limiting	>900	<1,950
3(b).......	>1,000	<1,950	Not limiting	>900	<1,950
4..........	>800	<3,200	Not limiting	>700	<3,200
5..........	Not limiting	Not limiting	Not limiting	Not limiting	Not limiting

[1]ATO = Accumulated temperature between January and June (°C days).
[2]AAR = Average annual rainfall (mm).
[3]ZSMD = Zero soil moisture deficit (days).

Table 3. Site requirements for potential land uses and qualities.

	Agriculture-	Woodland		
Category	Gradient	Gradient	Terrain	Windthrow class
1..........	<1:8	<1:5	Even + firm	<2
2..........	<1:8	<1:3	Uneven + slightly soft	<3
3(a).......	<1:8	Not limiting	Moderately rough + moderately soft	<4
3(b).......	<1:5	Not limiting	Moderately rough + moderately soft	<4
4..........	<1:3	Not limiting	Rough + soft	<5
5..........	Not limiting	Not limiting	Very rough + very soft	Not limiting

Soil. Soil factors affect the potential and management of agricultural and forestry soils, but may be secondary or tertiary to climate and site limitations. The principal limiting soil characteristics are texture (particle size distribution), structure (particle aggregation and stability when subjected to wetting and drying), thickness of soil layers, stoniness, fertility (nutrients), salinity, soil reaction, and toxicity. The same soil characteristics affect the potential and management of wildlife habitats, the development of landscape features, and utilization for amenity use.

The wetness of the soil profile influences agricultural use (i.e., range and utilization of crops) through ease of cultivation and trafficking and risk of damage through poaching by livestock. The droughtiness of the soil profile influences agricultural use through range of crops and level of productivity. Texture and structure are the most significant soil characteristics in determining wetness and droughtiness within the context of local climate and site features. Soil depth is also of importance, affecting degree of droughtiness. The chemical characteristics of soils do not usually influence agricultural use where fertility content and soil reaction (pH) can be maintained or corrected by standard practice of applying fertilizers, manures, and neutralizing agents (e.g., lime and limestone). Chemical characteristics only affect land use quality where there are detrimental long-term effects on soil physical conditions (e.g., the effects of salinity on soil structure) and/or direct effects on the range of crops grown, and their productivity and management (e.g., control of salinity, toxicity, soil reaction).

Conditions of soil wetness and/or droughtiness influence forestry use and woodland type and the quality of the timber product. The influence of wetness is largely through choice of species, productivity, timber quality, susceptibility to windthrow, and ground conditions that affect the ease of trafficking for maintenance and harvesting. Soil droughtiness influences forestry use through the range of species, productivity, and quality of timber. Unlike agricultural use, it is not usual to amend inherent chemical characteristics of soil to any degree and/or on a routine basis. Soil reaction (pH) and fertility are therefore of significance for the choice of species, productivity, and quality of the timber crop. Both also influence forestry use and woodland types. Other important chemical characteristics include salinity and toxicity (e.g., heavy metals).

Some of the physical criteria for differentiating land use and quality on account of soil characteristics are given in tables 4 and 5. For simplicity the interactions between these and climate are not presented.

Examples of the Use of the Physical Criteria

Some of the ways the above criteria have been used in the design of restoration schemes, in the specification of treatments, and in the assessment of the standard of achievement are illustrated below.

Design of Schemes

The physical criteria can be used to identify the type and potential of land uses. The criteria can be used in two main ways - to define the minimum requirements for the proposed land uses or, conversely, to suggest the most appropriate land uses for the proposed site and soil conditions. The following example concerns the matching of climate and the characteristic of soil droughtiness to woodland types that may be suitably planted. It also illustrates the use of the criteria in deciding the allocation of soil resources.

Table 4. Soil texture and stoniness requirements for potential land uses and qualities[1].

	Agriculture				Woodland-	
	Soil Textures[2]		Stoniness (vol. %)[3]		Soil Textures	
Category	Mineral	Organic	>20 mm	>60 mm	Mineral	Organic
1..........	SL, SZL	LS, SL, SZL	5	5	SL, SZL, ZL, SCL, CL, ZCL	LS, SL, SZL, ZL, SCL, CL, ZCL
2..........	LS, SL, SZL, SCL, CL, ZCL	S, LS, SL, SZL, SCL, CL, ZCL	10	5	SL, SZL, ZL, SCL, CL, ZCL, SC, ZC	LS, SL, SZL, ZL, SCL, CL, ZCL, SC, ZC
3(a).......	LS, SL, SZL, SCL, CL, ZCL	S, LS, SL, SZL, SCL, CL, ZCL	15	10	LS, SL, SZL, ZL, SCL, CL, ZCL, SC, ZC	Not limiting
3(b).......	Not limiting		35	20	LS, SL, SZL, ZL, SCL, CL, ZCL, SC, ZC	Not limiting
4..........	Not limiting		50	35	Not limiting	
5..........	Not limiting		Not limiting		Not limiting	

[1]For climate regime with zero soil moisture deficits of 176-225 days.

[2]Key to soil textures:

S	= sand.	CL	= clay loam.
LS	= loamy sand.	ZCL	= silty clay loam
SL	= sandy loam.	SC	= sandy clay.
SZL	= sandy silt loam.	ZC	= silty clay.
SCL	= sandy clay loam.	C	= clay.

[3]In upper 250 mm of soil profile.

Table 5. Soil wetness and droughtiness requirements for potential land uses and qualities.

	Agriculture				Woodland		
	SWC[1]	DSPL[2]	SMB[3]		SWC	DSPL	SMB
Category			Winter wheat	Potatoes			
1..........	<II	>800	+30	+10	<II	>800	>+50
2..........	<III	>620	+5	-10	<III	>600	0 - 50
3(a).......	<IV	>350	-20	-30	<IV	>450	-50 - 0
3(b).......	<IV	>350	-50	-55	<IV	>450	-50 - 0
4..........	<V	Not limiting	<-50	<-55	<V	Not limiting	
5..........	Not limiting				Not limiting		

[1]SWC = soil wetness class.
[2]DSPL = depth to slowly permeable layer (mm).
[3]SMB = soil moisture balance (mm).

At Gedling Colliery in the Midlands it is proposed to recover coal by washing the older tips and some lagoon material prior to final restoration. The former colliery (140 ha in extent) is to be restored to a mixture of agricultural land and public open space, incorporating woodland (65 ha), pasture (26 ha), grassland for amenity and wildlife (46 ha), and a sports turf area (3 ha). Because of its geographic location within the UK, climate is not a limiting factor for either agriculture or forestry. The only potential site limitation is gradient (table 3); whether or not gradient will be limiting will depend on the contouring of the washed and reshaped tips and lagoons. For woodland the restriction of gradient is less than for agricultural and sports amenity use. The soil physical characteristics are likely to be the principal limiting factor, largely through the degree of wetness and droughtiness of the soil profile. The former is largely a function of soil texture, structural development, and profile thickness, while droughtiness is influenced by soil texture, structural development, horizon thickness, and stoniness. The degree of wetness and droughtiness is also partly determined by the local climatic factors (MAFF 1988).

As is the case in many of the older collieries, not all of the soil materials on the site were stripped and stored for restoration before tipping the colliery wastes. Hence, there is a potential shortfall of soil material, and a need to allocate the available material to the best effect. A field survey of the soil resources on the ground and in store was undertaken, and the physical and chemical characteristics were recorded. This inventory of soil types and volumes was used as a basis for the allocation of soil material according to the preferred and required land use types and quality, and vegetation types.

Using the physical criteria, it was calculated that a soil profile with a soil moisture balance of >0 mm and a soil wetness class of I to III would be required to establish a productive, species-diverse, oak woodland typical of the locality. To achieve the above moisture balance with the minimum of soil cover over the colliery waste, and using the soil resources on site, it was calculated that 300 mm of topsoil and 400 mm of subsoil cover over a "rootable" colliery waste layer of 500 mm would be required. For soil covers of 450 and 200 mm, and for no cover, the moisture balances were calculated to be at best -34, -43, and -55 mm respectively (MAFF 1988, Meteorological Office 1989). These levels of moisture balance are typical of soils that support the relatively species-poor and unproductive birch-oak woodlands characteristic of excessively drained soils in the Midlands.

Because of the limited quantity of soil resources available (less than 80,000 m^3) and higher priority being given to a soil cover on the sports turf area and the agricultural grassland, it was decided that the woodland should be allocated little of the soil materials. Hence, it is proposed to plant a birch-dominated woodland type, which requires little or no soil cover. Locally, where a more productive and diverse woodland type is to be planted for landscape reasons, a thicker soil cover at the recommended depth will be provided.

Specifications of Treatments

The physical criteria can be used to specify treatments at restoration, particularly those relating to soils (thickness of soil layer, removal of stone, depth of decompaction). The following example concerns the effect of soil replacement and decompaction practices on soil wetness and hence, potential land quality for agriculture on the side slopes of colliery tips.

Soil wetness is a very important determinant of agricultural productivity and land quality in the UK (Humphries and Whittington 1988). It is partly determined by climate and hence location, soil texture, and depth to the uppermost slowly permeable layer (SPL). The latter can be briefly defined as a layer at least 150 mm in thickness with the upper boundary within 800 mm of the surface (MAFF 1988). Structureless soil horizons with firm strength are likely to be slowly permeable. This is also true of soils with weakly developed structure with granular, blocky, prismatic, or platy shapes and arrangements of peds or fragments and >18% clay.

Where soils are replaced by earth scrapers, they are likely to be compact and conform to the above criteria for semi permeable layers. Decompaction of the soil layer will be necessary (Bacon and Humphries 1987), and the depth of decompaction (i.e., depth to the SPL) needs to be sufficient to achieve the necessary drainage and hence degree of soil wetness, but also deep enough to provide the necessary available water capacity and hence, degree of droughtiness. For example, at Bevercotes Colliery in the Midlands, the gradient (1:12) limits the agricultural potential to category 3b (table 3). Here, decompaction to a depth of about 350 mm below the soil surface will meet the soil wetness class required by category 3b (table 5). In this case, ripping deeper would have been judged to be unnecessary.

Assessment of Restoration Achievement

The physical criteria can also be used as independent standards to determine whether restoration treatments have been successfully and fully implemented. Their use is considered to be a more sound and useful approach than vegetation-based parameters such as growth, productivity, or diversity, etc., that simply reflect the type and level of management practiced rather than the inherent structure and functioning of the restored site (Humphries et al 1984, Rowell and Humphries 1985, Humphries and Whittington 1988).

In 1984 the Land Capability Classification (Bibby 1982) was used to assess the restoration of a number of tips and lagoon banks to grassland at 26 collieries in the English Midland coalfields (Rowell and Humphries 1985). The Land Capability Classifications (LCC) is the forerunner of the MAFF system and uses similar physical criteria and categories to those listed in tables 1-5; LCC category 3 being equivalent to 3a in table 1, 4 to 3b, 5 to 4, and 6 to 5.

The objective in most of the cases was to restore site and soil conditions suitable for permanent pasture and grazing, and a grass cover to ameliorate the visual impact of the tips in the others. The LCC categories to be achieved would be 5 and 6 respectively. The categories of land use qualities identified in the field assessment are given in table 6. The limiting factors were generally a combination of gradient and/or erosion risk and stoniness and/or droughtiness. Droughtiness was generally the most constant factor owing to root growth being limited to a depth of 500 mm or less by the compaction of the colliery waste, and the sandy texture of the soils. Also, the gradient at a number of sites, and the moderate erosion risk at most, restricted the safe use of agricultural equipment.

Hence, the assessment demonstrated that the restored land at all of the collieries was shown to be LCC category 4 or 5, which was adequate for the land use quality required for the permanent pasture and more than adequate for supporting a grass cover for visual purposes. However, the restored sites are only capable of supporting stock-based farming enterprises. The land was not physically suited to arable or mixed enterprises, except for an occasional cereal (barley) break crop between resowing at some sites.

Table 6. Assessment of restoration achievement using LCC category according to climate, site, and soil limitations.

Colliery	Climate limitation	Site limitations: Gradient	Site limitations: Erosion	Soil limitations: Stoniness	Soil limitations: Droughtiness	Overall LCC category
Bilsthorpe............	1	-	4	2	4	4
Ollerton...............	1	2	2	4	5	5
Silverhill..............	1	4	2	3	4	4
Thoresby.............	1	2	2	2	4	4
Clipstone.............	1	4	2	2	5	5
Cresswell.............	1	3	1	2	4	4
Sherwood............	1	4	4	3	4	4
Harworth.............	1	3	2	2	5	5
Sutton..................	1	4	2	2	4	4
Bevercotes...........	1	4	2	3	4	4
Cridling Stubbs.....	1	1	1	2	5	5
New Fryston.........	1	3	4	1	5	5
Newmarket..........	1	3	4	4	5	5
Peckfield..............	1	2	4	1	5	5
Rothwell..............	1	5	4	4	5	5
Savile..................	1	5	4	3	5	5
Bentinck..............	1	3	4	2	4	4
Moorgreen..........	1	3	4	3	4	4
Pye Hill...............	1	3	4	4	5	5
Babington............	1	5	4	2	4	5
Hucknall..............	1	3	4	3	4	4
Arkwright............	1	4	4	1	4	4
Bolsover..............	1	4	4	3	4	4
Warsop................	1	2	2	4	4	4
Barrow................	1	4	4	1	4	4
Dodworth............	1	3	4	4	4	4

Conclusions

We have been using the above physical criteria as standards for some 6 yrs in the planning and design of restoration schemes and in specifying treatments, and for almost 10 yrs in the assessment of the achievements on restored sites. We believe the approach has been both robust and of practical benefit, and has resulted in more satisfactory and cost-effective restoration. The same criteria are now used routinely as the basis for assessing the environmental impact of developments on agriculture and forestry. As a planning and design tool it has also been accepted by industry, local government, and their statutory advisers.

The occurrence of semi natural vegetation types such as heath, mire, and bog is also influenced by similar physical criteria. At present there are no published criteria for semi natural vegetation and habitat types for wildlife and nature conservation interest in the UK. There is no reason why such criteria cannot be developed for wildlife land uses and semi natural vegetation types. Currently we are involved in developing a comparable approach for restoring and assessing semi natural vegetation and habitat types for wildlife and nature conservation (Humphries 1994).

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