Scottish Forestry
Coilltearachd na h-Alba

Cultivation for upland productive woodland creation sites

Applicant's Guidance

Contents

Scottish Forestry is the Scottish Government agency responsible for forestry policy, support and regulation. We are committed to promoting sustainable forest management across Scotland through policy, advice, regulation and grant aid in accordance with the UK Forestry Standard (UKFS).

The UKFS is the reference standard for sustainable forest management in the UK. It outlines the context for forestry, sets out the approach of the UK governments to sustainable forest management, defines standards and requirements and provides a basis for regulation and monitoring.

In order to comply with the UKFS, woodland creation projects need to carefully consider and reduce potential environmental risks, including those associated with cultivation. This guidance explains how this can be done through the choice of cultivation techniques and mitigation measures.

In the context of this guidance a 'woodland creation application' is considered as being:

- An application for grant support to create a new woodland;
- A Screening Opinion request to comply with The Forestry (Environmental Impact Assessment) (Scotland) Regulations 2017 for afforestation; or
- An application seeking Scottish Forestry approval for a woodland compensatory planting scheme required as a condition of a planning permission.

Introduction

The aim of this guidance is to support forestry practitioners in making decisions about what cultivation techniques to use for upland productive woodland creation sites. It provides a framework for discussion at planning stage, to ensure reasoned and appropriate choices for cultivation are made based on the site's soil type(s) and related characteristics and in the context of long-term management objectives. Applying this guidance will help ensure that cultivation operations comply with UKFS requirements and guidelines on water and soils.

Though FC Bulletin 119 'Cultivation of Soils for Forestry', 1999 remains a valuable source of reference for silvicultural advice, to reflect the current regulatory environment in Scotland in relation to water and recent scientific advice on soil disturbance and soil carbon loss, this guidance now takes precedence when selecting the most appropriate cultivation technique for woodland creation.

The more intensive methods of linear cultivation discussed in this guidance are not appropriate for creating native woodlands. When deciding the most appropriate technique for these types of woodland reference should also be made to FC Bulletin 112 'Creating New Native Woodlands', 1994

Cultivation is intended to increase initial tree survival rates and allow faster establishment. However, its impact on the tree will always be temporary so species must be chosen which are suitable for the site's abiotic conditions (temperature, windiness, moisture etc.), notwithstanding those changes that can be affected by drainage. Choosing species and cultivation techniques appropriate to the site will help deliver long-term management objectives and the relevant requirements of the UKFS.

Although certain cultivation techniques may improve drainage around the tree by creating an elevated planting position, they do not solve problems with waterlogging across the site in the long term. Cultivation techniques should not be used to manage excess water, instead an integrated drainage system should be put in place at the same time or immediately after cultivation.

The UKFS requires that soil and water are protected from the potential adverse effects of cultivation operations. Without appropriate design and/or mitigation measures, cultivation can have a range of undesirable and potentially detrimental effects, including:

- Enhanced weed growth.
- Water pollution caused by increased sediment runoff and the leaching of nutrients and contaminants.
- Damaged soil structure and increased risk of windblow, erosion or landslip.
- Greenhouse gas release through oxidation of soil organic matter.

The least intensive cultivation method possible should be used to successfully establish woodland.

Using this guidance

This guidance sets out the advantages and risks of cultivation techniques commonly used for productive woodland creation in upland areas. It offers a six-step process to identify the most appropriate techniques for establishing a woodland that must be resilient under the likely changing climatic conditions of the 21st century:

- **Step 1** •Identify the soil type(s) and choose appropriate tree species
- **Step 2** •Consider if cultivation is needed at all
- **Step 3** •Determine the soil-based objectives for cultivation
- **Step 4** •Identify technique(s) that will achieve those objectives
- **Step 5** •Choose the technique(s) that will have the lowest overall negative impact
- **Step 6** •Prepare the woodland creation plan

Step 1: Identify the soil type(s) and choose appropriate tree species
Site amelioration techniques such as intensive drainage or fertilisation can alter soil properties so that they are favourable for different species, but climatic constraints cannot be overcome. Only a site-orientated approach to tree species selection will allow sustainable forest management to be practiced and the UKFS to be implemented.

Identifying the extent and distribution of different soil types within the site is important to determine whether more than one technique will be required, or one technique with modifications. Wherever practicable different conditions on site should be addressed by employing different techniques or modifications.

Soil type(s) and phases should be identified from a site-based soil survey. Guidance on collecting soil data for a woodland creation proposal can be found in the FC field guide 'The Identification of Soils for Forest Management' FC Bulletin 124 'Ecological Site Classification', 2001 ESC Field Survey Pack and related online videos.

Ideally a survey should also identify soil texture and particle size (as this determines soil behaviour in relation to drainage and load-bearing capacity) and vegetation.

Soil texture can influence the choice of cultivation technique or machine used in these ways:

- Clay soils are very sensitive to compaction so soil disturbance and machine movements should be minimised. Cultivation features such as mounds, trenches and plough lines are likely to persist for a long time and affect future forest operations. Disturbance can also act as a source of pollution through siltation of watercourses.
- Loamy soils are also sensitive to compaction and are often easily eroded by water, risking siltation of watercourses. Cultivation features may persist, so soil disturbance should be minimised unless required because an ironpan or humus layer[1] is present.
- Sandy soils are often easily eroded by water and wind, and liable to desiccation.

All applications must use the FC soil classification system. A table which converts the Soil Survey of Scotland classification into the FC classification is available on the Forest & Woodlands page of the Scotland's Soils website.

Data from the soil survey and vegetation indicator species should then be inputted to the Ecological Site Classification Decision Support System (ESC) to assess the soil nutrient, moisture and climatic regimes of a site. This will help identify which tree species are ecologically suited to the site. Under the UKFS the species mix and the methods of cultivation used to establish them must be appropriate to the site's soil type.

Having selected an appropriate species mix and site layout – 'appropriate' meaning one where young trees are likely to survive as woodland at the required stocking density and deliver the stated management objectives - proceed to Step 2.

Step 2: Consider if cultivation is needed at all

Cultivation should only be used where it is clearly demonstrated to be the most effective means of providing a favourable environment for tree survival and early growth.

Tree roots need particular resources from the soil:

1. **Warmth** - Root activity tends not to occur below 5°C.
2. **Air** - Low oxygen concentrations in the subsoil can restrict rooting.
3. **Water** - Species will differ in their tolerance of waterlogged soils - cultivation of dry soils may be detrimental.
4. **Suitable density for rooting development** - "*Tree roots will not penetrate soil horizons with bulk density in excess of 1.0 - 1.6 g cm^3 in coarse textured soils (Faulkner and Malcolm, 1972; Prevost, 1992) or 1.2 g cm^3 in fine textured soil. The limitations on rooting depth due to dense horizons will restrict tree growth and anchorage*." FC Bulletin 119.

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[1] A humus layer contains >70% fine organic matter (ignoring roots) in which plant structures are generally not recognisable. Reddish brown to black in colour, fairly homogenous in appearance. Mineral grains may be present. This horizon is distinguished from peat by being formed in conditions that are not saturated with water for more than 6 months of the year. *FC Bulletin 124 – Appendix 2 Classification of humus forms.*

5. **Nutrients** - If the above are favourable then root growth should be expected, though trees also rely on mycorrhizal fungi for nutrient uptake.

Cultivation of some soils can have a negligible or even detrimental effect and should be avoided on the soil types listed in Table 1 (below).

Table 1 – Soils on which cultivation is not advised

Soil type	Why cultivation is not recommended
Some relatively fertile brown earth and cultivated gley soils	Existing soil conditions are good, so extensive cultivation is likely to promote weed growth and increase competition for nutrients and moisture
Calcareous soils over chalk or limestone	Soil mixing likely to increase the soil's alkalinity and exacerbate nutrient deficiencies
Skeletal soils	Negligible potential for improving soil conditions. Loosening could promote soil movement/slip and erosion on steeper slopes
Littoral soils	Limited potential for improving soil conditions
Some man-made soils	Loose soils unlikely to benefit from cultivation, while cultivation on some brownfield sites could release contaminants
Bogs (peat >50 cm)	Woodland creation not permitted due to risk of carbon loss

Where cultivation is not recommended, seek advice on vegetation management from the resources at Forestry & Water Scotland and Forest Research.

If it is clear that cultivation is needed to aid tree survival and growth, move to Step 3.

Step 3: Determine the soil-based objectives for cultivation

Once it is clear what the site's soil type(s) is and that cultivation of some form is needed, the next step is to identify which growth-limiting soil characteristics need to be addressed for the proposed woodland to grow well.

Note, some high impact forestry practices used in the past to significantly alter site characteristics, such as very deep ploughing, extensive drainage and intensive fertiliser regimes are no longer acceptable or consistent with modern sustainable forestry management standards. In practice this means it is important to select species that are suitable to the underlying site characteristics. In certain circumstances this will mean that some areas are not suitable for tree planting.

Making good cultivation decisions that address the soil's characteristics will set the context for how the woodland will be managed through to harvesting rather than just focusing on a five-year establishment plan.

Use Table 2 (below) and your data on the site's soil properties to identify which soil characteristics might affect growth and consequently the objectives for cultivation.

Table 2 – Soil characteristics that help identify objectives for cultivation

Soil type	Typical brown earth	Podzol/ podzolic brown earth	Ironpan	Gleys (non-peaty)	Peaty gley	Rankers (13b, 13g, 13p, 13z)
Soil properties	Free draining, wide range of textures. Little or no surface humus.	Free draining, aerated, acidic soil. Generally sandy texture. Often humus at surface.	Fine-textured podzolic soil with thin cemented layer of clays and metal oxides.	Waterlogged, variably textured soils.	Waterlogged, variably textured soils with surface peat layer of 5 to 50 cm.	Shallow versions of the main soil types, less than 30cm deep over bedrock or induration.
Soil Moisture Regime	Slightly Dry to Moist	Moderately Dry to Fresh	Fresh to Moist	Moist to Wet	Moist to Very Wet	Very Dry to Very Wet
Soil Nutrient Regime	Poor to Very Rich	Podzol Very Poor. Podzolic brown earth Very Poor to Poor	Very Poor to Poor	Poor to Very Rich	Very Poor to Very Rich	Very Poor
Soil factors limiting tree growth	Brown earths with medium to very rich SNR can have aggressive weed competition for nutrients and moisture. Can erode easily on exposed slopes, especially if a high humus or silt content.	Poor fertility because metal oxides have washed down from topsoil into subsoil. Sandy texture means risk of desiccation. Can erode easily on slopes if exposed. Vegetation likely to be heather, which makes planting difficult.	Root growth may be compromised by the ironpan. Anaerobic waterlogged conditions may arise if the downward movement of water is stopped by the pan. Poor fertility.	Waterlogged topsoil creates anaerobic conditions in topsoil and subsoil. Gleys with medium to very rich SNR can have aggressive weed competition. Gleys with poor SNR will have poor fertility. Can erode on exposed slopes, especially if a high humus or silt content.	Waterlogged topsoil creates anaerobic conditions in peaty topsoil and mineral subsoil. Imbalanced nutrient supply between peat and mineral soil can restrict rooting to the peat layer. Peaty gleys with medium to very rich SNR can have aggressive weed competition. Those with poor to very poor SNR have poor fertility. Can erode on exposed slopes, especially if a high humus or silt content.	Erosion after disturbance very likely on such shallow soils. Very poor fertility. Root growth affected by shallow soil depth and potential waterlogging.
Objectives for cultivation	Where needed, create weed-free planting position. Minimal soil disturbance.	Remove heather. Mix soil to improve soil fertility / nutrient availability. Minimal soil disturbance.	If it is within reach - break the iron pan immediately below the planting position to improve drainage and facilitate rooting. Mix soil to improve soil fertility / nutrient availability. Minimal soil disturbance.	Manage soil wetness and waterlogging from the water table. Where needed, create weed-free planting position. Where needed, mix soil to improve soil fertility / nutrient availability. Minimal soil disturbance.	Manage soil wetness and waterlogging from the water table. Mix soil to improve soil fertility / nutrient availability. Where needed, create weed-free planting position. Minimal soil disturbance.	Mix soil to improve soil fertility / nutrient availability. Reduce potential for waterlogging. Minimal soil disturbance.

Note that the information in Table 2 is necessarily simplified - greater detail on these matters can be found in FC Bulletin 119, for example, on the relationship between cultivation and soil temperature.

Step 4: Identify techniques that will achieve those objectives

The bottom row of Table 2 (above) suggests what the cultivation objectives for the site might be, given the soil's characteristics. Applying this information to Table 3 (below) will help identify which techniques will achieve those objectives.

If there is more than one kind of soil on the site, more than one technique, or adjustments such as a change of tool or setting, might be needed. Excavators will be more versatile in these conditions.

Table 3 – Capability of different cultivation techniques

Technique	Capability for cultivation objective(s)			
	Reduce weed competition for nutrients and moisture	Mix soil to improve fertility or nutrient availability	Reduce or break deep pan or induration >30cm	Create drained planting position (short-term effect)
Manual screefing	Y	N	N	N
Sub-soiling aka ripping or tining*	N	Very limited	Y	Depends on soil type
Patch scarification using excavator	Y	N	N	N
Inverted mounding	Y	Y	Y	Y
Hinge mounding	Y	Y	Limited	Y
Patch scarification using scarifier aka continuous mounding	Y	Y	N	Depends on depth scarification tool is set
Trench mounding*	Y	Limited	N	Y
Rotary (helix) ploughing*	Y	Depends on soil type	N	Y
Line scarification using disc scarifier*	Y	Y	N	N
Shallow ploughing ≤30cm*	Y	Depends on soil type	N	Y

*** Techniques that involve linear cultivation may result in enhanced run-off. Before deciding if they are appropriate to use, consider the characteristics of the soil type, the caveats of use and the necessary mitigation measures (described in the main text and appendix sheets).**

Y = Yes, achieves the objective. N = No, does not achieve objective and may exacerbate the problem.

Step 5: Choose the technique(s) that will have the lowest overall negative impact
Once you have identified which techniques deliver the cultivation objective(s), the technique(s) chosen should aim to cause the least soil disturbance possible to secure long-term management objectives, particularly on organo-mineral soils[2].

It is increasingly important to consider the influence of climate change on whether a cultivation technique could create a negative overall impact. Projected changes in the frequency and strength of rainfall, drought and wind mean a greater potential risk of soil erosion, soil desiccation and windblow.

Use Table 4 and 5 (below) and Appendix 1 to select the cultivation technique(s) which after mitigation will have the lowest overall impact on the forest and wider environment.

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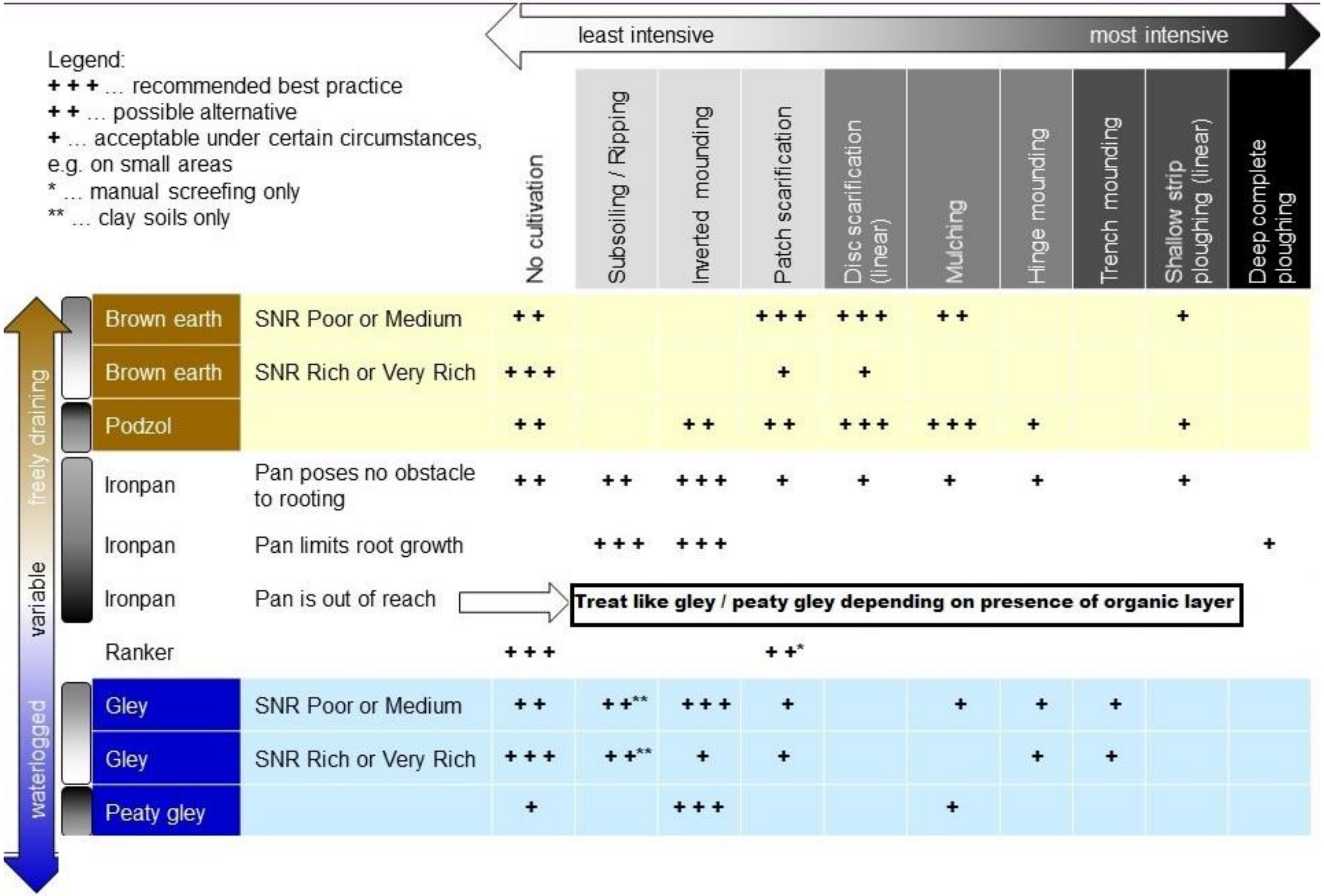
[2] The FC Soil Classification System classifies organo-mineral soils as having an organic layer that can vary from 5cm up to 45cm in depth, depending on soil type. These can include humus-iron podzols, peaty podzols, surface and ground water peaty gleys, peaty rankers and podzolic rankers.

Table 4 – Forest soils and ground preparation[3]



Legend:
+ + + … recommended best practice
+ + … possible alternative
+ … acceptable under certain circumstances, e.g. on small areas
* … manual screefing only
** … clay soils only

		No cultivation	Subsoiling / Ripping	Inverted mounding	Patch scarification	Disc scarification (linear)	Mulching	Hinge mounding	Trench mounding	Shallow strip ploughing (linear)	Deep complete ploughing
Brown earth	SNR Poor or Medium	+ +			+ + +	+ + +	+ +			+	
Brown earth	SNR Rich or Very Rich	+ + +			+	+					
Podzol		+ +		+ +	+ +	+ + +	+ + +	+		+	
Ironpan	Pan poses no obstacle to rooting	+ +	+ +	+ + +	+	+	+	+		+	
Ironpan	Pan limits root growth		+ + +	+ + +							+
Ironpan	Pan is out of reach →		**Treat like gley / peaty gley depending on presence of organic layer**								
Ranker		+ + +			+ +*						
Gley	SNR Poor or Medium	+ +	+ +**	+ + +	+		+	+	+		
Gley	SNR Rich or Very Rich	+ + +	+ +**	+	+			+	+		
Peaty gley		+		+ + +			+				

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[3] Table 4 produced by Dr Jens Haufe, Technical Development - Forest Research.

Table 5 – Caveats of use

Technique	Environmental constraint			
	Soil Carbon Can be used on soils with a peat depth layer up to 50 cm?	**Water Management**		**Forest Stability** Can be used on sites with DAMS score ≥ 16?
		Can be used within UKFS buffer areas?	Can be used on moderate or steep slopes?	
Manual screefing	Y	Y	Y	Y
Sub-soiling aka ripping or tining	Y	N	N*	Y
Patch scarification using excavator	Y	N	Y	Y
Inverted mounding	Y	Y	Y	Y
Hinge mounding	Y	Y	Y	Y
Patch scarification using scarifier aka continuous mounding	Y	N	Y	Y
Trench mounding	N**	N	Y	Y
Rotary (helix) ploughing	N	N	N*	N***
Line scarification using disc scarifier	N	N	N*	N***
Shallow ploughing	N	N	N*	N***

*** May be acceptable on moderate slopes where detailed analysis has established soil erosion risk is low and appropriate mitigation and controls are deployed.**

**** Where an integrated drainage system is put in place drain spoil may be used for mound formation on condition drain intensity does not exceed the minimum level required for successful site establishment.**

***** May be acceptable where additional mitigation measures are incorporated within forest design, see Appendix 3 Guidance Rationale – Forest stability.**

Step 6: Prepare the woodland creation plan

Once a suitable cultivation technique(s) and the associated constraints, impacts and relevant mitigation measures have been identified, the woodland creation plan can be prepared. It should demonstrate that the chosen technique – or multiple techniques / modifications on a single site - are the most appropriate for the site's conditions. Include the relevant data and ensure that it is accurate.

Explain how the technique will be applied on the ground and what specific mitigation measures will be used.

Applications that propose using linear cultivation techniques must provide a ground preparation method statement which demonstrates that any potential negative impacts have been considered, specify how the technique will be used on the ground and what mitigation measures will be used.

Make sure the measures are realistic and achievable – it is the forest manager's responsibility to ensure plans and measures are implemented effectively.

Applications which propose cultivation techniques that risk an unacceptable impact on the local site and provide no additional benefits compared to a less intensive technique are unlikely to be approved.

Appendix 1 – Technique sheets

These Technique sheets present information relevant to assessing the risk of soil disturbance, technical constraints, potential negative impacts and typical mitigation measures for each of the 11 cultivation techniques introduced in Table 3.

The silvicultural benefits of each technique in relation to individual soil type are discussed in greater detail in Bulletin 119.

Manual screefing

Removal of vegetation using a spade or mattock to achieve weed suppression therefore reducing competition for nutrients and water. Easily combined with other techniques on smaller sites, recommended for steep slopes, small and environmentally-sensitive sites.

Technical constraints

- Best employed in isolation on freely-draining mineral soils.
- To achieve cultivation objective the screef should be a minimum of 25*25 cm and planting position should be in middle of the weed-free zone.
- Limited effect upon soil and air temperatures.
- Poor option for achieving good survival and early growth, particularly if the soil has a high water table (unless planting common alder or eared or grey willow).
- Labour intensive.

Potential negative environmental impacts

- None.

Mitigation measures

- None.

Sub-soiling / Ripping / Tining

Tractor mounted sub-soiler / ripper specifically designed to break indurated layer in a continuous linear movement up to depths of approx. 60 cm thereby improving soil aeration. Agricultural ripper can be useful to disrupt plough pans and compaction associated with sheep grazing on clay soils.

Technical constraints

- Sub-soiling less effective in heavy soils.
- Tine can be deflected by rocks and shallow bedrock, making it difficult to maintain an even depth of disturbance.
- Only achieves very limited mixing of soil horizons.
- Tine requires a large tractor to pull it, presenting a slope limit.
- Planting position needs to be immediately adjacent to the rip so roots can penetrate shattered pan, planting in the rip should be avoided to reduce likelihood of desiccation.
- May need to be used in tandem with another technique e.g. scarifying or herbicide application to achieve objective.
- Voles can use rip channel to avoid predation and target saplings.

Potential negative environmental impacts

- Can create subsurface erosion channels, particularly on slopes, which can increase runoff and erosion delivering sediment to watercourses.
- Can intercept existing sub-surface drains and soil pipes, increasing erosion and risk of sediment pollution.

Mitigation measures

- Not to be used within buffer areas or steeper slopes.
- Contouring should be used to reduce the angle of fall.
- Leave 2 to 5 m wide breaks in sub-soiling at regular intervals on gentle slopes (i.e. every 70 m) and moderate slopes (i.e. every 40 m), especially where tine channels are likely to generate surface runoff.

Patch scarification (using excavator)

Excavator bucket removes surface vegetation to allow bare soil to be exposed, creating weed free planting position. Planting position should preferably be in the middle of the weed free zone, however can be varied depending on the suitability of the rooting material. Length and direction can be adjusted by operator to suit site conditions. Similar in effect to herbicide or manual screefing, so might be substituted by those techniques where appropriate.

Technical constraints

- Technique limited to weed suppression, only slight effect on air and soil temperature.
- Machine capability on steep slopes may be limiting.
- Particularly suited to lighter soils, scrape can become waterlogged in winter on moist to wet soil.

Potential negative environmental impacts

- Soil disturbance which is too deep on slopes with erodible soils could lead to washout and delivery of sediment to watercourses.

Mitigation measures

- Not to be used within buffer areas.
- Aim to achieve a shallow discontinuous scraping of the ground to remove only vegetation and expose underlying soil.

Inverted mounding

Excavator bucket lifts the soil and inverts it back into the excavation achieving an aerated, weed-free planting position so does not present future access issues experienced with other cultivation techniques. Mixes organic and mineral soils and can break a shallow indurated layer. Rooting symmetry is very good so improved stability can be anticipated.

Technical constraints

- Soil inversion that is too deep is likely to contain a large proportion of infertile sub-soil which could result in establishment failure due to nutrient deficiency.
- Machine capability on steep slopes.
- Requires a degree of operator skill to achieve desired effect.

Potential negative environmental impacts

- None.

Mitigation measures

- None.

Hinge mounding

Excavator bucket scrapes then upturns soil depositing it next to the excavation hole, creating a raised, aerated and weed-free planting position with increased soil temperature. A degree of mixing is also likely.

Technical constraints

- Water can pond within excavated hollows.
- Limited extent of ironpan mitigation.
- Soil inversion that is too deep is likely to contain a large proportion of infertile sub-soil which could result in establishment failure due to nutrient deficiency.
- Mounds planted before settlement risks desiccation of transplant.
- Can cause access issues for maintenance when site revegetates, unless pattern is readily identifiable.
- Machine capability on steep slopes.
- Planting position needs to be considered carefully in relation to site conditions.
- Mound specification needs to be considered carefully in relation to site conditions and cultivation objectives. Pages 60-61 of Bulletin 119 provides greater detail on selecting mound size according to site conditions.

Potential negative environmental impacts

- None.

Mitigation measures

- None.

Patch scarification (using scarifier) aka continuous mounding

Whether this is patch scarification or continuous mounding depends on the depth that the scarification tool is set, and whether it scrapes the vegetation or creates mounds of earth. Tractor mounted, two or more sets of mattock wheels turn at timed or pressure induced regular intervals, removing a discontinuous patch of surface humus to expose mineral soil.

Technical constraints

Scarification

- Limited extent of soil improvement.
- Planting position should avoid the ‘mound’, which consists mainly of rolled up turf or vegetation. Ideally planting should be near the edge of the scrape.
- Not recommended on weedy sites where colonisation and competition is rapid.
- Machine capability on steeper slopes.

Continuous Mounder

- Poor mound formation on loose and stony soils.
- Water can pond within excavated hollows.
- Soil inversion that is too deep will prevent humus layer being available for juvenile roots and may cause access issues when site revegetates unless the pattern is readily identifiable.
- Machine capability on steeper slopes.

Potential negative environmental impacts

Scarification

- Wheels set too deep on highly erodible soils could lead to washout on slopes.

Continuous Mounder

- Soil disturbance on highly erodible soils could lead to washout on slopes.

Mitigation measures

- Not to be used within buffer areas.
- Mattock wheels should be set no deeper than required to achieve cultivation objective.

Trench mounding

Excavator bucket extracts material from a trench and deposits it in mounds to create a raised, weed-free planting position. A degree of mixing can occur but this is very dependent on the depth of trench and type of material being excavated.

Technical constraints

- Deep trenches will often generate mound material unsuitable for tree establishment; soil inversion that is too deep is likely to contain a large proportion of infertile sub-soil which could result in establishment failure due to nutrient deficiency.
- Mounds created next to trenches restrict lateral root growth.
- Water can pond within trenches.
- Machine capability on steep slopes.
- Creates access issues, limiting future options for maintenance and mechanised harvesting.

Potential negative environmental impacts

- Represents a significant risk to soil carbon stocks on organo-mineral soils.
- Long trenches can generate surface runoff, potentially leading to erosion and sediment delivery to watercourses.
- Can result in a significant visual impact.

Mitigation measures

- Not to be used within buffer areas or organo-mineral soils[4].
- Ensure trenches are no longer than 30 m. If this is not possible, integrate with the local drainage system and meet the appropriate standards in terms of drain gradient and layout.
- For trench mounding done in connection with drains, use a maximum gradient of 3.5% (2^{o}), with drains leading towards the head of the valley.
- For trench mounding other than in connection with drains and on a gradient steeper than 5% (2.86^{o}), spoil trenches should be cut off after every 20 m.
- Leave a 2 to 5 m buffer of undisturbed ground between consecutive bands of trenches to act as a sediment trap.

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[4] Where an integrated drainage system is put in place drain spoil may be used for mound formation on condition drain intensity does not exceed the minimum level required for successful site establishment.

Rotary (helix) ploughing (aka rotary dollop plough)

Trailed or mounted the ploughshare creates a linear trace identical to a forest plough but the rotating helixes separate the removed material into 'mounds'.

Technical constraints

- Moderately extensive but limited depth of soil improvement.
- 'Mounds' can consolidate, or roll back into furrows on steeper slopes.
- Can sometimes cause issues achieving correct spacing between trees.
- Potential for asymmetrical rooting (although less than for conventional ploughing).

Potential negative environmental impacts

- Represents a significant risk to soil carbon stocks on organo-mineral soils.
- Linear trace can intercept and generate surface runoff, increasing peak flows and the risk of erosion and sediment delivery, resulting in diffuse pollution.
- Can result in a significant visual impact.

Mitigation measures

- Not to be used within buffer areas, steeper slopes or organo-mineral soils.
- To reduce risk of erosion remove tine where subsoiling is not required.
- Contouring should be used to reduce the angle of fall.
- Where feasible, change direction/gradient and alignment of furrows to slow runoff and reduce the risk of erosion.
- Leave 2 to 5 m wide breaks in plough runs at regular intervals especially where furrows are likely to generate surface runoff (i.e. every 70 m on gentle slopes and every 40 m on moderate slopes). Lift the plough and tine completely out of the ground.

Line scarification with disc scarifier

Rotating discs which offer flexibility in width and depth settings, removes a continuous strip of surface vegetation, raising soil temperature. Can achieve a slight mixing of organic matter with mineral soil offering some nutritional benefit to nutrient poor soils such as podzols. Can be used as an alternative to ploughing on podzols and less fertile brown earths. Similar in effect to herbicide treatment, so may be substituted by weed control where appropriate.

Technical constraints

- Flatter setting restricts the extent of soil improvement, but is more appropriate on weedier sites as it clears a larger surface area.
- Nutrient losses are larger than with patch scarification or mounding.
- Can cause compaction at sides of trench in some soil textures e.g. silt loam.
- Planting position is normally at the mid-point of the angled trench but should certainly avoid the ridge which is primarily the removed vegetation/litter layer.

Potential negative environmental impacts

- Represents significant risk to soil carbon stocks on organo-mineral soils.
- Creates linear trenches that can intercept and generate surface runoff and sediment delivery to watercourses, as well as increasing peak flows.
- Medium to high erosion risk on slopes, especially if the rotating discs have been set too steep making the linear traces too deep and narrow.
- Steeper settings can result in a significant visual impact.

Mitigation measures

- Not to be used within buffer areas, steeper slopes or organo-mineral soils.
- When using a steeper setting contouring should be used to reduce the angle of fall.
- Leave 2 to 5 m wide breaks in linear traces at regular intervals on gentle slopes (i.e. every 70 m) and moderate slopes (i.e. every 40 m), especially where traces are likely to generate surface runoff.
- Discs should be set no steeper than what is required to achieve the cultivation objective.

Shallow ploughing

Trailed or mounted, single or double throw mouldboard ploughs, are used to form continuous ridges and furrows up to a depth of 30 cm. Planting position should be varied between the ridge and the furrow, depending on the local water table and best material for a rooting medium.

Technical constraints

- Can encourage asymmetrical root growth, which reduces tree stability, particularly on fine loamy surface water gleys.
- Nitrogen mineralisation can proceed too fast on soils low in nitrogen, which can result in later growth check to sensitive species.
- Can promote weed invasion on cultivated loamy brown earths and cultivated surface water gleys.
- More extensive but limited depth of soil improvement.
- Turfs can roll back into furrows on steeper slopes.
- Can cause access issues, limiting future options for maintenance.

Potential negative environmental impacts

- Represents a significant risk to soil carbon stocks on organo-mineral soils.
- Continuous furrow can intercept and generate surface runoff, increasing peak flows and the risk of erosion and sediment delivery, resulting in diffuse pollution.
- Can result in a significant visual impact.

Mitigation measures

- Not to be used within buffer areas, steeper slopes or organo-mineral soils.
- To reduce risk of erosion remove tine where subsoiling is not required.
- Contouring should be used to reduce the angle of fall.
- Where feasible, change direction/gradient and alignment of furrows to slow runoff and reduce the risk of erosion.
- Leave 2 to 5 m wide breaks in plough runs at regular intervals especially where furrows are likely to generate surface runoff (i.e. every 70 m on gentle slopes and every 40 m on moderate slopes).
- Only plough to a depth required to achieve the site objectives:
    - Brown earth requiring weed suppression – do not use a tine. Flat plough to base of “turf”.
    - Ironpan – only use a tine to the depth required to shatter the pan.
    - Podzols - plough to depth of required mixing, i.e. to the top of the B horizon.

Appendix 2 – Undertaking a peat depth survey

On sites where deep peat may be present we expect an appropriate level of assessment to be carried out to identify its location. Where cultivation techniques that result in a medium to high level of disturbance are proposed, the peat depth survey should also assess and identify the presence of any peat layer, regardless of depth. As this information will be required in determining whether the proposed technique is acceptable.

Step 1 - Carry out a desk exercise to determine if peat is likely to be present
Use existing soil information, contour maps and aerial photographs to indicate the presence of peat, vegetation patterns, surface drainage and any erosion features such as gullies or 'hags'.

Identify the areas likely to be peat and prepare an outline map which will require ground truthing.

Step 2 - Ground truthing
Each likely peat area derived from Step 1 should be checked for the presence and depth of peat.

Common practice, in the first instance, is to use a GPS loaded with a pre-selected grid of 50*50m and the surveyor sampling at the exact grid references, however this method can miss areas of deep peat on-site and underestimate its true extent.

Where peat depths over 40cm are found more intensive and targeted peat depth sampling will normally be required to ensure that any areas of deep peat are accurately identified.

In particular, where ground conditions indicate deep peat could be present the distance between probing points should be reduced and when deep peat is encountered further targeted probing should be carried out to determine the exact boundaries and appropriate buffers for areas of deep peat.

During this phase of sampling the exact position of the probing point is more important than sticking to a pre-selected grid, as the purpose is to identify the boundaries of any deep peat.

Where sites are composed of a mosaic of variable peat depths particular attention will need to be given to identifying and protecting the areas of deep peat. Where small areas of deep peat are identified these need to be protected and buffered. In practice it may not be appropriate to plant areas with relatively small proportions of deep peat if it is widely distributed and would require extensive buffering.

Equipment required:

- Copies of any desk exercise map for on-site annotation.
- Peat probe (at least 80 cm in length).
- GPS.
- Notebook for vegetation and soil descriptions.

Output:

- GPS record of each sampling point, with peat depth to nearest 10 cm, when less than 50 cm in depth.
- Map of peat depths coded by depth.

To ensure they are left undisturbed and remain unplanted, areas of deep peat less than 0.25 hectare (considered unmappable) should be clearly identified on the ground and instructions to avoid these provided to machine operators prior to the commencement of any cultivation works.

Appendix 3 – Guidance Rationale

Soil Carbon

It is known that an increase in soil disturbance enhances the oxidation and mineralisation of soil organic matter, leading to a loss of soil carbon. The loss of carbon due to disturbance increases the greater the amount of organic matter in the soil, thus soils holding high organic matter such as organic and organo-mineral soils are more vulnerable to carbon loss than mineral soils holding much less.

To reduce potential carbon loss the UKFS asks forest managers to minimise the amount of soil disturbance necessary to secure management objectives, particularly on organo-mineral soils, and to consider the potential impacts of soil disturbance when planning cultivation operations.

There is no definitive threshold of what is an acceptable level of soil disturbance in relation to carbon loss because the impact depends on the soil type, previous land use, amount of vegetation cover removed in order to plant, and cultivation technique – and the extent to which carbon lost through cultivation can be balanced by the additional amount sequestered by better establishment and tree growth and litter input to soil.

A recent study[5] aimed at quantifying the impact of afforestation with Sitka spruce on carbon stocks of peaty gley soils observed a noticeable carbon loss of about 30% on sites which had experienced intensive site preparation practices during the first 30 years of the first rotation, consequently taking up to two rotations to recover and balance out the carbon deficit.

In preparation of this guidance further advice on soil carbon loss was sought from Forest Research. This analysis[6] identified that based on scenarios for 20 years, cultivation techniques which create a medium to high level of disturbance on organo-mineral soils with an organic layer >10 cm represent a significant risk of losing soil carbon. When extended over a 40 year period the depth of the cut of point increased to 20cm peat depth.

It should be noted that the evidence used to inform the cultivation guidance does not account for the full forest carbon balance, it only considers soil carbon.

There are a number of considerations in determining the most appropriate limits for use of medium and high disturbance cultivation techniques on organo-mineral soils:

- A major policy driver for tree planting in Scotland is the contribution to emissions reduction and achieving net zero by 2045, consequently it would not be acceptable for any planting to be a net emitter of carbon in the medium term.

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[5] Impact of Sitka spruce (*Picea sitchensis* (Bong.) Carr.) afforestation on the carbon stocks of peaty gley soils – a chronosequence study in the north of England. E.I. Vanguelova, P. Crow, S. Benham, R. Pitman, J. Forster, E.L. Eaton and J.I.L. Morison: https://academic.oup.com/forestry/article/92/3/242/5423201

[6] Calculated scenarios of carbon (C) change in peat soils due to different levels of ground disturbance associated with different cultivation techniques. Elena Vanguelova, Forest Research.

- Scottish Ministers have committed to a “precautionary approach” to protecting the environment in Scotland.
- On soils with organic layers <20cm it is likely that carbon losses arising from cultivation would be reabsorbed by the growing trees within 10 – 15 years, depending upon the growth rate of the trees.
- On soils with organic layers > 30cm the time taken for the growing trees to reabsorb released carbon may be over 20 years, depending upon the growth rate of the trees.
- There would be significant practical challenges to implementing a precise organic layer depth limit for cultivation, in the range 10-30 cm, as peat accumulation is often irregular and it is difficult to map the varying depth with precision across any given site. This means that it would be hard for operators to ensure good compliance with any depth limit.
- Lower disturbance cultivation techniques, which release less carbon are available and recommended by Forest Research for use on most organo-mineral soils with organic layers up to 50 cm in depth.

Taking into account all these factors the most appropriate approach is to exclude the use of medium and high disturbance soil cultivation techniques on all organo-mineral soils with a peaty phase[7] over 10 cm in depth.

To ensure that woodland creation proposals create a positive soil carbon balance within an acceptable timeframe, techniques which involve a medium or high level of disturbance (marked amber or red on the table below) should not be used on organo-mineral soils with an organic layer over 10cm in depth.

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[7] The FC Soil Classification System classifies a ‘peaty phase’ as a surface horizon containing more than 25% organic matter.

The expected impact of soil cultivation on soil carbon using different cultivation techniques.

Method and depth disturbed	Volume disturbed m3/ha	Approx. % of topsoil (0-30cm) disturbed	Level of disturbance
Manual screefing (10 cm)	Negligible	0%	None
Sub-soiling (ripping/tining) (45-60 cm)	60	2%	Low
Patch scarification using excavator (20 cm)	90	3%	Low
Inverted mounding (30 cm)	160	5%	Low
Hinge mounding (30 cm)	160	5%	Low
Patch scarification using shallow scarifier – aka continuous mounding (15 cm)	215	7%	Low
Trench mounding (50 cm)	380	13%	Medium
Shallow plough using double throw rotary mouldboard (30 cm)	560	19%	Medium
Line scarification using disc scarifier (shallow continuous strip) (20 cm)	630	21%	Medium
Shallow plough using double throw mouldboard (30 cm)	710	24%	Medium
Line scarification using disc scarifier (deep continuous strip) (20 cm)	840	28%	Medium
Deep plough without tine using single or double throw mouldboard (45 cm)	1,030	34%	High
Deep plough with tine using double throw mouldboard (60 cm)	1,430	48%	High
Deep plough with tine using single throw mouldboard (45 cm)	1,575	53%	High
Agricultural ploughing (30 cm)	2,500	83%	High

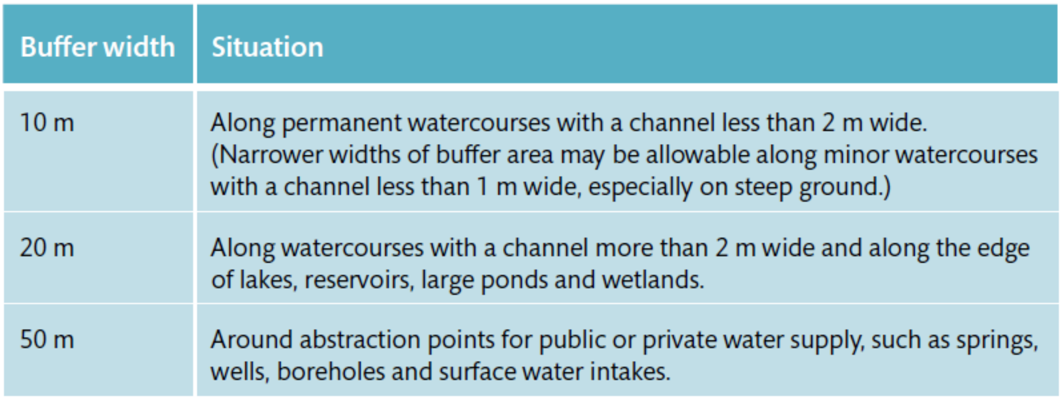
Water management – buffer areas

Mitigation measures should manage the pathway of water flow, and thus the potential movement of sediment and diffuse pollutants, which may be caused by the chosen cultivation technique. By slowing down runoff, reducing soil erosion and trapping sediment, mitigation measures can help limit a potential increase in peak flows and prevent sediment from reaching a waterbody, and so make the difference between if a technique has a higher or lower overall negative impact.

Watercourses, standing water, water abstraction points and wetlands should be protected from disturbance by using buffer areas. When planning cultivation consideration must also be given to groundwater dependant terrestrial ecosystems.

Mitigation measures should also consider the potential interactions between cultivation and existing site drainage, including overgrown connected ditches (whether they are dry or running), as any water channel that connects to a flowing body of water is classified as a watercourse.

The UKFS recommends the following **minimum widths** of buffer area:



Buffer width	Situation
10 m	Along permanent watercourses with a channel less than 2 m wide. (Narrower widths of buffer area may be allowable along minor watercourses with a channel less than 1 m wide, especially on steep ground.)
20 m	Along watercourses with a channel more than 2 m wide and along the edge of lakes, reservoirs, large ponds and wetlands.
50 m	Around abstraction points for public or private water supply, such as springs, wells, boreholes and surface water intakes.

In general, the aim in buffer areas is to establish and maintain a partial cover of riparian woodland comprising species native to the location and soils.

The UKFS states that within buffer areas, only hinge mounding should be used as a cultivation technique (Water Guideline 19). This guidance expands on that guideline: within buffer areas, cultivation is restricted to manual screefing, inverted mounding and hinge mounding, because they create a lower negative impact.

Further information on good practice water and soil management is available on the Forestry & Water Scotland website and in the FC Practice Guide: Managing forest operations to protect the water environment.

Water management – slope

When using techniques that create linear channels appropriate design and/or mitigation measures are key to reducing the risk of surface runoff, peak flows, soil erosion and sediment delivery into watercourses.

Long term Forest Research studies have demonstrated that the mitigation measures described in this Guidance are effective for controlling erosion hazards in most circumstances where the soils are of low or moderate erosion risk. However, erosion risk on slopes steeper than 11^0 (20%) is high for many soil types and confidence is reduced about whether mitigation measures would be effective at controlling the erosion risk and protecting the water environment. In these situations, where linear cultivation channels are being proposed it will be necessary to survey the soil and assess the soil texture and water absorbency in order to determine the erosion risk. Details of how to do this are provided in the FC soils identification field guide.

Linear techniques must be used in a way that complies with UKFS stipulations on water management and forest drainage, which in practice means:

Gradient of plough lines	To avoid the risk of soil erosion linear cultivation channels should not generally be used on slopes greater than 11° (20%). Only use discontinuous forms of cultivation on steep slopes Exceptionally, where a **detailed analysis** of the nature of the soil on site is carried out, and it is established that the soil erosion risk is low, it may be acceptable to create linear cultivation channels on moderate slopes, provided appropriate mitigation and controls are deployed.
For trench mounding done in connection with drains	Maximum gradient of 2° (3.5%), with drains leading towards the head of the valley.
For trench mounding other than in connection with drains and on a gradient steeper than 3° (5%)	Spoil trenches should be cut off every 20m.

Slope terminology[8]	Slope °	Slope %
Level	0-6	0-10
Gentle	6-11	10-20
Moderate	11-18	20-33
Steep	18-27	33-50
Very Steep	>27	>50

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[8] Forestry Commission – Technical Development Branch, Technical Note 16/95

Forest stability

Wind risk is one of the most significant threats to UK forests, a situation likely to be exacerbated by the projected increase in extreme weather events linked to climate change. Wind damage results in economic losses through reduced rotation lengths, reduced yields of recoverable timber and increased harvesting costs.

Windblow has a negative effect on the carbon balance of forests as storm damage increases carbon losses from the soil and overall carbon sequestration in trees is reduced, as shorter rotations lead to smaller long-term carbon stocks when compared to longer rotations. Windblow also has a negative impact on the landscape, wildlife habitat and can lead to an increase in the occurrence of tree pests and diseases.

The risk of windblow is significantly higher on sites with a DAMS score of 16 or above ‘highly exposed’, particularly on wet, poorly aerated soils such as surface water gleys and peaty gleys, where rooting depth is typically restricted to less than 50 cm. Where soil conditions prevent deep rooting, radial symmetry becomes increasingly important. The main structural roots are determined in the first 6-8 years of a tree’s life and their distribution is critically affected by cultivation.

Cultivation techniques should encourage conditions that will decrease the risk of windblow. Research carried out on stands of Sitka spruce and Lodgepole pine established that mounding encourages regular root development on poorly aerated soils, whilst spaced furrow ploughing or line scarification restricts root spread, thus prejudicing future tree stability.

Whether the impact on rooting results in catastrophic windblow will depend on many factors such as exposure, rotation length, thinning history or where felling for road lines or initial clear fell coupes expose unstable ‘brown’ edges in the remaining crop.

Ploughing or line scarification is not recommended on woodland creation sites with a DAMS score of 16 or above, particularly on gley soils.

When preparing your woodland creation proposal you will be required to evaluate the risk of the proposed cultivation technique on the long-term stability of the forest and its impact on future management options.

Where, despite the increased risks of windblow, ploughing or line scarification is proposed, future coupe boundaries and access roads must be carefully planned and implemented on the ground during forest establishment. This will involve incorporating unplanted permanent rides, sufficiently wide (15-20m minimum), to ensure the formation of wind firm coupe boundaries.

Alternative solutions include designing forests so adjoining coupe edges are composed of different species of different growth rates or long term management proposals such as an increase in permanent native woodland strategically integrated within the planting design.

Further information on managing forests to reduce storm damage can be found in Living with Storm Damage to Forests.

Landscape

Most linear cultivation (and some point cultivation) techniques have a strong visual impact due to the amount of material exposed and the regular patterns they create on the landscape. Visual ground disturbance will fade with time but the planted trees may carry on the pattern until the canopy structure matures.

Assessing the landscape context of a forestry proposal by appreciating its landscape and visual sensitivities is part of the forest design process. Advice on reducing the visual impact of a woodland creation proposal can be found at https://forestry.gov.scot/forests-environment/landscape