Ir. J. agric. Res. **18**: 279-292, 1979

TUNNEL DRAINAGE OF DEEP BLANKET BOG

L. Grubb
An Foras Talúntais, Creagh, Ballinrobe, Co. Mayo

W. Burke
An Foras Talúntais, Kinsealy Research Centre, Malahide Road, Dublin 5

ABSTRACT

The tunnel plough, first developed in 1959, was designed to provide a cheap means of intensively draining deep blanket bog. In subsequent use of the plough, various difficulties were encountered and interest in it declined. Changed circumstances caused a renewed interest in the plough in recent years. Further development work on the plough is described as well as methods designed to test the suitability of peat for tunnelling. It is concluded that worthwhile improvements have been achieved in all aspects of the work.

INTRODUCTION

The concept of tunnel drainage was first introduced in 1959 (1) and provides a cheap method of intensively draining deep blanket bog. In Ireland such drainage was provided traditionally by manually constructed sod drains which had a labour cost only. The physical properties of the peat, the climatic conditions prevailing at Glenamoy and the drainage requirements of the peat have previously been described in detail (2).

The Glenamoy tunnel plough was developed to provide a means of mechanising a drainage system similar to sod drains. Its mode of operation consists of splitting the bog and pushing the top fibrous sod to both sides. Then the bottom part of the plough causes a section of gelatinous peat immediately below the fibrous layer to be extruded to the surface through the plough body. When the plough passes, the top sod returns to its original position leaving a covered drain (or small tunnel) in the peat.

On testing, the plough was successful on certain types of peat only and the difficulties encountered caused interest in the plough to decline. The major difficulties arose from:
a) Variability in the peat,
b) Method of mounting the plough on the tractor,
c) Accumulation of fibre on the cutting edges of the plough.

Variability
Variability in the peat meant that while the plough produced perfect tunnels in some conditions, the quality of the tunnels was poor in several places and in extreme cases no tunnel was produced.

Mounting
The plough was mounted on the 3-point linkage. In operation, when the plough is moving, e.g., at 3.2 km/hr it is lifting approximately 90 kg peat per second vertically through a distance of about 1 m through the plough body. This creates a very large downward force on the back of the tractor (Fig. 1). When the tractor and plough reach a soft spot they immediately sink, and not only is there a tractor sinkage problem but the tunnel is also broken at that point.

Fibre
The third major problem resulted from the fact that the forward edges of the plough orifice collected fibre, thus in effect eliminating the cutting edge, increasing frictional resistance, and reducing the effective size of the orifice. The consequence was that the plough failed to make a tunnel in marginally suitable peat.

In recent years two developments have brought about a renewed interest in tunnel drainage: i) The vast increase in land prices, and ii) the observation that Sitka spruce

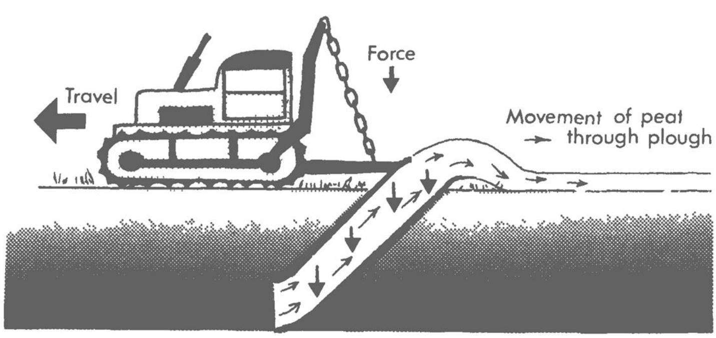

Fig. 1: Downward forces on plough and back of tractor

planted on tunnel-drained bog at Glenamoy had vastly superior root systems to those of trees on any other drainage treatment (3).

The concept of tunnel drainage has, therefore, been re-examined and improvements have been made both in plough design and in method of operation to overcome some of the earlier difficulties which were encountered. The purpose of this paper is to review these developments.

INVESTIGATION INTO THE DESIGN AND USE OF THE PLOUGH

With the renewed interest in tunnelling the whole concept of the plough and its use were re-examined. This was done on an *ad hoc* basis. Observations were made and tests and measurements were carried out where possible. The difficulties outlined above were all examined and in doing so such factors as orifice size, tunnel drain stability and effect of tunnelling on peat were also considered.

Variability in peat and determination of suitability for tunnelling

Because the plough was successful in certain types of peat only, a method was needed to determine in advance, areas suitable for tunnelling, thus avoiding unsuitable bog. Apart from the requirement of a deep peat with a smooth, gently sloping surface the two major factors that determine the suitability of the peat for tunnelling are: i) the consistency of the peat, and ii) the strength of the peat.

The consistency is important in relation to the flow of the peat through the plough and therefore in relation to the formation of the tunnel drain. If the peat is too soft it behaves like a liquid and at normal speeds tends to flow around the plough rather than through it, when the plough cavity becomes wholly or partially filled with peat. In this case the force created at the orifice by the forward motion of the plough at normal working speeds is not sufficient to overcome the back pressure of the soft peat within the plough body. If the peat is too hard, traction is a problem, and frictional and adhesive forces between the peat and the inside of the plough become greater than the force on the orifice, and in this case also the plough ceases to produce a tunnel. Intensive drainage is probably not required in such peat anyway. In practice it has been found that there is a well-defined range of consistency within which peat will flow through the plough, at normal working speeds.

As there is a relationship between the forward speed of the plough and the force at the orifice it follows in theory that, given sufficient velocity, liquid peat or even water could be forced up and out through the plough. It is also evident that in very soft peat the tunnel would collapse, due to peat flow, as soon as the plough had passed. Thus there is a minimum limiting strength in peat at which tunnel drains remain open. This suggests that some form of test for strength in the peat should indicate suitability for tunnelling.

Various methods of measuring strength were tried and a simple field vane test was finally chosen. The shaft of a Pilcon Hand Vane Tester was extended to permit its

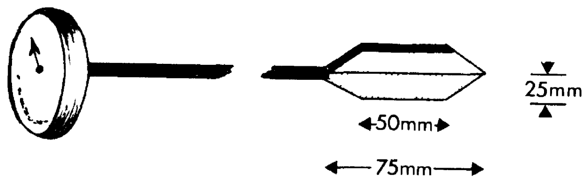

Fig. 2: Modified field vane

TABLE 1: Relationship between quality of tunnelling and shear vane readings for one specific run

Vane Reading	Comment
65	
90	No sod
90	
90	Broken sod
185	Bog firm — good tunnel formed
90	Broken sod—interrupted tunnel
135	Broken sod—interrupted tunnel
95	
110	
100	No tunnel
125	
140	
140	
130	Interrupted tunnel
140	
250 to 290	Very good tunnel formed over 100 m +

Direction of travel

Total length of run was about 300 m. Vane readings were taken at varying intervals depending on quality of sod extruded.

insertion in the bog to about 0.9 m. Various sizes and shapes of vane were tested and as a result vanes of the shapes and size shown in Fig. 2 were finally selected and fixed on the shaft. The top and bottom edges of the vanes were shaped and sharpened for easy insertion and withdrawal and the total vane area was 65 cm^2.

In practice the peat was sheared at a depth of about 0.6 m by the hand held vane. Observations on the quality of tunnels when related to a very large number of associated vane readings provided a scale indicative of suitability for tunnelling. The results of a typical run made in an area of variable peat are given in Table 1. This run extended over 300 m. The site was selected for test because of its very variable peat, ranging from soft and shaking to firm.

By using the vane in areas where tunnelling was successful as well as where it failed it was possible to arrive at the following empirical rule:

Vane readings greater than 150 — tunnel drains successful
Readings between 100 and 150 — success variable
Readings below 100 — no tunnels

The calibration of the modified vane in terms of shear strength proved difficult. Calculations based on the relative sizes and shapes of the two vanes indicate that readings taken with the large vane should be 13.5 times greater than those taken with the small vane for the same shear strength. However, field tests failed to confirm this value. In general, the small vane readings were very variable and much too low. We feel that this has been largely due to the nature of the peat. As the peat consists of gelatinous material in a matrix of fibrous strands the small vane can rotate between the fibres without shearing them. In effect the two vanes are testing different materials.

Thus, it seems more reasonable to use the calculated correction factor to calculate shear strength as determined by the large vane. This method gives a shear strength of 0.35 kg/cm^2 which is the threshold value for successful tunnelling.

In practice, readings greater than 300 were not common in undrained peat and it was not determined whether there was an upper (dry) limit at which tunnelling failed. It is probable that in such peat intensive drainage is not necessary anyway for grassland. Sites which mainly consist of peats with readings of greater than 200 are a practical proposition for tunnel drainage. Small areas with readings as low as 150 can be tolerated with careful management.

Further evidence of the relationship between shear vane readings and quality of tunnels is given in Table 2. In this table typical vane readings, taken in 1975, are given for sites successfully tunnelled in 1959, 1962, and 1974 respectively and where as far as can be ascertained the tunnels are still continuous. The similarity of the vane readings on all three sites is immediately apparent. The Van Post test was also found to be a simple practical test but it lacked the precision of the shear vane.

Mounting

The immediate problem with mounting arises from the downward thrust, on the plough sole and on the back of the tractor, resulting from the vertical lifting of the excavated peat through the plough. While various methods could be used to overcome this, e.g., increasing plough sole size or adding wheels or skids to the plough, it was considered that the best immediate solution was to mount the plough on a standard trailed plough frame. This method, while not necessarily the best, has been successful. The downward thrust on the plough is now taken up by the wheels on the frame, the function of the tractor is restored to the provision of tractive power and the total load is spread over a larger area of peat. Spot tests with a dynamometer has shown that the traction requirement is in the region of 1,350 kg to 3,150 kg for a tunnel plough with a cross-sectional area of 38 cm × 28 cm on a moderately soft peat.

TABLE 2: Some typical vane readings at 60 cm depth, and related data for areas successfully tunnelled in 1959, 1962 and 1974

Time of tunnelling	1959		1962		1974	
	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
Shear vane readings	217	257	337	259	243	272
	243	324	337	292	238	304
	244	303	270	245	202	291
	234	255	282	232	199	342
	255	173	273	281	217	258
	233	262	296	279	274	311
	225	237	256	246	267	310
	169	225	322	282	241	302
	258	273	283	275	234	302
	226	219	233	294	222	274
Mean	230	253	289	269	234	297
Standard deviation	25	43	34	22	25	24
Dry matter (g per 100 g sample)	8.9	10.0	7.8	9.5	7.8	8.1
Fibre % in D.M.	8.1	15.2	4.9	20.8	11.4	21.0
Cross-section of tunnel plough (cm × cm)	38 × 20	38 × 20	38 × 20	38 × 20	38 × 28	38 × 28
Cross-sections (cm × cm) of typical drains in 1975	28 × 5.0	20 × 4.0	10 × 8.0	10 × 8.0	18 × 7.5	42 × 18.0
Reduction in tunnel size %	81.6	89.5	89.5	89.5	87.3	28.9

Fibre

Fibre, collecting on the cutting edges, caused a problem and therefore attempts were made to quantify and qualify fibre content of the peat and evaluate them in relation to suitability of the peat for tunnelling. For this part of the investigation instruments were designed:—

a) To extract samples of the fibre from the peat.

b) To shear the peat in situ in such a manner that the main resistance to shearing was due to the contained fibres.

This approach did not give practical results. This was mainly due to the fact that fibre was not always dominant in relation to shear values. However, the testing resulted in an important observation in relation to the plough behaviour. It was seen that in peat with vane readings of 150 or greater, fibres did not collect to any extent. When the plough passed through "soft" peat (<150) it tended to collect fibre and when on the same run, it got back into firmer peat (>150), fibres continued to collect on the orifice edges. The reason for this was that in the firmer peat there was sufficient resistance for the cutting edges to shear the fibres, but in the soft peat there was not sufficient resistance and the fibres were dragged free and collected on the cutting edge. When the plough returned to firmer peat, in bad cases the fibre-covered edge could no longer cut the fibres in the peat, which therefore continued to build up, and tunnelling ceased. A small amount of fibre collection is not necessarily a problem in stopping successful tunnelling.

Table 2 also gives data on dry matter content of the peat, percentage fibre in dry matter, and sizes of typical cross-sections of the tunnel drains.

The variability in fibre is evident from the data presented. While the tunnel cross-sections are considerably reduced from the original size, they are still sufficiently large to function as drains, the areas are relatively dry and could be retunnelled if necessary. These areas have been relatively well managed, and have not been subjected to heavy traffic in the intervening period. Thus, it is evident that when tunnels are properly installed in suitable peat and subsequently well managed, they have a relatively long life.

Further data are given on fibre in Table 3. The fibre contents of the samples analysed here are relatively high. Taken in conjunction with the fibre data in Table 2 it is evident that fibre is always present in deep blanket bog in varying amounts. The difficulties encountered in practice of coping with variations in fibre and in shear strength led to attempts at the inclusion in the plough design of a feature for eliminating fibre build up on the cutting edges.

One attempt was to form the vertical cutting edges so that any fibre that caught on them was pushed to the surface of the bog with the rising section of peat from the tunnel and the cutting edges would thus be made self-cleaning. In this concept all cutting edges were made continuous. The top and bottom horizontal cutting edges sloped back at an angle and were continued outside the plough body. Any fibre collecting on those edges would be pushed back along them and off their ends by the forward motion of the plough. The vertical side edges were continued unbroken to the surface. Both the forward motion of the plough and the rising section of excavated peat would push collecting fibres along those edges until it dropped off at the surface. This was the simplest concept but it and other attempts have so far been only partly successful and require further development.

Size and shape of orifice

The size and shape of the orifice should be considered from two points of view: i) Optimum design for tunnelling, and ii) optimum design for drain stability.

TABLE 3: Fibre content of samples wet and dry peat[a]

	Dry matter (g/100 sample)	Fibre (g)	Non fibre D.M. (g)	Fibre as % D.M.
Site 1 Wet	7.0	5.7	1.3	81
Site 2 Wet	8.2	4.9	3.3	60
Site 1 Dry	6.8	5.6	1.2	82
Site 2 Dry	8.3	6.0	2.3	72

[a]The terms wet and dry in this table refer to a subjective assessment of surface conditions at sampling time.

TABLE 4: Comparison of tunnels made by ploughs with different sizes of orifice, and corresponding shear vane readings

Orifice size	Dimensions of tunnel (cm × cm)	Shear vane reading	Reduction in tunnel size %
	37.5 × 11.5	209	59.5
	32.5 × 12.5	251	61.8
38 cm × 28 cm	27.5 × 12.5	177	67.7
	30.0 × 9.0	192	74.6
	30.0 × 7.5	122	78.9
Mean	31.5 × 10.6	190	68.5
	20.0 × 10.0	212	74.5
	17.5 × 11.5	244	74.3
28 cm × 28 cm	7.5 × 5.0	204	96.8
	30.0 × 9.0	213	65.6
	25.0 × 11.5	270	63.3
Mean	20.0 × 9.4	232	74.9

An important factor in relation to tunnelling is the ratio between the cross-sectional area, and the length of the perimeter, of the orifice. This determines the ratio between the force driving the peat up through the plough and the frictional force resisting peat flow. Similarly the height and distance through which the peat must be lifted through the plough are also important as factors in frictional force and also as the determining factors in the weight of peat which is being extruded, and which acts downwards against the force generated at the orifice by the forward motion of the tractor. On purely theoretical grounds a circular orifice is the optimum shape and the larger the orifice the better. Similarly the shorter the path of travel through the plough the better. A circular orifice has disadvantages related to construction difficulties and also to tunnel stability and has not been tested in the field. However, constructional problems could be easily overcome.

The original tunnel plough had an orifice 38 cm high by 20 cm wide and was designed so that the roof of the tunnel was about 40 cm below the bog surface. The 40 cm depth was based on the observation that at approximately this depth there was a visible change from more fibrous peat above to more gelatinous peat below. This plough worked reasonably well. In the second plough the vertical dimensions were retained and the orifice width was increased to 28 cm, to provide a greater relative pressure-to-resistance ratio on the peat being extruded through the plough. This plough was more efficient than the original one but power requirements and mounting problems increased. In the third plough the sole plate was raised so that an orifice (28 × 28) cm^2 was formed.

The type of peat in which this plough could operate was restricted. Comparisons of the performance of ploughs with two different sizes of orifice in relation to vane readings are given in Table 4. Measurements were made only at points where tunnelling had been successful. It is evident that:

a) The drains resulting from the larger plough have stabilised with larger cross-sections than those from the smaller plough.
b) The vane readings associated with successful tunnelling by the larger plough are lower than those associated with successful or even partially successful tunnelling by the smaller plough. This is not presented as conclusive proof that the larger orifice is better but it bears out observations made at the times of tunnelling on the superiority of the larger plough.

The general conclusion that has been reached is that an orifice about 38 cm deep × 28 cm wide is near the optimum for present purposes. It was also observed that after tunnelling there is generally an initial almost immediate reduction in the size of cross-section followed by a much slower gradual reduction. The amount of the initial reduction in size and the rate of subsequent reduction are determined by the strength of the peat.

Stability of tunnels

In undrained deep peat the watertable is normally near the surface and thus there is an increase in water pressure with depth. The peat in which the tunnel is formed has low inherent strength and is very subject to plastic flow. The sides of the tunnel are subject to forces related to hydrostatic and hydrodynamic forces in the peat, and also the weight of the peat above.

These forces are greater towards the bottom of the tunnel and as the peat is usually weaker at that depth than higher up, there is a general tendency for some collapse of the tunnel floor and side walls. The final form of the tunnel in soft peat is dominantly triangular in cross-section and in theory the floor is nearer the surface than the depth at which the bottom of the plough was drawn.

Vane readings taken at different depths in drained and undrained peat are given in Tables 5 and 8. Irrespective of drainage it is seen that the peat gets weaker with increasing depth. This supports the hypothesis that the optimum depth for the tunnel for stability is between approximately 30 and 60 cm.

For tunnel drains to be of use in agriculture they must be capable of withstanding a certain amount of traffic. A simple method was designed to test their capacity to

TABLE 5: Shear vane readings at different depths

Depth below bog surface at which vane readings were taken	60 cm	90 cm	120 cm
Field drains at 90 cm—Site 1	262	211[a]	187
Field drains at 90 cm—Site 2	207	142[a]	152
Mean	235	177	170
Field drains at 60 cm—Site 1	224	199	209
Field drains at 60 cm—Site 2	264	178	162
Mean	244	188	186

[a]Mean of 20 readings — all others mean of 10 readings

TABLE 6: Effect of severe tractor traffic on tunnel drains in moderately soft peat 1 year after installation

		Average vane readings					Cross-sectional area of tunnels (cm^2)			Distance (cm) from bog surface to bottoms of tunnels	
Sample point No	Van Post values	No drains	Before cross traffic	Before up and down traffic	After cross traffic	After up and down traffic	No traffic	After cross traffic	After up and down traffic	Before traffic	After traffic
1	7	227	232	263	228	241	613	258	723	76	86
2	8	216	247	261	243	258	726	406	503	81	86
3	8	237	239	287	253	260	542	484	542	86	91
4	8	274	239	244	234	253	419	452	503	84	84
5	9	242	251	269	224		658	413		91	84
6	8	252	221	255	210		697	310		84	79
7	8	247	228	267	249		755	432		81	89
8	8	252	236	282	255		723	387		88	81
9	9	203	264	269	241		839	484		94	81
10	8	253	262	274	235		661	419		89	81
11	8	212	260		233		665	452		89	81
12	8	248	252		226		697	355		81	86
Mean		239	244	267	236	253	666	404	568	85	84

do so. To carry out the test an area of moderately soft peat was selected and tunnelled in autumn 1974. At this stage tunnels were carefully exposed at sample points. The dimensions of the tunnel and the depth of the bottom of the tunnel from the surface were noted. A standard MF 135 tractor fitted with rear twin wheels and carrying a load of 0.5 tonnes on the rear linkage was repeatedly driven slowly over the drains at 0.8 km/hr. The tractor was driven along some drain lines, and across others. Further measurements were made of drain cross-sections and depths to the bottom of tunnels from the surface. In addition, humification values (van Post) and shear vane readings were also made. The data are summarised in Table 6 which is presented primarily to show the effect of severe tractor traffic on tunnels in moderately soft peat.

The data indicate that heavy tractor traffic reduced tunnel size but did not reduce the drain depth. The major conclusion to be drawn from Table 6 is that tunnel drains properly installed in suitable peat can withstand occasional traffic, but frequent heavy traffic would not be advisable, unless further experience indicates otherwise. Tunnel drainage may be unsuitable, therefore, for draining peat for silage conservation, or other machinery-intensive farming operations.

Some typical cross-sections of drains in this site are shown in Fig. 3. While the cross-sections shown here are smaller than those given in Table 6 they demonstrate two things:

i) Drain cross-sections vary considerably (probably due to variation in the peat but they may also reflect to some extent the variable performance of the tunnel plough).

ii) Although the cross-sections vary greatly, the tunnels are generally large enough to provide adequate and continuous drainage.

Effects of tunnelling on the peat

Observations at Glenamoy have shown that animals grazing on drained bog appeared to make the surface more firm (2). Some vane measurements were made to test these observations.

Table 7 shows some shear vane readings made at and near the surface, and related to drainage and management. Where the drained sward was intensively grazed, vane readings and therefore the strength were increased at both the surface and 0.15 m depth. The increase in mean strength can be attributed to a drier surface, and to compaction of the drained surface by the hooves of the grazing animals. No data on grazed, undrained peat are given as it is not practical in general to graze intensively undrained deep peat.

Table 8 gives mean vane readings for nine depths on two sites as follows: i) Tunnel drained at 2 m spacing by 0.75 m deep in 1974, ii) adjacent undrained site. The vane readings were taken in November 1977. In both cases 10 vane readings were taken for all depths.

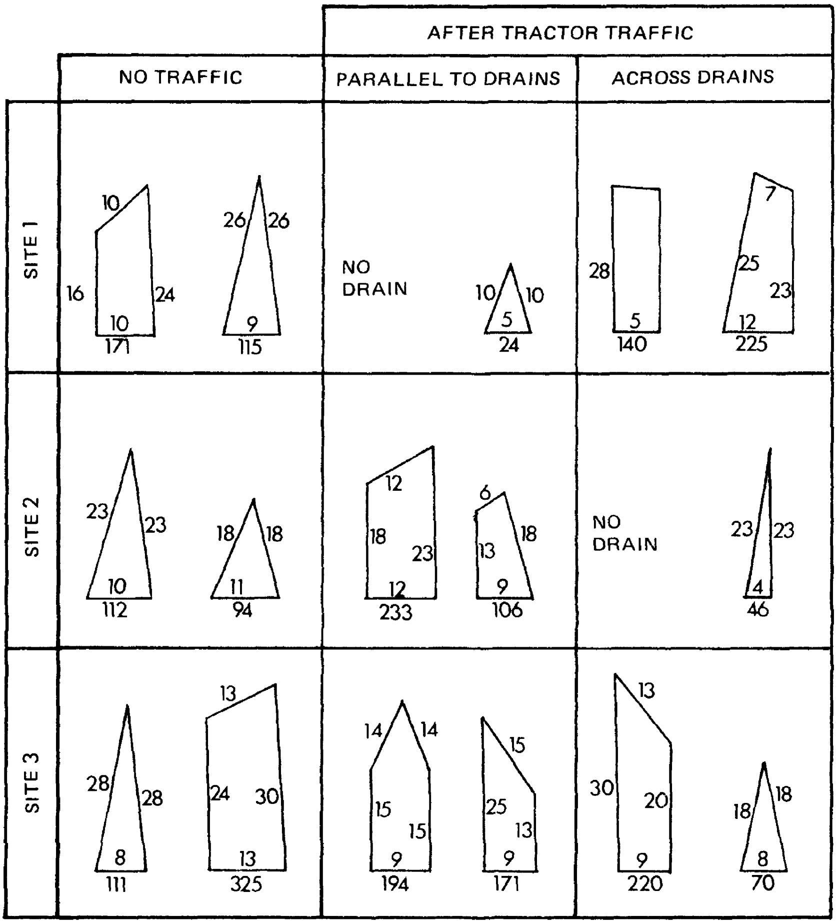

Fig. 3: Some typical cross-sections of drains: 1) no traffic; 2) after several passes of tractor along the line of the drains; 3) after several passes of a tractor across the drains

NOTE: Dimensions of drain (cm) are shown on perimeters of sections and cross-sectional areas (cm^2) are shown below cross sections

TABLE 7: Effect of drainage and management on shear vane readings at and near the surface; readings were taken with a smaller vane 2.5 × 2.0 cm and adjusted to the larger size vane

Treatment	Undrained, no grazing		Drained, intensely grazed	
	Surface	15 cm depth	Surface	15 cm depth
Mean[a]	127.7	170.2	214.1	349.7
Standard deviation	67.0	44.7	43.0	52.3
Max	316.0	252.8	278.1	450.9
Min	29.5	75.8	42.1	84.3

[a]Mean of 20 readings

TABLE 8: Comparison between shear vane readings at nine depths in tunnelled and adjacent undrained peat

Depth (m) below surface at which reading was taken	0.075	0.15	0.3	0.45	0.6	0.75	0.9	1.05	1.2
					Tunnelled area				
Mean of 10 vane readings	350+	350+	341	271	255	225	233	228	224
Standard deviation	0	0	18	36	31	23	15	15	23
					Undrained area				
Mean of 10 readings	350+	350+	295	230	217	199	196	188	184
Standard deviation	0	0	44	31	19	21	20	20	16

Table 8 shows that tunnelling has resulted in an increase in vane readings at all depths tested, below 0.15 m. This holds for readings up to 0.4 m below the tunnel floor, and indicates that the peat is losing water from well below the drain bottom — a phenomenon already observed at Glenamoy and elsewhere (2). At depths shallower than 0.15 m there was no difference between the vane readings on both sites, but all values lay outside the range of the vane.

SUMMARY AND CONCLUSIONS

Originally the idea of a tunnel plough derived from consideration of the drainage properties and drainage requirements of deep blanket peat in the West of Ireland. At an early stage of the investigation it became evident that only partial success in drainage could be achieved using the criteria normally applied for rigid specifications for drainage on more permeable soils. However, it was also observed that an intensive drainage system at about 3.5-m spacing gave sufficient drainage for grazing with light animals for about 6 summer months and some winter grazing. The very intensive system that was needed, ruled out conventional drainage because of cost.

These considerations led to the development of the tunnel plough. It was found that the original plough was difficult to use properly and it was largely abandoned until recent developments caused a renewed interest in it.

In the re-examination of tunnelling that followed it became obvious that full systematic testing was not practical. Thus, various tests were made on the peat, and plough performance was also observed. As a result the plough was modified.

At this stage of the work it is concluded that worthwhile modifications have been achieved both in the plough and its mounting. A useful simple method has been developed to permit assessment of peat suitability for tunnelling.

Regarding the application of the plough it is considered that it is a very useful implement for the drainage of deep blanket bog for forestry. In agriculture, its main use at present probably lies in providing a cheap means of drying large areas of soft to moderately firm blanket bog, thus permitting their semi-intensive use as pasture and taking them to the stage where they are dry enough and productive enough to warrant more intensive reclamation. However, where areas of deep blanket bog are variable in quality and intensive utilisation is planned, the gravel plough (4) is probably a more practical method of draining the bog for agriculture.

ACKNOWLEDGMENTS

The authors with to acknowledge the assistance of the following: Liam Burns, Glenamoy, for field testing and peat classification; Michael Meenaghan and Jerry McDonnell, Glenamoy, for design, fabrication and testing; and the Forest and Wildlife Service for providing suitable crawler tractors and plough frames for testing the ploughs.

REFERENCES

1. Armstrong, J. J., Burke, W. and Quinn, E. A new drainage plough for peatland. *J. Dep. Agric. Fish. Repub. Ire.* **57**: 149, 1960.
2. Burke, W. Long-term effects of drainage and methods of utilization on some physical properties of deep blanket bog. *Ir. J. agric. Res.* **17**: 315, 1978.
3. Dillon, J., Carey, M. L. and O'Carroll, N. The establishment and growth of coniferous tree species on blanket peat in the west of Ireland. *Proc. 5th Int. Peat Congr., Poznam, Poland,* p. 187, 1975.
4. Burke, W. and McCormack, P. Gravel drains for peat. *Ir. J. agric. Res.* **8**: 285, 1969.

Received August 31, 1978