The Tunnel Plough in Peatland Afforestation

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INTRODUCTION

Because of its cool moist climate, much of Ireland is covered by deposits of peat. These are known in Ireland as bogs or peatlands, and internationally as mires. There are two main classes of bog: raised bogs and blanket bogs. These have recently been mapped and described by Hammond (1979).

Raised bogs occur in undulating midland areas. Initiated as post-glacial lakes, they are now composed mainly of sphagnum and reach a thickness of 9m or more. These areas have been extensively developed for fuel production and pressure in that direction is increasing.

Blanket bogs occur on flat or undulating areas in the wetter parts of the country, down to sea-level along the west coast. Depth is variable, generally 2-3m but can be up to 6m. The main body of the peat is composed predominantly of the remains of *Molinia* grass and *Eriophorum* species with *Calluna vulgaris* and *Myrica gale* occurring locally (Hammond 1979).

The low level Atlantic type of blanket bog, occurring below 152m elevation and mainly in counties Galway, Mayo, Donegal, Kerry and Cork and the area of this type considered unmodified has been mapped by Hammond as covering 243,610ha.

The principal limitations in the use of peatlands for crop production have been waterlogging and infertility. The waterlogging is due to the gelatinous nature of the peat substance and its very low permeability, with hydraulic conductivity estimated by Galvin (1976) at about 10mm per day. Other data published by Galvin (1976) indicate that the air content of typical undrained blanket bog is less than 6%, whereas earlier work summarised by

Russell (1961) suggests that this should be at least 10% for the growth of various crops including trees.

A major attempt at peatland afforestation was made by the Government during the decade 1890-1900 on an area of about 400ha near the west coast at Knockboy in Co. Galway. This failed (O'Carroll 1962), but since drains in the deeper peat areas were 9m apart and from 0.9 to 1.8m deep (Schlich 1908) the failure was probably caused more by lack of fertiliser treatment than by water-logging.

An interesting plantation was established in 1952 in Cloosh Valley Forest, Co. Galway on a deep blanket bog which had previously been reclaimed for agriculture, but not intensively cropped. One of the basic elements of the reclamation technique was a system of drains of a traditional design, formed by excavating to a depth of 75cm, then constructing at the bottom an open channel of inverted sods, and refilling (O'Carroll 1962). The plantation outgrew contemporary plantations on adjacent virgin bog, but because of additions of gravel and fertilisers other than phosphorus on the reclaimed area its success cannot be simply ascribed to the deep drainage system. (The area was burned in 1976).

PLOUGHING

A comprehensive account of the development of ploughing techniques for pre-establishment drainage is given by Neustein (1976). First attempts in Wales and Scotland in the 1920s led to the development in the 1940s of a number of models built by Cuthbertson of Lanarkshire in Scotland. Two of these, the F (forestry) and the P (planting) were used in Ireland from 1951. The F model was a single mouldboard (SMB) plough designed to give drains 45-60cm deep and 50-90cm wide, while the P model, a double mouldboard (DMB) plough and that most widely used in preparation for planting in Ireland gave drains 20-30cm deep and 70-80cm wide. Similar ploughs were later manufactured by Clark of Parkgate, Drumfriesshire, Scotland.

Both these ploughs provided a drain to remove surface water and an elevated "ribbon" on which the young trees are normally planted. The ribbon is the continuous ridge of peat and its original vegetation, usually inverted, or sometimes turned on its side, which is removed by the plough and placed alongside the furrow drain at a distance determined by the design of the plough.

A new plough for peatland, later to be known as the tunnel plough[1] was designed and built at Glenamoy, Co. Mayo in the late

1 So named at the suggestion of Mr. H. M. Fitzpatrick of the Society of Irish Foresters, made during a demonstration of the plough to the Society at Glenamoy State Forest on 31st May 1960.

1950s (Armstrong *et al* 1960). This provided a closed drain similar in effect to the traditional sod drain already described, at a depth of about 75cm to the bottom of the drain. The first model gave a drain channel 38cm high and 20cm wide. The method of operation of this plough is shown is Figs. 1 and 2.

In 1960 the tunnel plough was incorporated into a formal experiment at Glenamoy Forest which forms the main basis of this paper. A further experiment with the tunnel plough was begun at Glenturk, part of Glenamoy forest, in 1967, and will also be reported briefly.

Fig. 1 Tunnel plough in operation at Glenamoy, Co. Mayo.

THE EXPERIMENT

GLENAMOY

This experiment was designed to achieve two objectives: first, to provide a direct comparison of the relative effects on tree growth of the Cuthbertson F (SMB) and P (DMB) ploughs, which were both then in widespread use; second, to compare the tunnel plough at various drain spacings with the standard open-furrow ploughs. The

two main tree species in use in peatlend afforestation, Sitka spruce(*Picea sitchensis* Bong., Carr) and lodgepole pine (*Pinus contorta* Douglas ex Loud.) were used in the experiment. The experimental treatments are summarised in Table 1.

Table 1 Glenamoy Experimental treatments

Plough	Furrow/Drain spacing*	Furrow depth
Cuthbertson P (DMB)	3.05m	28cm
Cuthbertson F (SMB)	1.52m	31cm
Tunnel	1.52m	n.m.
Tunnel	3.05m	n.m.
Tunnel	4.47m	n.m.

* Originally specified in feet. n.m. not measured.

The experiment is located in Glenamoy State Forest, Co. Mayo (Grid Ref. F8732) on peat 2.4m deep at an elevation of about 20m. The site has a slope of 2° and a north-east aspect. Vegetation before ploughing consisted predominantly of *Molinia caerulea* Moench., *Calluna vulgaris* Hull., *Erica tetralix* L., *Schoenus nigricans* L., *Eriophorum angustifolium* Honck., with occasional *Myrica gale* L. and *Scirpus caespitosus* L.

The site had been ploughed at 30m intervals in 1954 using a Cuthbertson B (bog) plough, DMB, producing furrows 1m deep. These had almost closed through horizontal subsidence of the peat when the experiment was established in October, 1960. The five ploughing treatments were combined factorially with the two species and the 10 combinations were replicated four times in randomised blocks. The plots were 27m squares (.073ha) located between the earlier 30m furrows.

The tunnel plough model used in this experiment had an intake orifice 37cm high and 28cm wide. The Cuthbertson ploughs were the standard models supplied at that time. The furrow depths given in Table 1 are the mean depths achieved in the experiment measured immediately after ploughing.

Planting took place in November, 1960 and was carried out either on the ribbons, or in the case of the wider tunnel treatments, on the ribbons and on mounds cut from the ribbons and spaced at 1.52m.

The Sitka spruce was raised from seed collected in Mountrath Forest, the lodgepole pine seed was from La Pine, Oregon, an inland source which would not now be acceptable in Ireland.

In the spring of 1961 each tree was given a spot application of ground rock phosphate, 57g to Sitka spruce and 43g to lodgepole pine, supplying 36 and 27kg P per ha respectively. In 1968, following a marked reduction in annual leader growth of the spruce, all plots were given a broadcast dressing of 90kg P and 125kg K per ha.

In 1973 observation of the soil water table was begun. Measurements were made in a series of boreholes lined with 70mm diameter slotted PVC drainage pipes. Six holes were bored in each Sitka spruce plot of two of the replicates.

In 1976 a number of root systems in each of the ploughing treatments were excavated and recorded by the method described by Carey and Barry (1975).

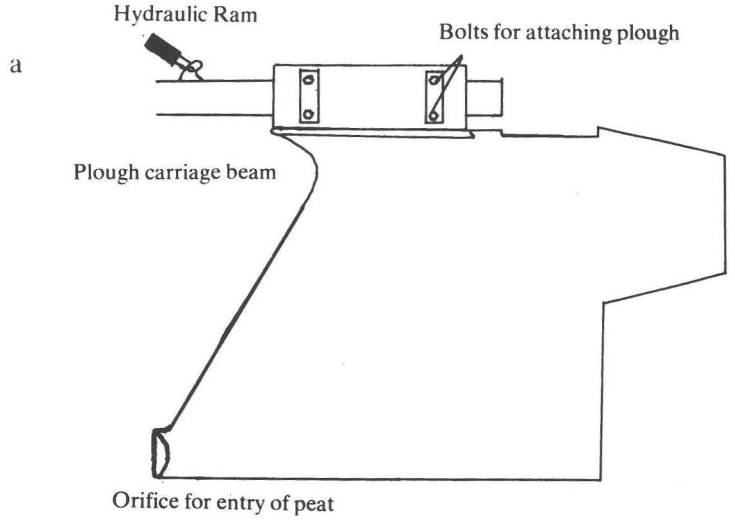
GLENTURK

The Glenturk experiment was begun in 1966 in order to gain further information on tunnel ploughing, which was by now showing promise in Glenamoy and had the obvious advantage of providing an unbroken forest floor, in comparison with the standard open-furrow techniques. A trial with lodgepole pine of coastal origin was also desired.

Glenturk is situated in Glenamoy State forest (Grid Ref. F8629). The site has an elevation of 15m and a slope of 1°. Vegetation was similar to that at Glenamoy but without the *Eriophorum* and *Scirpus*. Ploughing details are in Table 2. Plants were 1.52m along ribbons in the Cuthbertson plots and 1.82m along the ribbons and along the lines of mounds mid-way between each drain in the tunnel plots.

The ploughing treatments were replicated in four randomised blocks, with two plots of tunnel ploughing in each, so that the tunnel plough was replicated eight times and the Cuthbertson ploughs four times each. The ploughing plots, each 27.4 x 18.3m (0.05ha) were split equally for the two species. The seed origin for the Sitka spruce was Masset, Queen Charlotte Islands, British Columbia. The lodgepole pine derived from seed collected in a stand in Cloosh Valley Forest, Co. Galway which was from seed of unknown origin but believed to be from coastal Oregon or Washington.

Initial fertiliser treatment in the spring of 1967 was a spot application of ground rock phosphate supplying 36 and 18kg P per ha to the spruce and pine respectively. This was followed in



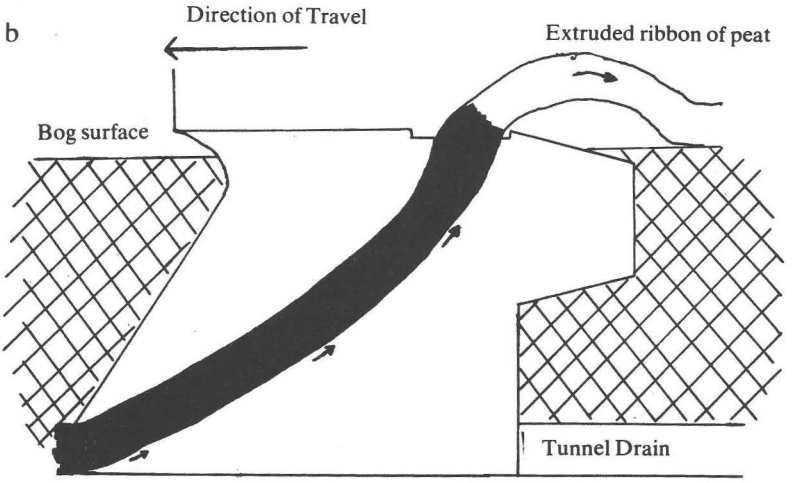


Fig. 2. a. Principal components of tunnel plough and b. Method of operation.

Table 2 Glenturk Experimental treatments

Plough	Furrow/Drain spacing	Depth
Cuthbertson P (DMB)	3.66m	30cm
Cutherbertson F (SMB)	1.82m	34cm
Tunnel	3.05m	n.m.

October, 1972 with a broadcast dressing which supplied 90kg P, 150kg K and 4kg Cu per ha.

A number of root systems in this experiment were excavated in 1978.

RESULTS

GROWTH: 1 GLENAMOY

Mean height of both species was assessed at three year intervals up to age 12. At age 15 mean height and breast height diameter of the Sitka spruce were measured, and these results are shown in Table 3. Results from the earlier assessments follow a very similar pattern to those shown in the table. In the variance analysis of the data at age 15 the following components of the treatments sum of squares were examined (cf Cochran & Cox, 1957):

1. Average Cuthbertson (SMB and DMB) *compared with* average of tunnel at 3 spacings.
2. Cuthbertson SMB *compared with* Cuthbertson DMB.
3. Linear effect of tunnel plough spacings.

There were no significant interactions between any of the ploughing components and species, so that the effects of the ploughing treatments are best estimated by the species means. The significant levels of the separate effects of the ploughing components are shown in Table 4.

2 GLENTURK

Mean heights of both species at age 12 are shown in Table 5. Because of the different replication of Cuthbertson and tunnel

Table 3 Glenamoy Mean height (m) of both species and diameter (cm) at breast height of Sitka spruce at age 15.

Ploughing	Mean height	DBH
DMB	6.1	9.3
SMB	5.7	8.2
Tunnel 1.5	5.7	9.0
Tunnel 3.0	5.2	8.7
Tunnel 4.6	4.4	6.2
S.E.	.40	.95
L.S.E. at 5%	1.2	2.9

ploughs separate standard errors must be calculated for their means, and it is not feasible to calculate simple least significant differences for comparison of the treatment means. The variation among ploughing treatments was significant. Use of the standard errors will show that the following significant differences occurred.

Sitka spruce: No significant difference.

Lodgepole pine: Cuthbertson ploughs not significantly different.

Tunnel significantly better than both.

Table 4 Glenamoy, F values of individual components of the ploughing effects in the assessment results shown in Table 3.

Component	Ht	DBH
Cuthbertson v tunnel (means)	4.72	1
SMB v DMB	1	1
Linear effect of tunnel spacing	5.38	4.34
Significant value 5%	4.75	

Any value in the body of table 5 greater than the corresponding significant value in the bottom line indicates that the component is significant at the 95% probability level.

Table 5 Glenturk, Mean height (m) at age 12.

Species	SS	LP
Ploughing		
DMB	2.46	5.12
SMB	2.48	5.05
Tunnel	2.44	5.54
S.E. (DMB SMB)	.110	
S.E. (Tunnel)	.078	

WATER TABLE LEVELS

Water level readings in the pipes at Glenamoy at fortnightly intervals since 1973 have shown those in the tunnel ploughing treatments to be consistently lower than in either of the Cuthbertson ploughing treatments (Fig. 3). The fluctuations in the water table level follow a seasonal pattern, with the lowest levels in July. the increased evapotranspiration by the crop during this period undoubtedly contributes to a further lowering of the water table. The overall means for the water table levels by treatment for the 1980 (Table 6) show conclusively the effect of tunnel ploughing on reducing the water-table depth. Rainfall data from the nearby Agricultural Institute field station for the same period also show a seasonal pattern with the minimum rainfall during the period April-May.

ROOTING STUDIES

Root excavations involved the digging of pits 3m long by 2m wide beside randomly selected trees so that one side of the pit approximately bisected the root system. At the Glenamoy experiment the Sitka spruce in the tunnel plots had a uniform radial distribution of root and the depth of rooting was greater than in either of the Cuthbertson ploughing treatments. Most of the larger roots in the latter treatments were confined to the ribbon. Occasional fine roots crossed the furrow bottom (Figs 4a and 4b). In the tunnel ploughing treatments prolific rooting to 60-65cms was common. At Glenturk the rooting pattern of the lodgepole pine was also affected by the ploughing treatment. In the Cuthbertson ploughing treatments most of the large roots (over 1cm diameter) were confined to the top 20cm of the ribbon. There were few

roots in the furrow bottoms. The tunnel ploughing treatments had roots growing to the bottom of the tunnel at 80cm depth and radial spread of surface roots was symmetrical. During both excavations the tunnel drains were located and though they had shrunk considerably (45cm^2 at Glenturk, compared with the original tunnel plough orifice of 1036cm^2) they are still discharging water to the cut-off drains.

Table 6 Mean water-table depth for 1980 (cm) at Glenamoy 16/61

		Treatment		
DMB	SMB	T1.5	T3.0	T4.5
38	43	80	78	55

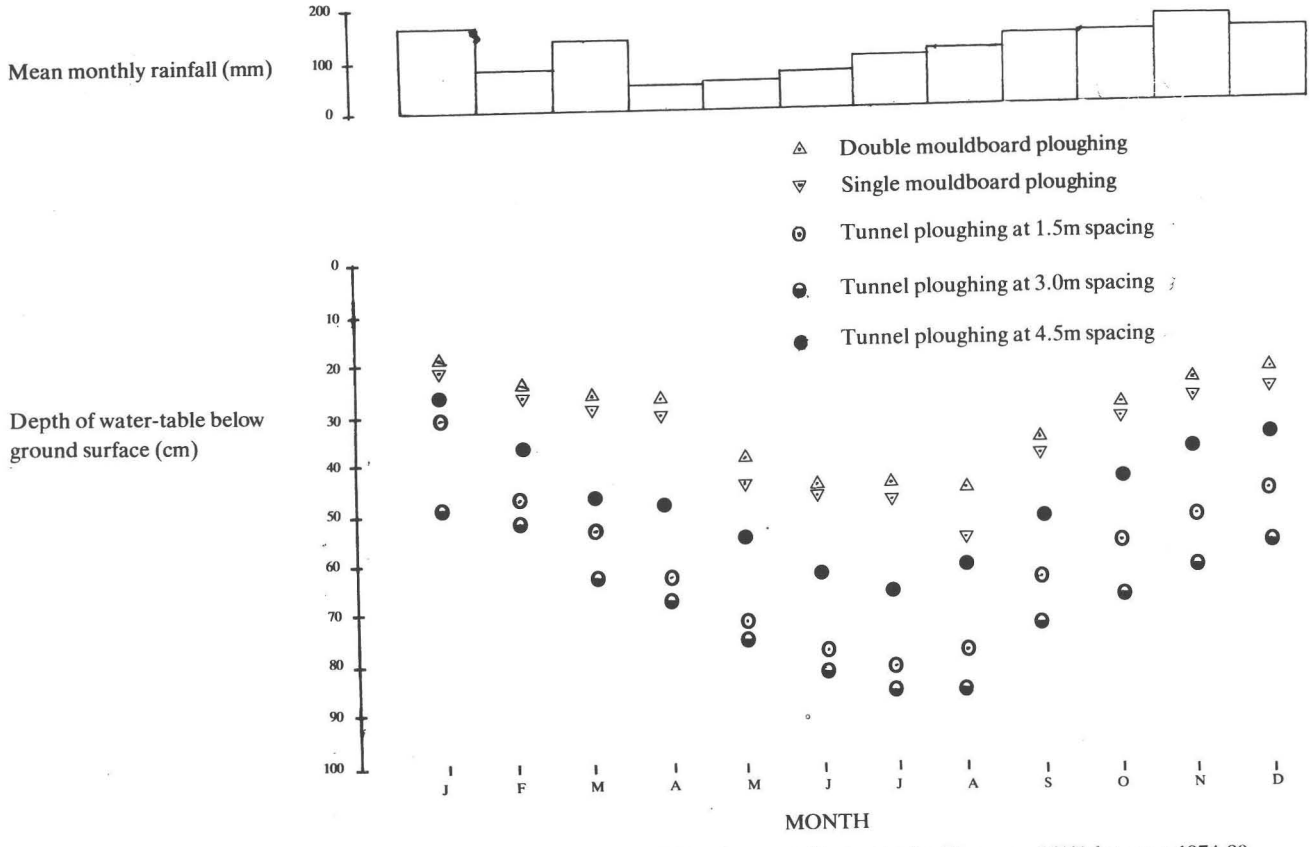
Standard error=3cm L.S.D. at 5%=6cm.

Effects on Peat

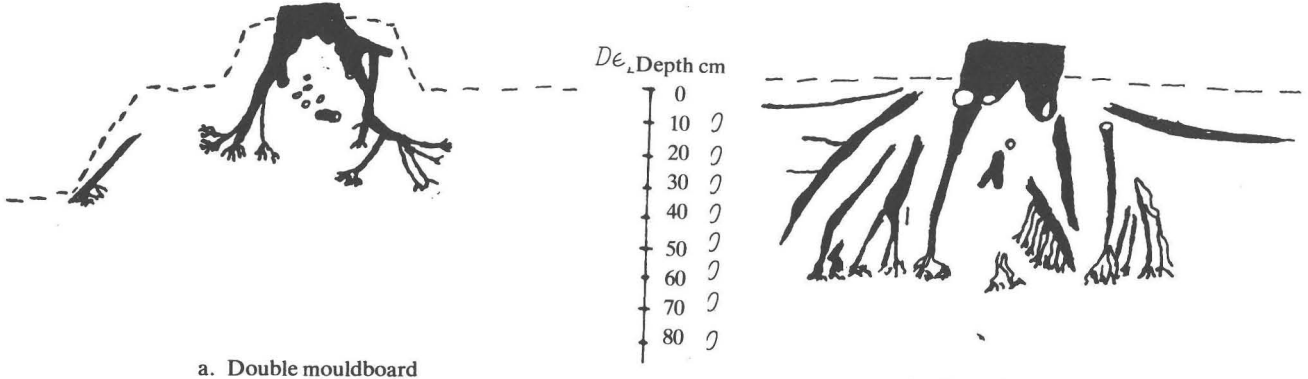
Samples for the measurement of peat physical properties reflecting the effects of two of the drainage treatments were collected in the Glenamoy experiment in late summer of 1977 by W. Burke, who has published the results in detail elsewhere (Burke 1978). Samples were taken at a range of depths in plots of SMB Cuthbertson and of tunnel at 1.52m Burke's data on air content and water content at the time of sampling are given in Table 7.

Table 7 Glenamoy. Air content and water content of peat in SMB and tunnel plots (both as % volume) as sampled in late summer 1977. Data from Burke (1978).

Sampling	water %		air %	
Depth (m)	SMB	Tunnel	SMB	Tunnel
.15	79.9	36.7	12.6	55.6
.30	89.6	54.0	4.3	36.5
.45	89.7	56.8	3.8	35.1
.60	91.5	75.1	2.5	17.1
.90	—	88.9	—	3.0



Average rainfall and water-table depths for Glenamoy 16/61 for years 1974-80



a. Double mouldboard

b. Tunnels at 1.5m.

Fig 4a & b. Typical root profiles of 15 year old Sitka spruce at Glenamoy 16/61.

Discussions and Conclusions

The present standard technique for forest establishment on peat is double mouldboard open furrow ploughing. This has proved to be satisfactory for early establishment and growth. Disadvantages of this technique now becoming apparent are the restriction of both horizontal and vertical root development which may give rise to relatively unstable crops and impedance of harvesting operations both by the elevated ribbons and the open furrows.

The experiments reported here show that the tunnel ploughing technique results in tree growth which is as good as or better than that following the present standard method, but it has the advantage that the lower water table (Fig. 3 and Table 6) and the better aeration (Table 7) encourage deeper root development. This, together with the more symmetrical habit permitted by the absence of open furrows and large ribbons is likely to result in more wind firm crops.

The absence of those furrows and ribbons also results in a more even forest floor leading to greater ease in harvesting operations. This is further enhanced by the uniform root spread, giving a greater load-bearing capacity to the peat surface.

The Glenamoy experiment suggests that tunnel drains spaced at 4.5m may be too far apart for optimum tree growth, and this question is now being investigated further.

Three tunnel ploughs are being used by the Forest and Wildlife Service at present. Large blocks have been successfully ploughed in counties Donegal, Mayo, Galway, Kerry, Cork and Offaly and it appears that the technique has widespread application on blanket bog peats deeper than about 1.5m provided that there is adequate slope to drain the water from the tunnels. It may also have some applicability in the preparation of road sites. There are some doubts at present as to its applicability on raised bog peats. It is intended to modify the plough design to make it suitable for shallower peats and two experiments examining tunnel plough spacing and planting position have been established in recent years.

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