TD JR105

Soil status assessment of legacy forest reclamation sites: Case studies

Project Report towards:

Reclamation Sites: Optimising organic amendments for tree growth in Central Scotland
FC Scotland contract 438
Operational guidance for the use of quality compost in forestry management
WRAP contract OMK004-021

Contents

Soil status assessment of legacy forest reclamation sites: Case studies

Summary

The case studies comprised visits to sites where trees had been planted in the 1980s on brownfield land reclaimed according to practices of the time.

The objective was to devise and test a scoping survey process for assessment of soil conditions at these 'legacy' reclamation sites and to compare results with visible tree performance over two or more decades. The studies focused on locations representing 'typical' legacy reclamation conditions in Central Scotland, although one of the seven sites was located in England.

The case studies suggest that all the sites are capable of growing apparently healthy woodland in a very shallow surface soil of 15 cm or less, including an often significant humus layer. However, crops on these sites were inherently unstable owing to shallow rooting, although structural roots may have grown deeper in any rip lines present. Therefore, the sites would still qualify for re-reclamation providing that ecological, social and other factors - including cost benefit - allow.

Laboratory analysis data alone do not always reflect actual woodland performance. The scoping surveys provided the key information necessary to assess the soil reclamation requirement of a range of formerly restored sites. Poor tree health is a good indication of reclamation requirement, assuming reasonable species choice, but apparently healthy woodland can also grow on very shallow soils.

The surveys revealed significant rooting depth deficiency. A simple but practical classification of soil forming material (SFM) was devised, based on soil consistence, stoniness and texture. A simple, very approximate assessment of bulk density of the rooting zone was also devised and worked well. A broad classification of the ground vegetation is also useful where skills are available, ideally at genus and species level.

Overall, the scoping survey has a role early in the reclamation planning process, but would need to be supplemented by a full Site Investigation should planning progress beyond scoping.

Introduction

There are a significant number of former mineral sites in Central Scotland that were reclaimed in the 1980s and planted with trees, which are now established as woodland in the landscape. Although reclamation practices the time are known to have left a degree of compaction and consequent poor rooting, tree survival, growth and health often appear to be reasonably good.

Current recommendations for reclaiming land for forestry aim to achieve good rooting depth and minimum acceptable conditions from which a soil structure can develop and further improve over time. Organic soil amendments such as green compost are recommended for use in reclamation to improve soil structure, nutrient supply, moisture retention and generally to boost the development of a healthy rooting medium to achieve woodland that is growing sustainably for the long term. However, for reasons of environment and efficiency, soil amendments should be matched to the needs of the site and the requirements of the trees to be established. There is a lack of evidence on the quantities of organic amendment that are essential, and secondly desirable, in different conditions.

This project was designed to characterise the conditions under which woodlands, established on reclaimed sites in Central Scotland, have grown over two or more decades, to highlight the potential role of organic soil amendments. This would also provide information to help develop recommendations on the optimum application rates to effectively restore typical brown-field sites for tree growth in Central Scotland.

A better understanding of appropriate application rates will support well-informed reclamation planning for damaged and impoverished soils on derelict and other brown-field land for the purpose of growing trees.

Objectives

The objective of the case studies was to characterise the soil conditions under which trees had grown, apparently successfully, over two or more decades on reclaimed land in Central Scotland, to clarify the key soil requirements.

This was achieved by devising and testing a scoping survey process for assessment of soil conditions at 'legacy' reclamation sites and comparing results with visible tree performance achieved after two or more decades.

The surveys characterised soil properties to show the importance of key soil parameters, particularly organic matter, nutrients and potential rooting depth, and thereby how cultivation with organic amendments might improve results.

Work method

The site visits were used to devise a simple scoping survey process. Soil status was determined through sampling and laboratory analysis. Amendment needs were assessed partly in the light of results of ongoing field trials using compost and AD on reclamation sites planted since 2008 in Central Scotland. These were supplemented by the assessments of the performance of established woodland surveyed on the sites.

There is a wide range of site types and it would not be possible to assess them all for organic amendment requirement within the resources available. A representative range of site types was chosen for the purposes of this study, each having characteristic soil forming materials (SFMs).

The SFMs were grouped according to origin/shared features, e.g. colliery spoil, hard rock/civil engineering wastes etc. Each group has characteristic plant nutrient content ('fertility') and, potentially also pH values (acidity/alkalinity). Organic matter content and compaction are additional important variables, but are more variable. This yielded six categories of SFM[1] **(Table 1)**.

Table 1: SFM categories for assessing organic amendment requirements

Main SFM type	Sand	Chalk	Clay	Colliery Spoil	Hard rock	Civil.Eng. Wastes
Nitrogen[1]						
Phosphorus[1]	☝		☝☝			☝☝
Potassium[1]	☝		☝			
Magnesium[1]	☝	☝☝☝Dolomite	☟	☝☝		
CEC-fertility[2]						☝
pH[3]	☝		☝-☟☟	☝☝-☟		☝☝
Associated SFM type	Gravel	Limestone	Opencast	Opencast	Slate, shale, oil shale	Aggregate

Notes: (☝) May be one or two categories higher or (☟) lower. [1] - Plant available [2] - Cation Exchange Capacity; in general, the higher the CEC, the higher the potential soil fertility (Wikipedia), although there are exceptions (Litterick, A, Pers Comm) [3] - where low is 'deficient'

Key	0 Severe deficiency	1 Moderate deficiency	1b. Slight deficiency	2 Adequate	3-7 Slight excess	8-9 Moderate excess

Sites representing the six categories of SFM were sought for physical inspection and those deemed suitable were designated for a case study survey, subject to availability and allowing for constraints of geography and cost. In this regard, a 'sand' example was not found and the 'civil engineering wastes' category subsumed into the 'hard rock' category **(Table 2)**.

[1] Adapted from Table 3.4: Soil Forming Materials: Their Use in Land Reclamation. Bending N.A.D., McRae S.G. & Moffat A.J. (1999). DETR, The Stationary Office, London.

Table 2: SFM classes represented in assessments

SFM class	Sand	Chalk	Clay	Colliery Spoil	Hard rock / C.E. Wastes
Site Visits	*No example*	√ Ferriby, East Riding	√ Bothwell Pk	√ Fauldhouse √ Loganlea √ Whitrigg √ Easton	√ Hermand (Oil shale)
Associated SFM type	Gravel	Limestone	Opencast	Opencast	Slate, shale Oil shale

Case study surveys

The purpose of the case study surveys was to provide information on the main soil characteristics relevant to tree growth, on a range of former industrial sites where trees are growing. This information, together with data published in various advisory documents[2], allows assessment of the minimum quantity of compost that is needed to support tree growth.

The information required from the survey included:

- *Soil characteristics relevant to tree growth:* potential rooting depth, organic matter and nutrient content, wetness/drainage, compaction, stoniness.
- *Basic survey information:* visual assessment of site and soil conditions, ground vegetation and trees.

Case study sites

The site visits took place in February and March 2013 and focussed on 'typical' micro-site conditions of tree growth. The method adopted, if successful, might then be justified as a scoping survey process for use in the early stages of considering sites for reclamation or re-reclamation.

Seven sites were selected for the surveys (**Table 3** and **Plates 2 - 8**), which were either previously restored sites or sites that had naturally regenerated with tree cover that had been visited previously and for which some site history was known[3].

[2] E.g. Code of Good Practice for the use of sludge, compost and other organic materials for land reclamation. Sniffer (2010)
[3] Wall, M. 2011. FCJR059, West Lothian Council, Prospects for Land Reclamation using anaerobic digestate for SRC-SRF Production: System Evaluation. FC Technical Development

Table 3. Case study survey locations and characteristics summary

Location[4] & date	Status	SFM class / Ground prep / slope	Sample / subsoil	Trees[5]	Ground Vegn
Fauldhouse, CS NS 926 600 27/2/13	Restored c1980, planted <1985	Colliery spoil Spaced plough *(ridge planted)* Level	5 cm humus & 5 cm grey shale / >10 cm compact shale	LP/SS c.30 yrs	Moss, *Juncus*, *Deschampsia cespitosa*, *Danthonia d*,
Loganlea, CS NS 977 620 27/2/13	Restored c1980, planted c1985	Colliery spoil Ripped (probably) *(flat planted)* Level	5 cm humus & 6 cm red shale / >11 cm compact shale	SP, EL (SBi, Haw, Asp, IAR, DBi) c.30 yrs	Fescue, Cr.bent, moss, *Calluna vulgaris*
Whitrigg, CS NS 968 646 27/2/13	Restored & planted c1985-90	Colliery spoil, Ripped (probably) *(flat planted)* Level	5 cm humus & 4 cm humus/shale / >9 cm compact shale	OK, Bi, AH, Asp c.25 yrs	Fescue, *D.cespitosa*, moss, *Calluna*
Easton, CS NS 960 692 27/2/13	Restored c1985-90, planted c1992	Colliery spoil, Ripped (probably) *(flat planted)* Slight slope	3.5 cm humus & 3.5 cm humus/shale 4 cm red shale / >11 cm compact shale	CP, DBi (SYC, CAR) Holly natural regeneration	Moss, *D.cespitosa*, Cr.bent, *Juncus*,
Hermand, CS NT 010 647 27/2/13	Levelled c1967-86 Natural Regen	Aged oil shale spoil, Graded - *but no forestry g. prep,* Level	2.5 cm humus & 2.5 cm red & black shale / >5 cm compact shale	SBi (DBi, SP, GWi) Natural regeneration c.23 yrs (1989)	*D.cespitosa*, Cr.bent
Ferriby, HB Country Pk, NE TA 019 261 28/2/13	Chalk quarry slope abandoned c1920-60	Aged red-brown clay with chalk *No ground prep,* On 40 deg slope	22.5 cm red-brown humic clay / >22.5 cm more compact clay	AH/SYC Natural regeneration (Haw, Yew, GWi) c.60 yrs (<90)	None in immediate vicinity. Varied herbs elsewhere
Bothwell, CS NS 717 590 13/3/13	Restored c1980	Red-brown clay over colliery spoil, Graded - *but no forestry g. prep,* Level	15 cm dark-brown humic clay / >3 cm spoil/clay	D.Bi, GWi Natural regeneration c.20-30 yrs	*Danthonia d*, Cocksfoot, vetch

Plate 2. Fauldhouse former colliery 16/3/11

Plate 3. Loganlea former colliery 27/2/13

[4] CS = Central Scotland, NE = North England
[5] SS-Sitka spruce, LP-Lodgepole pine, SP-Scots pine, CP-Corsican pine, EL-European larch, SBi-Silver birch, DBi-Downy birch, Haw-Hawthorn, AH-Ash, Asp-Aspen, CAR-Common alder, IAR-Italian alder, Syc-Sycamore, GWi-Goat willow

Plate 4. Whitrigg former colliery 27/2/13

Plate 5. Easton former colliery 27/2/13

Plate 6. Hermand oil shale bing 27/2/13

Plate 7. Ferriby, former chalk quarry 28/2/13

Plate 8. Bothwell Park 13/3/13

Owing to the limited time and funds available for the scoping surveys, they focussed on the main soil physical characteristics that affect growing trees. Trees generally have a wide tolerance of conditions within a 'normal range', for example most trees will grow in pH from mildly alkaline (pH 8) to moderately acidic (pH 5) conditions, although they will have a narrower preference within that range. The same is true for soil type, moisture content, stoniness, etc.

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Scoping survey process

The scoping survey aimed to link site conditions at a precise location to tree performance and to provide sufficient information to understand whether further reclamation was likely to be required. Ideally such an assessment might serve as a tool for early-stage 'scoping' of reclamation or re-reclamation needs, to start any necessary reclamation planning process.

The case study locations were selected according to a method designed to provide key information on suitability of soils for tree growth from historical maps, current aerial photography and a targeted assessment. An approximate location for a scoping survey comprising a soil sample and visual check of conditions at a specific 'point' was then selected.

The survey point represented a typical part of the site where trees were growing so that the conditions within which that growth was taking place, and any resulting issues of stability or health, could be determined.

Once the visit was underway, the site condition was reviewed and an exact location chosen so as to represent typical tree growth as far as could reasonably be visually determined. This was an empirical judgement. Clearly, the soil and tree growth assessment subsequently made related to the precise location and its immediate vicinity, but this should be able to be taken within reason as representative of the site. This presupposes that a pre-site visit decision is made where necessary to exclude obvious extremes from the 'site' assessment.

A soil sample was collected at each scoping survey point location using a steel core tool **(Plates 9** to **16)**. This was capable of collecting a cylinder of humus and mineral 'soil' of known volume that, together with the sample fresh weight, enabled calculation of approximate *in situ* bulk density. The soil sample represented the entire likely rooting depth, which was usually to the barrier formed by an underlying hard, compacted SFM layer at a generally shallow depth which depended on the site.

Plate 9. Fauldhouse core (Note [6])

Plate 10. Loganlea core

Plate 11. Whitrigg core

Plate 12. Easton core

Plate 13. Hermand core

Plate 14. Bothwell core

[6] Scaling, Plates 8 – 13: Bag is 22.5 cm * 35 cm. Tool cylinder is 12 cm deep (apertures - top 7.5 cm, bottom 6 cm)

Plate 15. Ferriby core - upper

Plate 16. Ferriby core - lower

The factors assessed at each scoping survey location are summarised in **Table 4**. Those indicating a requirement for reclamation are highlighted (thus).

A simple scoring system of Good (satisfactory), Medium (borderline) or Poor (unsatisfactory) is used, whereby a tendency towards a reclamation need is indicated by the key '**reclamation indicators**': tree health and present rooting factors.

A "**Medium**" classification indicates a possible need for reclamation but should be considered in the context of the site as a whole. For example, a 'medium' soil depth of 50 cm can be sufficient to support healthy woodland in some situations.

The physical character of the Soil Forming Material below the present rooting zone is **supplementary information** because it is relevant to any proposed reclamation specification. Similarly, the ground vegetation at the sample location is supplementary because it may be influenced by a wide range of factors including canopy. Vigorous, diverse vegetation on a loose, well-drained surface is a 'good' sign **(Plate 17)** and sparse, limited, checked vegetation on clearly compacted ground is 'bad' **(Plate 18)**.

Plate 17. Woodmuir former colliery 2/8/06
Complete cultivation with biosolids

Plate 18. Whitrigg former colliery 14/3/11
Graded but uncultivated spoil bing

Table 4. Factors assessed in scoping surveys & reclamation indicators

Characteristic Assessed	Reason	Categories (Reclamation Indicator)	Method
		Reclamation requirement indictors	
Tree health and growth	Key indicator of soil suitability	Good Medium Poor	Visual assessment. *Ideally record species, age, growth rate, deficiencies as supporting evidence*
Rootable depth (*including humus layer*)	Key for tree growth & stability	Good (> 50 cm) Medium (< 50 cm) Poor (< 25 cm) *Qualifiers:* Actual cm	Pit / core to compact root barrier
	Assess soil volume supplying nutrients	*Qualifiers: **H**umus layer* *And/or **T**opsoil* *And/or S**u**bsoil/SFM* *Record Actual layers in cm* ***W**ater-logging*	-do-
Rootable soil type (*simple*)	Assess mineral / organic character	Good (friable, few stones) Medium (friable, stony) Poor (stony, clayey) (/ peat) *Qualifiers: S**a**nd, **S**tony, **C**lay, **H**umus, **P**eat*	Visual assessment of pit / core
Rootable soil BD (*bulk density*)	Confirmation of rootability	Good (<1.3 g/cm^3) Medium (1.5-1.7 g/cm^3) Poor / compacted (>1.7 g/cm^3)	Weight of core volume. *Avoid stones*
Rootable soil **Status**	Determine soil quality supporting current growth (*N P K Mg, Organic matter, Bulk Density & other key characteristics*)	Good (compliant**) Medium (largely compliant) Poor (largely non-compliant)	Laboratory analysis
		Supplementary information	
Ground **vegetation** (*exclude heavily shaded ground*)	Indicates soil conditions: compaction, drainage organic matter & fertility	Good (vigorous) Medium (reasonable) Poor (sparse) *Qualifiers: **W**et, **V**aried/**U**n**v**aried, **I**ndurated*	Visual assessment. *Ideally identify main characteristic vegetation at micro-site assupporting evidence*
Soil Forming Material (*physical character below present rooting zone*)	Assess physical potential to cultivate & ameliorate	Good (potentially friable) Medium (workable) Poor (rocky, heavy clay) *Qualifiers: **S**tony, **H**eavy **C**lay, **I**ndurated*	Visual assessment of pit / core

Notes: * OM = Organic Matter ** Refers to FC Minimum standards (Appendix 3)

A **Poor** classification in **Tree Health** is a strong reclamation requirement indicator

A **Poor** classification in any of the four **Root-able soil** parameters is a strong reclamation requirement *if replacement of the existing tree cover is justified for other reasons*

Discussion

The scoping survey method is intended to be simple, so it inevitably involves professional judgement based on varied, inter-related visual evidence, considered as a whole rather than independently. This requires professional skills.

The method, as currently outlined, will not cover some less common site types, although such sites would probably not be reclamation candidates for ecological or other reasons. However, the process could be adjusted to suit.

The scoping survey should also take account of the influence of ecological, social and landscape factors on the reclamation requirement of a site. For example, healthy but slow growing community woodland already satisfying its objectives probably would not be a reclamation candidate. Similarly, an infertile, compacted site supporting a priority acid heathland habitat may have a greater overall benefit if left untouched. A priority habitat should be protected as a SSSI or similar.

Following a Scoping Survey, the reclamation planning process, if initiated, would then involve a more detailed site assessment, including mapping and sampling of soil conditions across the site. An example of a detailed site assessment specification is at **Appendix 1**. In cases where chemical contamination or physical features such as mineshafts are known or expected to pose a health and safety risk, then a bespoke Site Investigation should be discussed with a suitable specialist minerals agency that could include the soil survey and other features of the site assessment.

Scoping survey results

The results of the soil sampling are given in **Appendix 2** and the individual Scoping Survey scores are shown in **Table 5**.

The results of the scoping survey suggest that **all the sites are capable of growing apparently healthy woodland** in a very shallow surface soil **(Plates 19 and 20)**.

Plate 19. Whitrigg core location

Plate 20. Easton core location

The growth achieved was despite a lack of phosphate. In most cases the root-able soil comprised a relatively significant accumulated humus layer and loose mineral spoil or clay.

However, **all sites had poor root-able depth** with six of the seven sites having 15 cm or less, including an often significant humus layer, although structural roots may have grown deeper in any rip lines present.

Table 5. Scoping survey results summary

Site	Key Reclamation Requirement Indicator					Supplementary	
	Tree health	Root-able Soil				SFM (physical)	Veg'n
		Depth	Type	BD[7]	Analysis*		
Fauldhouse *Restored colliery spoil*	Good	Poor H 5 cm U 5 cm	Medium S H	Good	Pass [Except P]	Medium S I	Medium Uv
Loganlea *Restored colliery spoil*	Good	Poor H 5 cm U 6 cm	Medium S H	Good	Pass [Except P]	Poor S I	Medium Uv
Whitrigg *Restored colliery spoil*	Good	Poor H 5 cm H/U 4 cm	Medium S H	Good	Pass [Except P]	Poor S I	Medium Uv
Easton *Restored colliery spoil*	Good / Medium	Poor H 3.5 cm H/U3.5 U 4 cm	Medium S H	Medium	Pass	Poor S I	Medium Uv
Hermand *Aged oil shale spoil*	Good	Poor H 2.5 cm U 2.5 cm	Medium S H	Good	Pass [Except P]	Poor S I	Medium Uv
Ferriby *Aged chalk quarry clay*	Good	Poor U 22.5 cm	Good C	Medium (Poor lower)	Fail on [pH, P, OM & BD]	Poor HC	Good V
Bothwell Park *Restored clay/colliery spoil*	Good	Poor H/U 15 cm	Medium C	Medium	Pass [Except P]	Poor HC	Medium Uv
Colour coding	Poor	Medium	Good				

Note: * Compared to FC minimum Standard (Appendix 3). Excludes C:N ratio because this is obscured by coal fragments within the sample
Note: H, U, S, H, C, SI, HC, Uv, V - Reclamation indictors - see Table 4.

A soil depth of less than 50 cm is unlikely to support long term tree stability and is clearly well below the 1m FC guide depth **(Appendix 3)**.

Therefore, on the basis of the physical characteristics surveyed, the case study sites **would qualify for re-reclamation** providing that ecological, social and other factors - including cost benefit - allow.

However, the results illustrate the difficulties in making judgements based only on figures. All sites are growing reasonably healthy woodland, and the one site that fails

[7] Bulk density - approximate value based on fresh weight and core volume extracted. FC Minimum standards <1.5 g cm^{-3} to at least 50 cm depth & <1.7 g cm^{-3} to below 1 m depth

to meet the guidelines on pH, Organic Matter and (marginally) Bulk Density is the site supporting the largest broadleaved trees. This site, Ferriby, appeared on visiting to be the least in need of reclamation and is in fact a Local Nature Reserve.

The characteristics assessed in the Scoping Surveys had different correlations with the resulting reclamation requirement conclusions as follows:

Tree health
Woodland of 20 to 30 years of age was growing reasonably well on all sites, although there were occasional signs of poor stability due to shallow rooting depth and, in one isolated instance at Easton, obvious slow growth and nutrient deficiency.

Poor tree health can clearly be regarded as a good indication of reclamation requirement (assuming reasonable species choice), but apparently healthy woodland can also grow on very shallow soils.

Root-able soil
Depth: the rooting depth assessment was simple using trowel, spade or corer.

The simple technique quickly revealed significant rooting depth deficiency on all sites, most of which had been restored, in the 1980s.

Type: A simple assessment of broad soil type was straightforward.

The simple classification, based on soil consistence (loose, friable, firm), stoniness and texture (sand/silt/clay content) was practical and likely to be relevant to reclamation planning.

Bulk Density: The rooting zone on all sites was within, or very close to, the minimum standard for the 50 cm surface layer fresh, *in situ*, of 1.5 g / cm^3, although in several cases this also included a humus layer and the simple surface core assessment method likely to be approximate.

A simple, approximate assessment of bulk density of the rooting zone was feasible and readily combined with collection of a laboratory sample.

Status: Soil sample laboratory analysis enabled a simple comparison with the minimum standards and most sites passed all but the extractable Phosphorus test.

The one site that failed in respect of status (on pH, C:N ratio, P, OM and BD) also had by far the lowest Nitrogen level, was also perfectly healthy, and growing the largest broadleaved trees which were also apparently stable.

Care is needed when interpreting laboratory sample figures because they may not reflect woodland performance on site.

Laboratory data for total nitrogen on the previously restored wooded sites visited, varied considerably and appeared poorly correlated, if at all, with woodland performance.

Much of the total nitrogen in samples containing coal or shale fragments will be “fossil” nitrogen in rock and therefore not plant available. This would explain much of the poor correlation with woodland performance.

Underlying SFM

A simple visual and trowel based assessment will indicate the physical nature of the material **(Plate 21)** that would need to be cultivated to improve the rooting zone, especially its compaction, stone and clay content and organic matter status. The depth to a very compacted or very waterlogged layer indicates the present potential rooting depth and hence the amount of material that needs to be improved to increase the rooting depth to the 100 cm or more regarded as ideal for most tree species.

Plate 21. Halside former steelworks – shallow, stony but moderately vigorous ground cover

A broad classification of the underlying SFM is readily obtained on most sites and is useful scoping information.

Ground Vegetation

The broad categories of vegetation based on vigour and diversity, although simple to apply, were potentially very dependent on light levels and therefore tree species, age and vigour. Ground vegetation is potentially very revealing of soil conditions but its assessment in the field requires a high degree of skill in plant identification. Ground vegetation information at genus or species level is likely to be useful supplementary information for those with the necessary skills, but is not crucial for the Scoping Survey itself.

A broad classification of the ground vegetation is readily obtained on most sites and may be moderately useful scoping information but, where skills are available, identification at genus or species level is likely to yield more useful information.

Conclusions

The case study scoping surveys provided the key information necessary to assess the soil reclamation requirement of a range of formerly restored sites. A similar technique based on a few, pivotal and readily assessed key characteristics could be used for un-restored open ground.

The **results** suggest that:

- all the sites are capable of growing **apparently healthy woodland** in a very shallow surface soil.
- All sites had **very limited root-able depth** with six of the seven sites having 15 cm or less, including an often significant humus layer, although structural roots may have grown deeper in any rip lines present.
- On the basis of the physical characteristics surveyed, the sites would qualify for **re-reclamation** providing that ecological, social and other factors - including cost benefit - allow.

The factors included in the scoping survey revealed **key issues** related to reclamation and were relatively easy to assess:

- **Poor tree health** can clearly be regarded as a good indication of reclamation requirement (assuming reasonable species choice), but apparently healthy woodland can also grow on very shallow soils.
- The simple technique quickly revealed significant **rooting depth** deficiency on all sites, most of which had been restored, in the 1980s.
- The simple **soil classification**, based on consistence, stoniness and texture was practical and relevant to reclamation planning.
- A simple, and probably very approximate, assessment of **bulk density** of the rooting zone was feasible and readily combined with collection of a laboratory sample.
- Care is needed when interpreting **laboratory sample** figures because they may not reflect woodland performance on site.
- Laboratory figures for **total nitrogen** (as a percent of laboratory sample) on the previously restored wooded sites varied considerably and were poorly correlated with woodland performance, possibly due to "fossil" nitrogen in geological material.

- o Nevertheless, a broad classification of the **underlying SFM** is readily obtained on most sites and is useful scoping information.

- o A broad classification of the **ground vegetation** is readily obtained on most sites and may be moderately useful scoping information but, where skills are available, identification at genus or species level is likely to yield more useful information.

- o The **Scoping Survey** provides a firm basis on which subsequent investigation can be based and therefore have a role in the early stage reclamation planning process.

- o The case studies and coping survey would **need to be supplemented** by a full Site Investigation if planning progresses beyond scoping.

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Appendix 1

Example Site assessment protocol to determine site suitability for tree growth and potential need for amelioration

<u>Site characteristics</u>
History: previous use(s), how long has site been in the present form
Location: relation to surroundings, distance to nearby housing, farmland, woodland, drainage courses, etc.
Type of site: spoil heap, landfill, demolition site, quarry, etc
Ground conditions: loose tipped, graded by bulldozer, landscaped, ploughed, drained, etc
Type of material: topsoil, subsoil, mainly sandy/gritty/gravelly/stony, clay, shale spoil, slag, quarry waste, organic material
Landform and slopes: steep on conical coal bings, undulating, fairly level, or a combination such as steep sides with flat top etc.

<u>Existing vegetation</u>
Ground cover: % Vegetation cover/% bare ground
Dominant vegetation types: grass-dominated, marshy, shrubs, small trees, large trees, etc
Trees: existing tree species & growth/health & trees naturally colonized or planted.

<u>Soil characteristics</u>
Horizons: identify horizontal layers in the soil with distinctly different colour and/or material
For each horizon record - colour, texture, stoniness (visual estimate of volume), presence of roots and earthworms
Other factors: soil drainage, compaction and depth at which it occurs, potential tree rooting depth - this could be limited by compacted or other impermeable/hard layer, water table, landfill cap etc.

<u>Soil sampling for analysis</u>
Number and location of samples: these should be representative of the site and soil forming materials; as a guide, 3 samples per hectare or per specific soil forming material would be a minimum. Each sample should be a composite of 5 sub-samples. The sample depth should be 5 to 15 cm in profiles with no significant horizon development. If two or more distinct horizons of significant thickness are present, they should be sampled separately.

Analysis: pH in water; organic matter (by loss on ignition); total nitrogen; extractable phosphorus, potassium, magnesium. Analytical results to be assessed by comparison with published guidelines.

Use analytical data to calculate existing content of plant nutrients in soil forming material, adjusting for bulk density and stone content if necessary to give kg of nutrient per hectare to rooting depth (e.g. 30 cm).

N.B. Coal and coal shale contain carbon and nitrogen that is not available to plants and is sometimes referred to as “fossil” C or N. Samples taken from coal mine spoil heaps and some other sites can contain varying amounts of coal or shale and the analytical techniques used will not distinguish between fossil and non-fossil sources. The results can therefore be over-estimated and this should be taken into account.

On some sites the soil forming material may need to be analysed for potentially toxic elements and/or other chemical parameters, but this would require expert advice. Such sites would most likely be determined when assessing the site characteristics, i.e. from site history and field observations.

Assessment of site suitability for trees

A site can be assigned to one of the following four categories of suitability for tree establishment as a further aid to overall site assessment. In each category the site could be limited by one or more of the factors. In Class 1 little or no intervention would be required to achieve good tree growth and young stock could be planted directly into the ground. In classes 2 to 4 there are increasing limitations and amelioration required. This classification does not take account of factors such as the need for rabbit or deer fencing, fire protection etc., or the availability of machinery.

Class 1: High suitability – very good vegetation cover over all or most of site; healthy plants and trees; no or few restrictions to access and potential management operations; very good or good soil conditions and potential tree rooting depth; little or no need for amelioration/intervention

Class 2: Moderate suitability – good vegetation cover but some areas with poor cover; generally healthy plants and trees but some areas showing stress or poor growth/health; some restrictions on access/management due to steep slopes, obstacles, landform, etc; adequate soil conditions and potential tree rooting depth, may be sub-optimal in some areas; some areas could benefit from amelioration/intervention depending on cost/benefit analysis.

Class 3: Low suitability – generally low vegetation cover, although some areas may be good; generally poor growth and health of plants and trees, some indications of stress, nutrient deficiency, disease, etc; access and management restricted by very steep slopes, unstable ground, etc; generally poor or sub-optimal soil conditions and potential tree rooting depth; amelioration is essential and may include ground works (e.g. re-grading, drainage, de-compaction, etc), and the application of amendments such as compost and/or fertilizer.

Class 4: Very low suitability – very little vegetation cover; good growth only in some tolerant plant species; severe restrictions to access/management; very poor soil conditions (e.g. very high stone content, severe compaction at surface, very low or high pH, very low plant nutrient content, excessive toxic element content, etc.); amelioration is essential but will be costly and difficult.

Assessment of compost application rate

Use overall site assessment, including analytical results, to determine required application rate of compost.

Main benefit is organic matter content acting as a soil improver. Slow release nutrients an added bonus. Nitrogen and phosphorus content are the limiting factors for compost application rates.

Andrew Hipkin, Soil Consultant, 21st March 2013

Appendix 2

Scoping survey soil sample results

Parameter	Target	Fauld-house	Loganlea	Whitrigg	Easton	Hermand	Ferriby	Bothwell Park
pH	4.0 - 8.0	4.8	6.3	5.8	5.4	6.2	8.5	7.8
Stone>2mm (% v/v)	< 40%	20%	27%	40%	30%	25%	12%	23%
N Total (%)	~ > 0.08%[1]	0.28%	0.33%	0.51%	0.20%	0.27%	0.05%	0.26%
C Total	n/a	11%	6%	10%	7%	6%	4%	7%
C:N Ratio	<25:1[2]	40	17	20	36	22	38	26
P avail (mg/kg)	[DEFRA 2]	7 [0]	7 [0]	9 [0]	61 [5]	9 [0]	3 [0]	3 [0]
K avail(mg/kg)	[DEFRA 2]	115 [2]	211 [2]	319 [3]	118 [2]	656 [4]	118 [2]	122 [2]
Mg avail (mg/kg)	[DEFRA 1]	228 [4]	578 [6]	241 [4]	236 [5]	263 [4]	74 [3]	300 [6]
OM (LOI) (%)	>10%##	19%	10%	17%	12%	10%	3%	11%
B.D. loose (g/cc)	<1.5	1.4	1.1	1.2	1.5	1.2	1.6	1.5
FC Guideline[1]	Pass Fail	Restored Colliery Spoil	Restored Colliery Spoil	Restored Colliery Spoil	Restored Colliery Spoil	Aged oil shale spoil	Aged chalk quarry clay	Restored clay / colliery spoil

Note:
[1] The relationship of the %N in the soil sample to the FC Guideline target of 1,500 kg N / ha is dependant on site soil moisture content (m.c.), bulk density (B.D.), stone content by volume (s.c.) and depth of soil used for rooting. For high values of 50% m.c. (w.b.), 1.5 g/cc (B.D.), 40% (s.c.) and 50 cm rooting depth, 1,500 kg N is roughly equivalent to 0.08% N in the lab sample. Lower figures will reduce this.
[2] Not representative if coal is present
[3] OM also affected by coal content. Ferriby affected by carbonate content.

Appendix 3

Minimum standards for soil forming materials acceptable for woodland establishment[8]

Parameter	Standard	Comments on method
Texture	No limitations; however, the placement location of materials of different texture on site should be related to site factors e.g. topography	Texture (% sand, silt and clay) should be determined by pipette method. Preferably > 25% clay
Bulk density (after placement)	<1.5 g cm-3 to at least 50 cm depth <1.7 g cm-3 to below 1 m depth	
Stoniness: Clay or loam	<40% by volume of material > 2 mm in diameter and <10 % by volume of material > 100 mm in diameter	Measure mass of stone >2 mm and >100 mm in a known mass / volume of soil; divide each value by 1.65 to calculate the volume
Stoniness: Sand	<25% by volume of material greater than 2 mm in diameter and <10 % by volume of material greater than 100 mm in diameter	
pH	Within the range 4.0 to 8.0	Based on a 1:2.5 soil: $CaCl_2$ (0.01 M) suspension
Electrical conductivity	<0.2 S m-1	Based on a 1:1 soil:water suspension
Iron pyrite content	<0.05 %	British Standard 1016
Topsoil nutrient and organic matter content	N >1500 kg N ha-1 (See footnote) P >16 mg l-1 (ADAS Index 2) K >121 mg l-1 (ADAS Index 2) Mg >51mg l-1 (ADAS Index 1) Organic matter content >10%	Standard ADAS methods
Specific metal and organic contaminants	These should fall between the Soil Guideline Values (DEFRA and EA, 2002) for residential without plant uptake and industrial / commercial, where no SGVs are available acceptable limits should be derived using a risk based approach for human health. Levels of copper and zinc should not exceed 130 or 300 mg kg-1 respectively.	Determination according to substance using a method comparable with the Soil Guideline Values being used. Approval should be sought from Forest Research on the guideline concentrations being used before soil placement begins.

[8] Foot K. & Sinnett D., (2006). Best Practice Guidance for Land Regeneration. BPG Note 5. Imported Soil or Soil Forming Materials Placement. Forestry Commission.