Afforestation of industrial cutaway peatlands in Ireland: problems and principles

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Summary
In Ireland, industrial cutaway peatlands account for about 80,000 ha, of which 58,000 are currently in production, mainly in the midlands. Amongst other possible after-uses, commercial forestry could be a suitable option on a proportion of this area. At present, this area is estimated by Bord na Móna to be between 16,000 and 20,000 ha. Due to the heterogeneity of these sites and the complexity of the reclamation process, the adoption of a single afforestation blueprint is not appropriate (Renou & Farrell, 2005). This paper attempts to lay down some key components that should be considered in afforesting successfully a range of industrial cutaway peatlands.

Key index words: industrial cutaway peatlands, afforestation, peatland forestry, species, site cultivation

Introduction
The results from over 200 ha of experimental and demonstration plantations carried out under the BOGFOR Research Programme (Renou-Wilson *et al.*, 2008b) conclude that the successful afforestation of cutaway peatlands is possible but requires (a) a sound plan with specific objectives, (b) a careful selection of sites with suitable characteristics and (c) the use of specific operational methods tailored to the site conditions and species requirements. Commercial forest crops have been successfully established on certain cutaway site types, each requiring a combination of necessary actions pertaining to site assessment, site preparation, species performance, tree establishment, fertilisation, late spring frost and vegetation management.

Site availability and site selection
Only a proportion of the total cutaway peatland area will ever be suitable for commercial forestry. This total area has been estimated by Bord na Móna to be between 16,000 and 20,000 ha. These figures exclude all cutaways that are pumped or will not be drainable when they are out of production. However, each cutaway peatland unit investigated within the project contained small areas that were not suitable for forestry. Drainage was most commonly the limiting factor in these spots. This is to be expected in all cutaway due to the undulating sub-peat mineral soil layer. It should be accepted that such areas should be managed for biodiversity or amenity or as wetland.

The variety of peat profiles found across the 200 ha of the BOGFOR studies confirmed the heterogeneity of these sites and the complexity of the reclamation process for forestry. As a result, peat properties can show marked variation over short distances resulting in a complex mosaic of mineral nutrient regimes. At another level, the combination of peat type and sub-peat mineral soil can present physical difficulties with regard to drainage and this will limit site preparation options. Correct site appraisal is essential to the success of the forest enterprise and a detailed site survey (including peat depth and peat type as well as drainage status carried out preferably in the winter time) is required to provide reliable information which will help in the choice of management options, for example, site preparation and choice of species.

Afforestation was successful on sites where the drainage system (gradient and suitable outlet) was adequate.

Woody fen was found to be the most favourable site types for commercial afforestation, followed by *Phragmites* peat with a deep aerated peat layer. Deep *Sphagnum* peat sites (>1m) were problematic for the growth of trees except for pine species. The nutrient status of both Norway and Sitka spruce stands established in the late 1980s on *Sphagnum* peat, deteriorated over time with trees suffering from P deficiency before reaching 10 years of age (Renou-Wilson and Farrell, 2007b).

Site preparation
On the basis of present knowledge, no site preparation is considered necessary on woody fen peat or shallow *Phragmites* peat that has a well aerated layer. Site cultivation methods tested did not improve survival or growth where trees were planted in such peat. Spruce and pine species benefited from mounding (using spoil from excavated drains to create mounds) when planted in poorly drained woody fen or *Sphagnum* peat but mounding *Phragmites* peat created an unsuitable medium for all species.

Deep ploughing was the most successful site cultivation technique, especially on deep *Phragmites* peat; it succeeded

Table 1. Physical and chemical characteristics of the peat (0-20cm) in East Boora, Co. Offaly after 3 years

		N		P		K		Bulk density		Depth		Aeration		pH	
Treatment	n	g/kg	s.e.	g/kg	s.e.	g/kg	s.e.	g/cm^3	s.e.	cm	s.e.	cm	s.e.		s.e.
No cultivation	18	9.10	0.8	0.18	0.01	0.25	0.06	0.141	0.035	113	11	39.7	2	4.57	0.14
Deep plough	18	12.00	1.4	0.17	0.01	0.19	0.08	0.136	0.038	118	8	56.4	3	4.61	0.10
t-test (*p* value)		0.08		0.75		0.78		0.55		0.49		<0.0001		0.71	

in aerating the peat (Table 1) and improving the early growth of Norway spruce (Fig. 1). It makes a furrow approximately one meter in width and one metre in depth and produces an upturned 'turf' that provides a drier site for the tree and encourages root growth. It is the most extreme form of site preparation that has been tested so far on cutaway peatlands and also the most expensive (€400-500/ha).

Species performance

While there is still little knowledge of the long-term performance of various species on cutaway peatlands, survival and growth results of a range of species showed that the following species can be generally regarded as being suitable: Norway spruce, Sitka spruce (under a nurse crop), Scots pine, Corsican pine, hybrid larch, pedunculate oak, silver and common birch and common alder (Table 2). Given the problems with late spring frosts in the Irish midlands, Norway spruce and pine species should be the preferred conifer species in open cutaway peatlands even though Norway spruce is not risk-free.

Of the broadleaves, alder was the fastest growing species, performing uniformly over a variety of site types. Like birch, its pioneering properties make it most suitable to quickly establish a forest cover (Renou *et al.*, 2007). Pedunculate oak has shown potential on the most fertile peats and with adequate shelter from exposure (Renou-Wilson *et al.*, 2008a).

This range of suitable conifer and broadleaved species affords the forester the opportunity to create interesting landscapes that will later provide options for diverse markets, as well as being ecologically acceptable. The variation in site conditions encountered in any given cutaway peatland means that, not one, but several species might flourish within a given area, thus enhancing the sustainability of these new forests.

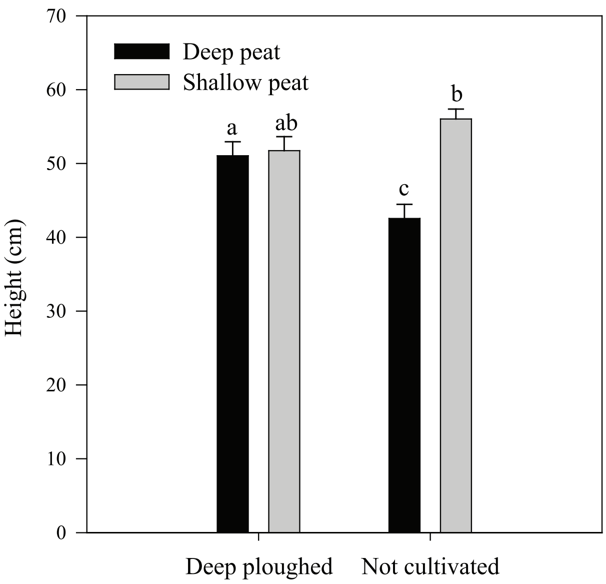

Figure 1. Effect of cultivation x peat depth on Norway spruce height in East Boora after three growing seasons (bars denote least square means ± one standard error). Means having the same letter are not significantly different (p>0.05)

Tree establishment

Early results from field trials showed that direct seeding of birch or alder was not successful; shelter and fertilisation seem to be critical to improve germination and survival. Planting seedlings from cold stored stock in April/May is a successful practice on these sites. Planting should not take place, however, any later so as not to delay fertilisation. Protection of broadleaves from hares is critical and fences must be well maintained throughout the first three years following planting.

Late spring frosts occur frequently in the low-lying cutaway peatlands in the Irish midlands, sometimes as late as June (Renou-Wilson *et al.*, 2008b). These often cause serious damage during the bud burst period of some species, particularly Sitka spruce, even when late-flushing provenances were used. Norway spruce was found to be less frost-sensitive than Sitka spruce, but it is not a risk-free species like pine. A near complete over-storey shelter system was found to be the best form of protection. Norway spruce, Sitka spruce and oak performed the best when planted under nurse crops of birch, alder or hybrid larch but attention must be given to subsequent management issues (e.g. timely vegetation control and pruning of whipping nurse crop). Any nurse crop (natural or planted) should reach a sufficient height and density before underplanting.

Nutrition and fertilisation

Initial fertilisation (at planting) with phosphatic fertiliser was found to be essential for the survival of all species on cutaway peatlands. However, increased P fertiliser rates did not necessarily lead to increased growth of Norway spruce (Fig. 2).

Results from water monitoring studies confirmed that the occurrence and magnitude of phosphorus (P) losses from fertilised cutaway peatlands plantations depends on edaphic characteristics, fertilisation variables and transport

Table 2. Range of species tested within the BOGFOR studies

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BROADLEAVES	English name	Latin name	Irish	Comments
Alder	Common alder	*Alnus glutinosa*	Native	Successful
	Italian alder	*Alnus cordata*		Successful
Ash	Common ash	*Fraxinus excelsior*	Native	Unsuccessful
Aspen	Aspen	*Populus tremula*	Native	Unsuccessful
Beech	European beech	*Fagus sylvatica*		Unsuccessful
Birch	Silver birch	*Betula pendula*	Native	Successful
	Downy birch	*Betula pubescens*	Native	Successful, but not as good as Silver birch
Oak	Pedunculate oak	*Quercus robur*	Native	Promising, under nurse crop especially
	Sessile oak	*Quercus petraea*	Native	Unsuccessful
Poplar	Poplar	*Populus Beaupré*		Unsuccessful
Maple	Norway maple	*Acer platanoides*		Unsuccessful
Sycamore	Sycamore	*Acer pseudoplatanus*		Unsuccessful
CONIFERS				
Larch	Hybrid larch	*Larix x eurolepis*		Successful, on dry sites only
	Japanese larch	*Larix kaempferi*		Promising
Pine	Corsican pine	*Pinus nigra var. maritime*		Successful
	Lodgepole pine	*Pinus contorta*		Successful, but prone to Pine Shoot Moth
	Macedonian pine	*Pinus peuce*		Successful
	Scots pine	*Pinus sylvestris*	Native	Successful
Spruce	Norway spruce	*Picea abies*		Successful
	Sitka spruce	*Picea sitchensis*		Successful, under nurse crop only
Cedar	Western red cedar	*Thuja plicata*		Unsuccessful, except in very dry sites
Yew	Irish yew	*Taxus baccata*	Native	Unsuccessful

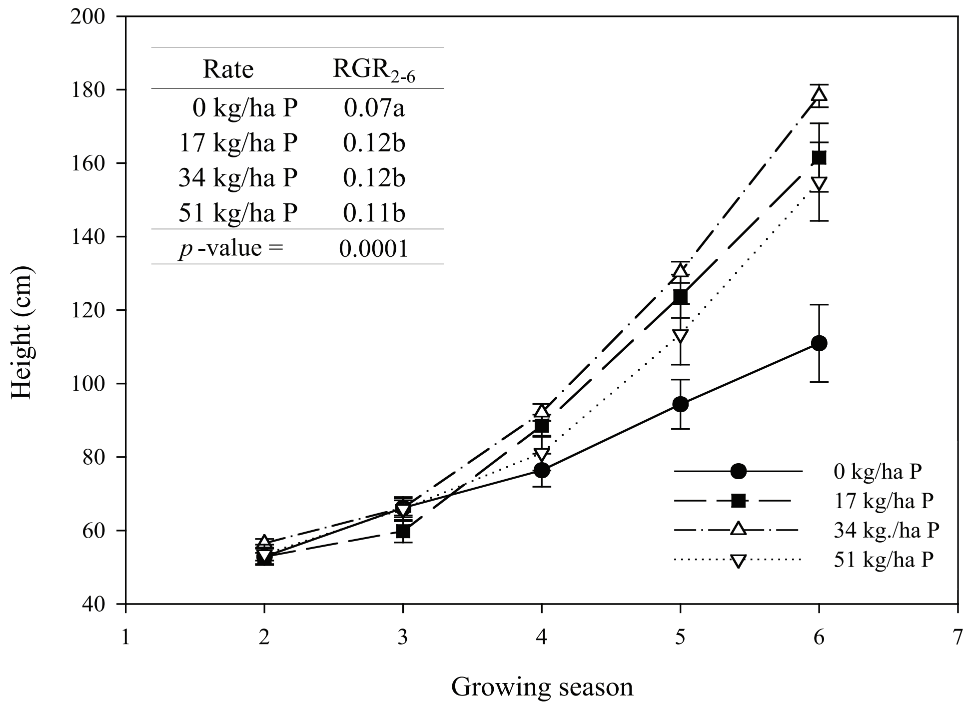

Figure 2. Effect of fertiliser rate x time on Norway spruce height (bars denote least square means ± one standard error) in the fertiliser trial. Inset shows fertiliser rate effect on relative growth rate between year 2 and year 6 (RGR2-6). Means having the same letter are not significantly different ($p > 0.05$)

factors such as surface runoff which is directly related to hydrological processes and climatic conditions. Phosphorus losses will occur when applying phosphatic fertiliser to peat soil unless edaphic properties are altered. Application of superphosphate in the current recommended practice (42 kg ha^{-1} P) did not affect P concentrations of the soil water when the peat was mixed with sub-peat calcareous mineral soil. This provided the soil matrix with a strong P-binding ability. However, a split application of fertiliser is recommended on cutaway peatlands, especially on bare peat fields: half of the conventional rate of 350 kg of rock phosphate (12.5% P) should be applied at planting and the other half, two years later. Applying fertiliser no later than June would also minimise the risk of removal of fertiliser particles by heavy precipitation and would be available to the trees for a whole growing season (Renou-Wilson and Farrell, 2007a).

As initial broadcast application led to increase P losses and vegetation control difficulties, fertiliser should be applied in bands at planting and broadcast for the second application, carefully avoiding drains (minimum 20 cm from the ditch) and waterlogged areas.

Vegetation

It is important to reduce the colonisation of main competitors such as *Juncus* firstly by improving drainage and, secondly by following a rigorous vegetation control plan. Timely and efficient vegetation control operations are necessary using the most appropriate machine to control the type of weeds present. Cutaway peatlands were found to be well suited to mechanical cleaning with purpose-built equipment such as mowers and weed-wipers (semi-chemical/semi mechanical). The spraying of herbicides is not recommended on cutaway peatland plantations due to the poor weather conditions (wet and windy).

Conclusions

The results from the BOGFOR research programme have opened the door to the future afforestation of industrial cutaway peatlands. However, the initial results from the project should be verified by continued monitoring of the trials and demonstration areas that have been established. A phased approach to the afforestation of the cutaways peatlands is needed, with due consideration to wider land-use issues.

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