# AFFORESTATION OF PEAT SOILS

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THIS paper proposes to deal in broad outline with the place of peat soils in Irish Forestry, to summarize experience gained to date, and to examine generally the technical problems involved in afforestation on peat.

In order to see the problems in their proper perspective it is necessary to sketch in the background of forestry in Ireland and to relate it to European conditions in general.

## The Place of Peat Soils in the Irish Afforestation Programme

Apart, perhaps, from the blanket bog areas of the west, Ireland is situated in the temperate forest zone and was, in fact, heavily forested up to early historic times. Yet its forests dwindled until they occupied little more than 1 per cent of the land surface in scattered plots and these woods were mostly of artificial origin. Before World War II these woods supplied less than 10 per cent of the country's total timber requirements. In order to fulfil the forest policy, which is to supply as far as possible all our timber needs, it is necessary to make a substantial withdrawal of lands from present agricultural use. In order to create the least possible disturbance of agricultural production this must be made almost entirely from what, in the official statistics, is classed as " other lands," i.e., land which is neither arable in the broadest sense of the term nor existing woodland. The official description is " grazed and barren mountain, turf bog, marsh, water, roads, etc." The area is roughly 5¼ million acres, of which about 60 per cent is estimated to be peat-covered.

The Irish climate, with its mild winter and abundant rainfall, favours gramineous vegetation and has given agriculture a strong bias towards stock-raising on open range; and rough grazing has always played an especially important role in the economy of the farm. It is extremely difficult to purchase the better class rough grazings, which are the most productive forest sites, giving very high yields of spruce—up to 200 cubic feet or 6 tons of timber per acre per annum. In practice it is necessary to spread acquisition over a wide variety of soil types and to accept a high proportion of peat

soils of varying degrees of fertility and suitability for tree growth. In recent years it is estimated that more than half the plantable land acquired would come within the definition of peat (with peat 12″ deep or more). In terms of area this has meant the acquisition of close on 10,000 acres of peat soils per annum. It will be appreciated, therefore, that afforestation of peat is relatively more important to Ireland than to almost any other country.

### Peat Afforestation on the Continent

On the Continent in France, Germany, Denmark, the Netherlands, the pressure on peat lands has been towards agricultural reclamation. This followed, naturally, from greater density of population, intensive land use and scarcity of arable as compared with forest land. In Scandinavia the forest industry was based on slow growth rates, long rotations, low cost production methods; and the low stumpage values of timber up to World War II precluded expensive preparatory work on bogland. Consequently, the approach was highly selective and only the more fertile peats in the drier and warmer climatic regions were considered capable of economic afforestation. It will be seen that Continental experience is, on the whole, limited and the probabilities are that Britain and Ireland must play a leading part in future developments in this line.

### Peat Afforestation in Britain

It is necessary to pay more detailed attention to British work on afforestation of peats. Britain has large areas of peat, especially in the high-rainfall areas of the North and West of Scotland and in the Welsh mountains. Private planters in Scotland tackled peat areas and imported from Belgium the technique of turf planting, i.e., inverting a square sod of surface peat and planting the tree in this sod instead of burying its roots in a pit. This proved a marked improvement on previous methods, especially with spruce, and the Research Staff of the British Forestry Commission concentrated from about 1927 onwards on applying machinery to turfing and draining, the aim being more thorough preparation of the planting site at reduced cost. With the development of efficient tracked Diesel tractors and the design of special heavy peat ploughs, success was achieved; and it became practicable to plough with furrows and continuous inverted furrow slice (or " ribbon ") at 5 or 6 feet espacement. This treatment resulted in more effective drainage and aeration than was economically possible by hand methods, and trees did better on the ribbon than on turves. This ploughing technique, or some adaptation of it, has become standard practice in Britain on peat soils, except where rock outcrops or steep slopes make it impracticable.

Side by side with the development of the mechanical treatment of the planting site went investigation of the chemical requirements

for satisfactory tree growth and the deficiencies of peat soils in this regard. After some rather desultory initial experiments with lime and a variety of fertilizers, it became clear that phosphate was easily the most significant mineral deficiency in peat soils, and small applications of phosphatic fertilizers (e.g., Basic Slag, Ground Mineral Phosphate) have given remarkable results even on Scirpus moorland. Satisfactory growth of a variety of conifers has been obtained over a period of some twenty years as a result of initial dressings of as little as 2 oz. per plant, while untreated control plots have stagnated or died.

While many problems will undoubtedly arise in the future, research has emphasized two basic necessities in peat afforestation: (1) Intensive drainage and aeration by ploughing at close spacing, and (2) addition of phosphates. It appears that for certain pines at least, the mineral requirements are extremely low and that small applications of phosphate can have an enduring beneficial effect on tree growth. In contrast with agricultural crops, trees remove very little mineral matter from the soil and the closed circulation of minerals, soil-roots-leaves and twigs-soil, contribute to this result. But the phosphate seems also to accelerate the decomposition of peat and the release of nutrients by fungal or mycorrhyzal action. The exact *modus operandi* is still a matter of conjecture and is a field of fundamental research still largely unexplored.

## Peat Afforestation in Ireland: Introduction of New Techniques

The Irish Forest Service followed with keen interest these developments in Britain and in 1951, when machinery imports again became freely available after World War II, twenty-two tractor-and-plough units were purchased. Considerable experience has been gained in the use of this type of equipment and ploughing is now accepted practice on peat soils. The use of phosphatic fertilizers has also been adopted on poor sites and preliminary results are promising. The groundwork had been done in Britain and Irish investigations are concentrated on ascertaining the optimum quantity, form and time of application according to site fertility and tree species.

As a consequence of these developments it is now possible to establish plantations on bogland which requires intensive preparation and application of phosphates within an all-in cost of £20, including fencing, draining, ploughing, plants, planting and fertilizing. Percentage of planting failures is reduced and little or no cleaning of competing vegetation is required. With costs more than halved as compared with hand methods and satisfactory growth, afforestation of bogland can be an economic proposition.

USE OF PINUS CONTORTA ON PEATS

At this stage it becomes necessary to refer to what is, perhaps, the greatest divergence as between British and Irish afforestation practice. Irish foresters have been cautious in the use of spruce (which is regarded as a more exacting " successor " species) on poor peats, especially when heathers (*Calluna* and *Erica* spp.) are present in any quantity. In such cases reliance has been placed on *Pinus contorta* (Douglas), an importation from the Pacific coast of North America. Although this species is widely distributed in its native habitat where it is estimated to account for one-third of the total growing stock, it has been little studied for afforestation work by United States or Canadian foresters. It is practically unknown in artificial afforestation outside Britain, New Zealand and Ireland. New Zealand has planted only about 3,000 acres of *Pinus contorta*, and in Britain its use has also been very limited—although its value as a " pioneer " is coming to be more highly appreciated.

In Ireland *Pinus contorta* has proved invaluable, frequently thriving in conditions where everything but Mountain Pine (*Pinus montana*), which is hardly a timber tree, failed. The oldest forest plot is now thirty-three years planted; but there are some 3,000 acres twenty years or over; and some 20,000 acres under twenty years. Almost all is on peat soils or on soils with at least a skin of peat. In view of the special Irish experience with this species some silvicultural notes with special reference to peat soils may prove of value.

This species has a wide range of variation from the Shore provenance, *P. contorta*, true or restricted sense, to the inland mountain, Lodgepole type, *P. contorta, var. Murrayana, P.C. var. latifolia*, reaching altitudes of up to 11,000 feet. Several distinct provenances occur in Irish forests but preference is given to the lowland or shore type, seed supply being received from the Lulu Islands off British Columbia. This is of more rapid height growth, with dense canopy and is generally more aggressive than the mountain types but stem form is more variable. 1 + 1 plants (one year in seed-beds, one year in transplant lines) are usually well rooted and are most satisfactory for cheap turf or ribbon planting with a dibble. Under favourable soil conditions growth in early years is rapid and this has led to difficulties on peats of moderate to high fertility, e.g., on flushes with strong *Molinia* dominant, *Calluna* sub-dominant. In such circumstances strong, bushy crowns are formed with leaders of 2-3 feet annual growth within three to four years of planting; and many plants tend to heel over when 4 to 8 feet high, especially on exposed sites. Check follows and the trees may grow on vertically but with a twisted butt which detracts from the timber value. On fertile peats there is some evidence that fast grown stands may never regain stability; there are examples of stands in the 40-50 feet height class with all stems leaning away from the wind and numerous recent windfalls. On the other hand a recent survey (1952) of all stands seventeen years and upwards indicates that the great

majority had an adequate proportion of straight stems. It seems that on less fertile peats growth is reasonably slow and upright, especially when the peat itself is firm. or made so by deep drainage. Experience as regards stability points to three significant factors: (1) Avoidance of fertile peats capable of growing spruces; (2) intensive, deep drainage; (3) early attention to thinning—as soon as advanced groups are fit to prune. Further investigation of various provenances in regard to stability and stem form is also indicated.

At the other end of the scale, on the poorest peats characterized by the presence of *Scirpus caespitosus* and weak-stunted growth of *Calluna*, *Erica tetralix*, *Eriophorum*, *Molinia*, etc., *Pinus contorta* tends to go into prolonged check with short yellowish needles persisting only one year. On such sites, there are indications that small phosphate applications can have a dramatic effect which persists over many years. Pinus contorta has proved extremely sensitive in its response to phosphate and there is grave danger of forcing frowth to the point of instability. Determination of critical rate of application, therefore, requires the most careful investigation and trial plots were laid down in 1952-53.

### Use of Spruce

The new afforestation techniques also called for a new approach to selection of species. Owing to difficulties in establishing spruce on peats of intermediate fertility by the older methods, *Pinus contorta* came to be used as a substitute. It now seems evident that these are better suited to Sitka Spruce, with ploughing and phosphate application to overcome the initial check customary with this species. It would be dangerous, however, to push spruce too far on infertile peats where the crop might go into check after a promising start boosted by phosphate. On the more fertile moist peat types (*Molinia* and *Juncus* types) spruce is the normal selection—Sitka in the western and exposed areas, Norway in the Midlands and valley bottoms where spring frosts are severe.

### Classification of Irish Peats

In the second part of this paper it is proposed to examine the problems of forestry in relation to the two main Irish peat types—Raised and Blanket Bogs. The third general classification, Valley Bogs, covers a restricted area and from the practical forestry angle approximate either of the two main types.

### Raised Bogs

These are well-defined entities, usually with a considerable depth of peat, the upper layers consisting of only slightly humified, highly acid, *sphagnum* peat. While there is evidence from estate planting that, with heavy expenditure on drainage and fertilization, trees can be made to grow on *sphagnum* peat, the Forestry Division has not

undertaken any large-scale afforestation of virgin raised bogs. In many parts of the Central Plain where these bogs occur, turbary for local users is already scarce and the raised bogs still extant are likely to be developed within reasonable time by local initiative, by Land Commission turbary schemes, or by Bord na Mona. Systematic development for fuel is accepted as a priority use by the Forestry Authorities and the cut-over bog will normally be a better forestry subject than the virgin bog.

Unfortunately, much private turf-cutting has been haphazard, and the cut-over has been left in a very irregular and uneven state, with fall for drainage difficult or impossible. These difficulties are accentuated where first cutting failed to reach the marl base and second cutting followed, perhaps generations later, without any proper face-bank or method, leaving high banks of *sphagnum* peat alternating with deep bog-holes. Such areas cannot be afforested economically and are in danger of remaining a permanent eyesore of waste land. On the other hand there is adequate evidence of successful forestry on systematically worked raised bog under the traditional hand methods in which the top layer of young *sphagnum* peat was discarded as fuel and thrown back to form, with the spoil from various depths, the new levelled surface. The Forestry Division includes such afforestation in their normal programmes at many forests, using Scots Pine, Norway Spruce and *Pinus contorta* as the main species. Provision of satisfactory drainage outfalls is the most critical factor.

It is noted with satisfaction that Bord na Mona, in its operations, is mindful of the state of the cut-over bog, providing for an adequate depth of spoil on a level cut-over surface and for satisfactory drainage outfalls. The cut-over resulting from use of the Bagger machines should not be markedly different from that after hand cutting and the afforestation problems are likely to prove similar.

In the case of raised bog developed by milled peat methods the cut-over will usually consist of undisturbed bottom peat of the alkaline fen type. This is of high fertility and afforestation should not present insoluble problems.

Irish Central Plain bogs contain unusually large tree stumps and often entire boles of *Pinus sylvestris*. As well as presenting a problem to the fuel cutter these may prevent the use of mechanical drainage equipment and increase afforestation costs considerably. The depth of spoil over the marl needs also to be considered. In view of the unfavourable nature of the substrate, it seems desirable to leave not less than 3 feet of spoil in order to allow for settlement and losses by decomposition.

The decision on final use as between agriculture and forestry of cut-over raised bogs is, of course, a matter of high policy but the case for forestry may be put briefly as follows: Ireland is generously endowed with arable land by European standards—3-4 acres per head. On the other hand she is critically short of forest, with only

1/10th acre per head. She produces an agricultural surplus but only a fraction of her timber requirements. There is, therefore, a strong case for reversing the Continental order of priority as between agriculture and forestry, especially while output from the present arable acreage remains so much below its potential and could be raised substantially at a low " per unit " cost. Finally, planting of cut-over bogland would obviate the necessity for transferring a corresponding acreage of rough grazings from agricultural to forest use.

### Blanket Bogs: Origin and Variations

Blanket bog covers large expanses in the western counties, especially in Kerry, Galway, Mayo and Donegal, where low summer temperatures, high rainfall, constantly high relative humidity and acidic rocks prevail. While ecologists attempt to draw sharp genetic distinctions between blanket, valley and raised bog and heathland, from the forestry point of view there appear to be many gradations between the types. While blanket bog is definitely associated with well-recognized climatic conditions its degree of development or maturity is greatly affected by soil and topography, base-rich, free-draining soils and the steeper slopes being resistant to the peat-forming process. While in the case of the broad, flat, pool-studded expanses, peat formation may have begun under lake conditions, it is clear that such conditions are not a necessary pre-requisite for blanket bog formation. Numerous observations over a number of years of western soil profiles under blanket bog suggest strongly that on sloping ground and in undulating terrain, the post-glacial soils were rather coarse, free-draining, acidic sands and gravels such as would support a pine-heath vegetation. Under a leaching climate a strong podsol profile developed with impermeable hardpan and consequential drainage impedance at the mineral surface. Then followed the development of an exaggerated $A^0$ podsol horizon to a thickness usually of several feet. The blanket bog is, therefore, very frequently a variant of the podsol under Sub-Atlantic climatic conditions. Under drier conditions the parent material would give rise to heath or dry pine forest. In fact on a steep, sandy ridge (where drainage conditions are naturally very favourable) surrounded by typical pool peat at Oweninny, Co. Mayo, there is developed a strong heath community (Callunetum) on a dry, firm, heather peat which, however, exceeds 2 feet in depth.

Even within the extreme oceanic climatic region it should be realized that, in response to soil, topography and seepage of mineral-charged water, there are numerous variations of blanket bog which are of significance to the forester and which (in addition to the important exposure factor) have been taken into account in choosing the initial areas for afforestation.

Outside the extreme western type drier variants of blanket bog occur under the influence of local climate in the mountain ranges.

On the gentle slopes of the Old Red Sandstone hills of East Clare and South-east Galway—the Slieve Aughty mountains—apart from hollows, the peat is firmer and drier and usual depth is less than 18 inches as compared with 24-28 inches under similar topographic conditions in the extreme West. Again, on the Old Red Sandstone ranges of the South (Galtees, etc.) on gentle slopes and plateaux, firm peats of less than 12 inches in depth over podsol with hardpan are frequent. In the vegetation *Calluna* is dominant over a continuous but diffuse, layer of *Molinia*, with *Scirpus* occasional. This appears to be a transition between blanket bog and heath, the latter community being of extremely limited occurrence under Irish climatic conditions.

### Afforestation on Blanket Bog and Related Types

Some private attempts at afforestation of western blanket bog were made during the last century but these were usually on a small scale, exact records of treatment are lacking, and in general, little success was achieved. Probably the most ambitious effort was at Ballynahinch (Co. Galway), where a wide variety of species (e.g., Austrian, Corsican, Scots and Maritime Pines, Norway Spruce, *Picea alba*) were planted some fifty to seventy years ago. These failed to form a crop but stunted specimens still survive, especially of *Picea alba*. Plantings on adjoining mineral soils did well.

The only other large-scale effort before the establishment of the Forest Service was at Knockboy (Co. Galway) by the Congested Districts Board between 1891 and 1900. About 1,000 acres were planted, 3,000,000 trees and some twenty-five species then known to European foresters being used. The area was particularly ill-chosen and would afford little prospects of success even by up-to-date methods. The plantation is one mile from the coast on rising ground, elevation 50 ft.-250 ft., in a most exposed peninsula, open to Atlantic winds from north, south and west. The southern half was on poor peat about 10 feet deep and, after repeated planting failures, was abandoned to turbary use. The northern half varied from solid granite outcrop to peat of depths up to 3 feet over solid granite. Mountain pine scrub has reached 8 feet in height on this peat but other species made little headway except in sheltered hollows amounting in all to about 15 acres where the peat had an admixture of mineral matter. On these pockets, *Pinus radiata* has done best (50 ft. high, 10 ins.—Q.G.B.H.). *Cupressus macrocarpa* and Maritime Pine also did well, followed by Sitka Spruce, *Thuya plicata*, *Abies alba*, Grey Poplar (*P. canescens*).

After this inauspicious start the State did not look favourably on projects for large-scale afforestation of western peats. After the establishment of the Forest Service from 1904 onwards attention was directed towards the Midlands and the south-eastern highlands where conditions were more favourable. About 1935, after considerable experience with peat in the east, work extended to the Slieve

PHOTOGRAPH I

NEPHIN BEG PILOT PLOT, JULY, 1951

Drain and ribbon after peat draining plough, turves beside drain. Vegetation beginning to respond, e.g., *Myrica* 10 ins. (against rubber boot).

PHOTOGRAPH II

NEPHIN BEG PILOT PLOT, APRIL, 1954

Area treated with Basic Slag on right of soil sampler; untreated area on left. *Molinia* extremely vigorous, especially along slagged "ribbon." *Calluna* and *Myrica* also show strong response.

PHOTOGRAPH III

NEPHIN BEG PILOT PLOT, APRIL, 1954

*Pinus contorta* plant on right treated with 2 oz. Basic Slag. *Molinia* and *Myrica* now dominant. *Calluna* on left.

PHOTOGRAPH IV

NEPHIN BEG PILOT PLOT, APRIL, 1954

*Pinus contorta* plant without slag treatment. *Molinia*, strong *Myrica*. *Calluna*, some *Eriophorum vaginatum*.

Aughty peats on the Galway-Clare border. In 1936 a forest was established at Pettigo (Co. Donegal) on blanket bog, but planting was confined to the more fertile areas with manual preparation and turf planting. In 1951, with the introduction of new techniques which promised results on deep peats, action was taken to establish a number of forests well distributed through the western blanket bog regions, and afforestation on blanket bog types is now proceeding at the following centres:

Co. Kerry—Brosna.
Co. Galway—Maam Valley, Ballynahnich, Ross, Cloosh Valley.
Co. Mayo—Doolough, Nephin Beg.
Co. Sligo—Lough Talt.
Co. Donegal—Gweedore, Ballybofey (Crohonagh).

In addition, the more difficult peats at Pettigo, Co. Donegal, and some other forests, are now being tackled.

It is, of course, too early to draw definite conclusions in such a long-term business as forestry necessarily is, but there are at least preliminary indications that the new methods will yield tangible results where older methods were a complete failure.

## Description of Pilot Experiment

As an example, the first plot planted on deep blanket bog in the spring of 1951 at Nephin Beg Forest is worthy of detailed description.

*Situation :* 7 miles north of Newport, Co. Mayo.

*Elevation, Exposure :* 130 ft.; good shelter from west, south-west and north-west by mountain range 830 ft.- 2,340 ft.—exposure slight to moderate.

*Peat :* Deep peat, brown and fibrous for first 20 ins. at least, lying between a peat-covered, sandy ridge and the broad quagmire flats bordering the Srahmore River; there are slight flush effects along seepage channels; very soft and waterlogged before ploughing.

*Vegetation, 1951 :* Dwarf, diffuse vegetation without definite dominants: main species: *Molinia, Eriophorum vaginatum, Calluna vulgaris, Erica tetralix, Sphagnum* spp; *Narthecium, Schoenus nigricans* and *Rhynchospora alba ; Myrica gale*, local, mainly along seepage channels.

*Treatment :* Drains opened with single mouldboard draining plough. Ploughed 20 ins. deep with double mouldboard planting plough, furrows 10 ft. escapement, ribbons 5 ft., the sods lying on their sides, not inverted. Due to waterlogged soft peat, cleats had to be used to extend tracks to $3\frac{1}{2}$ ft. Planted with 1 + 1 *Pinus contorta*, Lulu Island origin, at 5 ft. x 5 ft. with semi-circular spades. Five acres were treated with 2 oz. basic slag applied around each plant on surface of ribbon shortly after planting; remainder was left unslagged as control strips. Photograph I shows area in July, 1951—turves used beside drain. Vegetation is beginning to respond, especially *Myrica*.

Inspections in August, 1953, and April, 1954, indicate considerable changes. Photograph II (April, 1954) shows slagged area to right of soil sampler and unslagged area to left. Drainage is effective vegetation has increased considerably in vigour and height on both types. *Calluna*, *Molinia* and *Myrica* (up to 30 ins.) have responded well, the two former tending to form a closed community with *Erica tetralix* occasional, ousting weaker species of waterlogged conditions such as *Rhynchospora* and *sphagnum*. The surface of the ribbon remains bare except for vegetative invasion of *Molinia* and germination is largely confined to the slagged patches. Here the moss, *Ceratodon purpureus* (Hedw.) Brid., forms dense colonies and the surface peat has blackened and is evidently decomposing. In a few cases strong plants of *Juncus communis* have become established on the slagged patch. *Molinia* is strongest along the margin of the ribbon, especially close to the point of application of the slag.

The contrast in the development of the *Pinus contorta* after three growing seasons shows clearly in Photograph II. The slagged plants are well furnished and average around 30 inches, with leaders of 10-16 inches last season. A typical vigorous plant had successive annual growth of 4, 8 and 16 inches. The first row of unslagged plants between drain and soil sampler are intermediate in development, while the plants on left of drain average rather less than 12 inches, with short yellowish needles and growth of 3-4 inches last season. Photographs III and IV show the contrast between typical slagged and unslagged plants.

In view of the strong response it is now thought that smaller phosphate applications would be safer and sufficient; and adjoining trial plots tend to support this view on the basis of one season's growth. In the first year 1 oz. of either Basic Slag or Ground Mineral Phosphate has given results not noticeably inferior to the heavier application. Pending further observations, phosphate applications on *Pinus contorta* in general are being reduced.

### Afforestation After Milled Peat Operations

It is understood that Bord na Mona intends to use the milled peat method on western blanket bogs. The outlook for forestry on the subsequent cut-over area is not as clear as in the case of the Midland raised bogs. The residual bottom peat will be highly acid, highly humified, of low fertility and permeability, with pine stumps as a further possible obstacle. Drainage and aeration may prove difficult as compared with fibrous, slightly humified peats. Where this peat is underlain by a sand with shallow, leached layer over hardpan, the best prospects would appear to be in deep ploughing, breaking through the pan in order to allow free vertical water movement and mixing sand from A and B horizons with the peat. In this case optimum depth of peat after milling would be 9-12 inches or even less. Pilot plots on a sample area (when available) would be worth while.

## Conclusion

From this summary of afforestation work on peats it will be seen that the Forest Service is fully alive to the problems and possibilities involved. Substantial areas have been acquired and a determined effort is being made to convert bogland to productive forest land. Satisfactory results have been achieved already on peats outside the western blanket bog region. There is now a steadily increasing concentration of planting operations in western districts and representative areas of all peat types are under investigation and trial. The present attitude is one of qualified optimism and it is hoped to overcome all obstacles and to foster the development of an integrated timber production and utilization industry in the West, thereby making a major contribution based on natural resources towards the rehabilitation of the Congested Districts.