Site Amelioration for Reforestation

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INTRODUCTION

At present reforestation accounts for 8% of the planting programme of the Forest and Wildlife Service — around 400ha annually. During the next five years (1979-83) over 5000ha are due for clearfelling. Most of the clearfelling during this period will be confined to the east of the country. For the following five year period the pattern will remain essentially the same. It is during the following decade that the emphasis will shift to the clearfelling of those crops planted during the early fifties — notably those established on Old Red Sandstone and blanket peat sites. When these crops are being clearfelled their regeneration will involve an annual planting programme of at least 4000ha annually. Clearly although reforestation is having some impact now its importance will increase considerably in ten to fifteen years time when the annual regeneration area will have increased ten-fold.

The areas being clearfelled at present are, as already indicated, mainly in the east of the country. These crops have grown without the aid of ploughing or fertilising at planting. This is an indication of their fertility. Part of this fertility is due to their use previous to forestry. Many of them are sites of abandoned farms. These would have received cultivation and manuring while under agriculture. This phenomenon of increased growth on sites which were farmed at some time relative to those which were not is well recognised. It has been referred to as the 'Old Field Syndrome' in parts of the Southern U.S. (Haines et al 1975).

The regeneration of these areas has been progressing for several years now. There is however, an absence of clear-cut criteria on which the forester can base his decisions. This is evidenced by the fact of the large number of species being used and the use of cultivation in some instances and not in others. Part of the reason for this uncertainty is undoubtedly the absence of vegetation which is commonly used at afforestation as an aid to species selection.

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SITE AMELIORATION

Before going on to deal with specific means of site amelioration it would be useful to define what is meant by this term. There are many factors which influence production at a given site. Man can modify some of these by for instance, plant breeding. The site factors most amenable to change are vegetation and soil. Site amelioration therefore usually refers to physical and chemical manipulation of the soil brought about by ploughing, ripping or some other form of cultivation coupled with additives of inorganic fertilisers, mainly P under Irish conditions. In the case of reforestation there is the additional factor of logging residues. Because they are a store of potential nutrients they can have a beneficial effect upon growth when they are broken down. In addition their shading of the soil surface may have beneficial effects such as reducing soil temperature fluctuations (Cochran 1975).

What criteria can be used in assessing the need for site amelioration during reforestation? It may be that there is no choice but to carry out some form of amelioration on some sites or the trees will simply not grow or survival will be very poor; such is the case with amelioration of blanket peats for afforestation. However, the choice is unlikely to be so clear-cut during reforestation.

A lot of the clearfelling sites will be able to support regeneration for a number of years without any form of site amelioration apart from treatment of the slash where it is heavy. Any assessment of the efficacy of site amelioration will probably be over a longer time period in reforestation as opposed to afforestation. Even now we are becoming conscious of the long term effects of amelioration for afforestation. Here for instance the disadvantages of spaced ploughing are becoming apparent when ribbons and furrows remain an obstacle to extraction right up to final harvesting.

The main criteria used in judging the need for site amelioration is whether or not the operation results in an increase in height (volume) growth which is sustained over the rotation. The resulting increase if obtained can be quantified in money terms by relating the

Table 1 — Effect of increase in Yield Class (m^3/ha/annum) on NDR of Sitka spruce

Yield Class	NDR (£/ha)
18	573
20	774
22	979

It is stressed that these figures are not intended to represent absolute NDRs and are intended only for comparison.

increase in growth to an increase in Yield Class (m^3/ha/annum). Yield Classes can be compared by looking at their NDRs (net discounted revenues). This is shown in Table 1. Clearly an increase in Yield Class results in very large increases in NDR especially for lower Yield Classes. These data also highlight the financial implications of correct species selection.

Clearfelling and Harvesting

Following clearfelling a great deal more water reaches the soil surface because of the removal of the forest canopy. This results in an increase in the moisture content of the soil especially on soils where the drainage system is not able to remove the additional moisture. In Finland (Heikurainen 1967) it has been calculated that depending upon site, the water table in peat soils rises by between 20 and 40cm following clearfelling. This has the effect of bringing the water table within the potential rooting zone of many conifers, so if growth retardation of the regeneration by excess soil moisture is to be avoided then drainage will have to be carried out. On peat sites in this country afforested with the aid of ploughing/drainage the consequences of clearfelling on the water regime are not known. It is possible that physical changes which may occur in the peat, such as cracking, will make for better natural drainage during the second rotation.

Harvesting also has large implications on the need for site amelioration. There are two main reasons why this should be so. Firstly there is the effect on the nutrient store of the site in terms of the percentage of the total crop which is removed. Secondly the actual removal of the crop will have physical effects upon the soil.

In recent years much attention has been given to the effect of total tree harvesting. With increases in demand for wood fibre harvesting limits will probably decrease so that a greater proportion of the crop is removed. Since most of the nutrients, particularly N, P and K are concentrated in the growing points — needles, twigs, bark cambium and roots — the effect of harvesting these parts of the crop will have a very large effect upon the amounts of nutrients which are removed. During normal harvesting operations (top diameter limit of 7cm) most of the nutrients are left behind on the site. What effect would decreasing the harvesting limit have on growth during the second rotation? On poor sites the removal of the total crop would more than likely entail the application of amounts of nutrients similar to those removed in material additional to the main crop. The problem lies in the identification of those sites where removal of the whole crop would result in growth retardation during the second rotation.

The spatial distribution of slash varies according to the extraction system. With full-tree skidding a good deal of the branchwood and needles will be removed to the logging deck. However, for spruce stands in Southern Bavaria it has been estimated that 20-30% of the branchwood is broken off during full-tree skidding and that in addition from 5-20% of branchwood is broken off during felling with power saws (Kreutzer 1976).

In this country the most common method of extraction is by traction of the material over the ground surface. Whether extraction is by skidder or forwarder, extraction pathways or 'skids' are used. They carry heavy traffic many times during the removal of the crop. Soil compaction often occurs as a result, especially when the soil is moist and is prone to compacting e.g. surface-water gleys. This compaction results in the poor growth which is often seen on old skidding trails. In New Zealand this effect has been demonstrated for *Pinus radiata* — trees growing on skidding trails represented a volume/ha of 5.2m^3 whilst those on an adjacent cutover area had a volume of 34.3m^3/ha (Anon. 1977). This effect remains to be demonstrated for this country but it undoubtedly exists at some reforestation sites. On vulnerable sites it may be possible to overcome the problem by confining harvesting to drier months of the year or using lower ground pressure machines. Where existing compaction is thought likely to result in delayed growth it may be possible to overcome it by ripping along the compacted skid before planting.

Treatment of Residues

The treatment of residues will be dealt with in another paper. I will concentrate on the likely effects that such treatment will have on growth.

Depending upon the previous crop, harvesting limit, extraction system and the conscientiousness of the timber merchant the amount and spatial distribution of slash will vary. For instance, Clark and Taras (1974) have shown how the amount of slash varies according to the harvesting system.

Where the slash is heavy there is the option of bulldozing it into windrows and planting in between. From a forest manager's viewpoint the chief attraction of this operation is its simplicity. The area is left clear for planting and it receives some cultivation when the slash is being pushed into piles. However, during windrowing, especially where a blade rather than a rake is used, it is inevitable that some of the top soil/forest floor will be removed into the windrow. On poor sites this will lead to irregular growth because the soil nutrient reserves or their rate of release will not be sufficient to sustain growth at the same rate obtaining near the edge of the windrow where the nutrients are now concentrated. The fall-off in growth with distance from the windrow can be quite large in some instances. This effect has been noted at several locations where windrowing has been carried out in this country. At one site in Rathdrum forest, Co. Wicklow an unthrifty pole stage crop of Scots pine was clearfelled and the slash and other residues were piled into windrows about 20m apart. The area was then planted with Sitka spruce. It is now apparent that growth is very uneven. Foliar nutrient levels have been measured and growth data obtained (Table 2). Clearly height growth is very irregular and management of this uneven growth will be a problem.

Table 2 — Effect of windrowing on foliar nutrient levels in Sitka spruce at Rathdrum forest (planted 1970).

Position	% d.m.					Mean Height
	N	P	K	Ca	Mg	(m)
Edge of windrow 1	1.52	0.134	0.55	0.30	0.06	4.5
5m from windrow 1	1.19	0.106	0.40	0.43	0.13	3.0
Midway between windrows	0.99	0.104	0.46	0.42	0.11	4.0
5m from windrow 2	1.12	0.106	0.50	0.51	0.10	2.0
Edge of windrow 2	1.48	0.134	0.47	0.28	0.17	5.0

On poorer sites it is likely that remedial fertilisation will have to be carried out some time following windrowing unless a sufficiently heavy application is made before the replanting takes place to balance the uneven distribution of nutrients. Where the slash is heavy it is likely that windrows spaced 20m apart will not decay sufficiently to allow ready access across them during early thinning stage. Large windrows can occupy up to 20% of the surface area so it should be remembered that their creation alone will involve a volume loss since the site is not being fully occupied. On better sites windrowing where the rows are 5-10m apart may be an option — but on these sites we may be thinking of removing the whole crop anyway.

An alternative to windrowing is to burn the slash. This can be accomplished through either broadcast burning or by windrowing and then burning. Since burning encourages the development of *Rhizina undulata* it has not been practiced to any great extent in this country. The main objection to burning in other countries is that it may lead to substantial losses of N and S by volatilisation. On poor sites losses of N of the magnitude usually found following burning could not be tolerated by the regeneration. Where the soil reaches sufficiently high temperatures soil organic matter can be destroyed leading to a breakdown of soil structure. This occurs especially where windrows are burned.

If cultivation is thought to be necessary then it is possible to combine it with the treatment of residues. Disc ploughs especially designed to work under reforestation conditions are used extensively in the U.S.A. and Scandinavia. The possible beneficial effects of such a treatment have been outlined already. Where the slash is heavy it may be necessary to reduce it by crushing before discing. This treatment has, I feel, great potential.

Present Work

Almost all our work to date on reforestation has concentrated on field experiments. Most of the sites chosen for these experiments have carried low yielding crops of either lodgepole pine *(Pinus contorta)* or Scots pine *(Pinus sylvestris)*. These sites have received no fertilisation at any time during the first rotation and while they may have been cultivated if they were farmed prior to afforestation there was no specific cultivation carried out for afforestation. On these sites the aim of site amelioration is to supply sufficient amounts of P and to achieve a degree of cultivation necessary for vigorous growth — this is accomplished through the addition of unground rock phosphate and by either ploughing or ripping. Ideally site amelioration treatments for reforestation should help to maximise any beneficial effects the first crop may have had on the sites. More recently slash retention/removal treatments have been included in reforestation experiments here to investigate these effects.

Table 3 — Site details of reforestation experiments*

	Avonmore	Kilworth	Shillelagh
Geology	Ordovician shale/ quartzite	Old Red Sst.	Mica-schist
Soil	Brown podzolic	Podzol	Brown podzolic
Elevation (m)	200	160	210
Previous crop	Scots pine	Lodgepole pine	European larch/ Scots pine
Treatment of slash	Left *in situ*	Removed	Removed

*Located between 52°10' and 52°50' N.

In a series of reforestation experiments laid down in 1976 (Table 3) the ameliorative measures tested (Table 4) include cultivation and P application. Different species have been included because of the almost complete lack of information on choice of species for the second rotation. There is a general belief that a more demanding species can be used for the second rotation following one of a 'pioneer' species such as lodgepole pine. This however has not been clearly demonstrated under Irish conditions and there is always the possibility, referred to earlier, of site degradation following complete tree harvesting or windrowing on nutrient-poor sites.

In all of the 1976 experiments ripping has been included as one of the ground preparation treatments. The advantages of ripping over spaced ploughing are that it leaves a relatively unbroken surface which eases future extraction and that it probably leads to deeper rooting and hence better stability. Preliminary rooting studies in an afforestation ground preparation trial at Ballyhooley forest have shown deeper rooting (to 90cm) in the ripped treatment compared with Clark tine ploughing (to 40cm).

Table 4 — Treatments in 1976 series of reforestation experiments

Main treatments:	I	Clark tine ploughing; spaced ploughing at 2m spacing with a furrow depth of 40cm and a tining depth of 60-70cm
	II	Ripping at 2m spacing to a depth of 60-70cm
	III	Control, no cultivation
Sub treatments:	1	Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco)
	2	Sitka spruce (*Picea sitchensis* (Bong.) Carr.)
	3	Lodgepole pine, south coastal provenance (*Pinus contorta* var. *contorta*). At Kilworth only
Sub-sub treatments:	A	0 kg P/ha
	B	30 kg P/ha
	C	60 kg P/ha
	D	90 kg P/ha

Results after three growing seasons are presented below (Table 5). Height increments have been used because of the differing heights of the species at planting. For Avonmore both Sitka spruce and Douglas fir columns are included because of a significant species x cultivation x level of P interaction. While the results show a trend for the superiority of Clark tine ploughing over both control and ripping the magnitude of the difference between ripping and ploughing is small. This difference reaches statistical significance at only one site, Kilworth, which is the poorest of the three in terms of nutrient availability and where ploughing would be likely to have a short-term beneficial effect. Indeed the long term beneficial effects of intensive cultivation have often been called into question (van Goor 1977).

Table 5 — Mean height increment (cm) three growing seasons after establishment

AVONMORE

	Control		Clark tine ploughing		Ripping	
kg P/ha	†S	*D	S	D	S	D
0	23	25	52	25	40	36
30	28	25	36	28	51	33
60	19	29	45	24	37	26
90	20	24	45	31	31	35

Standard error of difference between two means = 5.4cm
Least significant difference at 5% level = 11cm

KILWORTH

	Control	Clark tine ploughing	Ripping
0	36	53	46
30	62	72	53
60	54	73	56
90	66	75	52

Standard error of difference between two means = 5.4cm
Least significant difference at 5% level = 11cm

SHILLELAGH

0	35	34	37
30	34	51	37
60	38	50	47
90	38	48	40

Standard error of difference between two means = 4.3cm
Least significant difference at 5% level = 9cm

†S = Sitka spruce
*D = Douglas fir

At this early stage it appears that P applications of up to 30 kg P/ha are justified on some Old Red Sandstone reforestation sites. This is to be expected since O.R.S. soils are generally low in 'available' P. At the other two sites there is little evidence so far of a response to P. It is hoped that soil chemical analysis will help to explain further the reason for positive responses at some of these sites and not at others.

Finally to return to the choice of species. Table 6 shows that at least as far as early growth is concerned significant differences have emerged between species and if these trends hold for volume growth then the suppositions about replacing lodgepole pine, for instance, with either Sitka spruce or Douglas fir will have to be re-examined.

Table 6 — Mean height increment (cm) three growing seasons after establishment

	KILWORTH	
Sitka spruce	Douglas fir	lodgepole pine
55	45	72

Standard error of difference between two means = 9.7cm
Least significant difference at 5% level = 27cm

	SHILLELAGH	
33	47*	—

*Difference between means significant at 99.9% level

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