"European Peats, Drainage and the Effects of Climate"

By T. M. BLACK

CONSIDERABLE work has been done in Europe on peat drainage and the methods applied and results obtained are worthy of consideration, especially in view of the large areas of plantation which have been established on deep peat in Ireland.

In Norway Thurmann-Moe has devised a classification for peat bogs which divides them into two main types—wooded and treeless—each of these types is divided into five grades ranging from very good to poor. The grading is done mainly on the basis of vegetation on the grounds that vegetation reflects the nutrient content. However, the degree of humification, depth of bog, and climate all have to be considered. The type of ground mainly afforested in N. Ireland falls into the lowest grade of the treeless section. In another publication Thurmann-Moe makes it clear that he considers only wooded bogs i.e. those carrying birch, Norway spruce, and Scots Pine, are worth draining. In some areas even bogs of this type are considered unsuitable for draining because the increase in production will be limited due to climatic or site conditions (see Löddesöl, 1948). Work on the afforestation of treeless peats has been done in Norway and Table I is one of the products of this research. From this it would appear that the drainage effect in Norwegian peats extends for a considerable distance from the edge of the drain. This is confirmed by Thurmann-Moe who recommends drains 15-30 metres apart and 80-130 cm. deep according to latitude, altitude and rainfall (Thurmann-Moe, 1959).

Sweden is also more concerned with draining existing forests than with afforestation. However the peat bogs and moors which are mainly in the west of the country cover 6,000,000 hectares and if afforested it is estimated would yield 13,00,000 cubic metres per year. The present annual timber production of Sweden is about 50,000,000 cubic metres. (Thorbjornson, 1954).

Finland has probably more experience of peat drainage than any other country in Europe. This is not surprising as about a third of the land surface is peat covered. In the period 1958-1962 more than 450,000 hectares were drained. However, the bogs drained are mainly covered by forests and there is no large scale afforestation of open peat lands. It is interesting to note that fertilisation of peat lands is now common practice. The figure of 450,000 hectares may appear large but Finland has more than 10,000,000 hectares of peatland of which 6,000,000 hectares are forested. It is estimated that about

3,000,000 hectares could be drained economically and a further 1,000,000 could be drained if economics were not considered. In addition it is estimated that nearly 1,500,000 hectares of ordinary firm forest soils need drainage. (Heikurainen, 1960 : Kivinen, 1954 : Numminen, 1962).

Peat soils can be classified by the plant remains and the following types are distinguished in Finland.

(1) Sphagnum.

(2) Eriophorum-Sphagnum.

(3) Carex-Sphagnum.

(4) Sphagnum-Carex.

(5) Carex.

(6) Bryales-Carex.

(7) Miscellaneous peats containing wood remains.

Peats in Finland are usually of low humification and it is evidently fairly easy to distinguish the different kinds of peats. The peats containing wood remains are most humified and their identification can cause some difficulties. (Kivinen, 1954 : Heikurainen, 1964 : Salmi, 1954).

Drains are normally spaced 40-60 metres apart and if the ditch reaches mineral soil a depth of 60 cm. is considered adequate. On deep peat the depth is normally 70-80 cm.

The Soviet Union has vast areas of peatland but forest drainage is apparently concentrated in the north western part of the country. During the period 1959-65 it was planned to drain 843,000 hectares (Pintshuk in Heikurainen, 1964). One worker (Vomperskij, 1958) in discussing surveys of peatland prior to drainage emphasised that ash content of the peat governed the site class. Thus, for Pine, peat of more than 5-6% ash content gave a Class I site : peat of less than 2% ash content gave only Class IV-V sites, while Norway spruce grew well only on peats with an ash content of more than 8%. It was considered that a layer of poorly decomposed peat more than 40-50 cm. thick made the site unsuitable for tree growth, irrespective of the ash content of the peat. The drains formed are seldom closer than 80 metres or deeper than 60 cm. although it is recommended that the mineral soil be reached where possible. It is interesting to note that the planting of dense spruce and pine along ditches has been recommended the idea being that the shade will reduce the overgrowing of the drain bottom. However, it is also recommended that a clear strip be left alongside drains for mechanised maintenance (Timofeev, 1959).

In southern European Russia, conditions are different. Regal (1947) states that irrigation has been used to improve the growth of grasses on acid peat and Kozhanov (1953) describes how the water requirements of agricultural crops on drained peat bog can exceed the precipitation, and reserves of available moisture, in dry years on the Polesia plain. He recommends watering when the groundwater level falls below 75-80 cm. This practice has increased the yield of perennial grasses by up to 44% and barley by up to 41%.

In Latvia an area of 210,000 hectares was to be drained during the period 1959-65 and experiments (Buss and Sabo, 1959) indicated that the optimum ditch spacings and depths were :—

Sphagnum type peats—100-140 metres apart, 70 cm. deep.

Carex/Phragmites types—160-200 metres apart, 100 cm. deep.

Molinia/Vaccinium types—90 metres apart, 60 cm. deep.

France has only a comparatively small area of peat land, about 100,000 hectares (in Burke and O'Hare, 1962). However, some work has been done on the agricultural reclamation of the Vernier Bog in Normandy. Here the drains are normally 50 metres apart and 75 cm. in depth. A layer of fibrous peat which is relatively pervious has been found at a depth of 60-80 cm. and ground drained to this depth dries comparatively quickly (Ferroniere, 1954). It was also discovered that cultivation resulted in a loss of some of the colloidal properties of the peat and, hence, it has been recommended that the peat should be left bare for as short a time as possible and that a quick growth of vegetation was desirable to protect the peat against loss of moisture (Hedin and Lefebure, 1954).

Holland is another country where peat is evidently not a problem. Pliny has described the origin of the peat industry in Holland in the sentence :— "The mud of their soil they knead with their hands, dry it in sun and wind, after that they burn it to cook their food and to warm their stiff bodies".

One classification of peat in Holland is very simple, only two types being recognised:

Black peat which can be irreversibly dried and is used for fuel and *White peat* which is reversible on drying and very hygroscopic.

At one time the most important use of peat moss was in horses stables. However, this use is now decreasing rapidly but new markets are being developed e.g. in horticulture (Sijbolts, 1954).

The Florida Everglades offer a good contrast to European conditions. Most of the Everglades peat is formed from weeds and sedges, mainly saw-grass, and is light and fibrous. Water control is essential and the aim is to keep the water table as high as possible consistent with a proper root environment for the crop. In fallow periods the fields are sometimes flooded as this reduces subsidence and the incidence of some insects and diseases. Hence the drainage system must be capable of dealing with heavy rain and, at the same time, capable of acting as an irrigation systeem (Forsee, 1963).

A considerable amount of work has been done on the effect of drainage on forested bogs. In Sweden a survey of drained peatlands showed that all the plots examined, originally unproductive and carrying few trees, had improved and were all covered with young well grown trees. (Borjeson, 1957). In Latvia Buss and Sabo (1959) examined tree growth on a sedge-pine swamp 30 years after drainage was carried out. They found a correlation between tree growth and the distance of the tree from the ditch — the nearer the ditch the better the growth. Other swamp types were also examined and it was found the poorer the swamp the steeper the correlation i.e. the beneficial effects of drainage were lost very much quicker as distance from the ditch increased. Similar studies in Finland also showed a close correlation between drain spacing and the increment of the growing stock after draining (Heikurainen, 1959, in Heikurainen, 1964).

However, Heikurainen and Kuusela (1962) showed that small trees grow better after drainage than big ones. The marginal dimensions of the size over which height increment cannot revive appear to be about 15 cm. diameter at breast height and 12 metres in height. In regard to radial growth only the marginal dimension of 22 cm. diameter was found. Over these size values trees grow less after drainage than before it. Age had some effect in that the youngest trees increased their height increment most, trees 30-70 years of age grew fairly well, and the oldest trees hardly grew at all after drainage. However, it was concluded that the size of the trees at the time of draining was more important than the age.

Ground water levels have also been studied and Huikari (in Heikurainen, 1964) found that only with very narrow spacings of 5-10 metres could the ground water level be definitely lowered; with spacings of 40-100 metres no clear differences were found. The effect of drain spacing on run-off was also studied and here also it was found that very narrow spacings (5-10 metres) were required to increase the run-off. These results were obtained on infertile Sphagnum swamps and it would appear from the generally beneficial effect of drainage on tree growth that the results are different on better, more fertile swamps.

The drying characteristics of peat turfs have been studied and some results are of interest in that they underline the difficulty of draining or drying peat. The drying characteristics of peat sods depend on the physical and chemical manner in which water is held by the peat.

Ostwald states that water held by peat may be divided into the following categories :—

(1) Occluded water, held in pores over 1 mm. in diameter.

(2) Capillary water, held between and within capillary walls.

(3) Colloidally bound water.

(4) Osmotically held water within undecomposed plant cells.

(5) Chemically bound e.g. water of crystallisation.

A simpler classification (Stadnikoff's) only distinguishes two categories :—

(1) Mechanically held water which is easily removed by pressure, and

(2) Colloidally bound water. (See Dalton, 1954).

However, tests on pressing samples of peat at 450 lbs. per sq. in. for a period of two minutes have indicated that the moisture content can only be reduced from 90% to between 70 and 80% (Grinsted, 1954).

Ditches obviously vary in their draining effect under different conditions and in different peats. Field capacity can be defined as the amount of water held in a soil after the excess has drained away. Drains cannot reduce the moisture content below field capacity and since the field capacity of peats is high the direct effect of ditches must be comparatively limited (Heikurainen, 1964). This is especially true of well humified peats with their very low permeability (see Table II). Furthermore, the effect of drains has, in many cases, been measured by the drop in the ground water table. This is by far, the simplest and most convenient method of measuring drainage effect. However, the correlation between the level of the ground water table and the moisture content of the peat above this level is known for a few peat types only and it is clear that the existence of the ground water table at, say, 25 cm. does not imply that 25 cm. is available as a rooting medium. In Finland tests indicated that water content was linearly related to the depth of the water table (Heikurainen, Paivanen, and Sarasto, 1964), but the relationship depends entirely on the type of peat and degree of humification.

The relationship between climate and drainage has been investigated and in Norway Thurmann-Moe (1963) distinguished five climatic divisions giving conditions suitable for drainage. The divisions are based on summer temperatures, the mean monthly temperatures for the four months June-September being considered. If the temperature falls between 13.6 and 14.°C conditions are considered to be excellent for draining. The other divisions are :—

Very good	12.4-13.6°C
Good	11.7-12.4°C
Fairly good	11.1-11.7°C
Moderately good	10.5-11.1°C

Rainfall is also important but the effect of high rainfall in reducing the suitability of an area for draining will be less for high than for low temperatures.

In Finland the country has been divided (by Heikurainen, 1963 and 1964) into five climatic zones based on the growth of the trees within these climatic zones. The zones are related to latitude and in the northern one which is situated on the Arctic Circle forest drainage is hardly carried out at all.

Robertson, Nicholson and Hughes (1963) studied the run-off from a raised bog in Lanark having a Calluna/Eriophorum/Sphagnum vegeation. The average rainfall was 32 inches per annum and the run-off was equal to 19 inches per annum. It was concluded that the 41% loss of water was due to evapo-transpiration. Huikari (1960) in a Finnish study concluded that evaporation, especially in dry summers, had a greater drying effect than seepage into drains. He also concluded that the amount of tree growth had a decisive drying effect and that drain spacing was more important than drain depth.

There are several reports of the drying effects of forest cover. Two adjacent catchments in the Harz Mountains, one having a heavy crop of Norway spruce and the other a short grass crop were studied and it was concluded that the evaporation from the forest area was about 10% greater than from the grass area (in Penman, 1963). In Yorkshire Law (1956) compared water losses from a small plantation of Sitka spruce with those from adjoining grass land and concluded that Sitka spruce was responsible for the loss of 11 inches of rainfall more than the grass. In the Phillippines the piped water supply from a small stream failed regularly for a few hours in the afternoon and recovered in the evening. This was attributed to heavy transpiration by the forest on the catchment area (Wendover, 1950). Clear felling of aspen in Wisconsin resulted in a rise in the water table of 14 inches and converted a well drained soil into a semi-swamp (Wilde and others, 1953, in Penman, 1963).

The total evaporation from an area covered with vegetation consists of the following components :—

(1) Evaporation of intercepted water.

(2) Transpiration.

(3) Evaporation from the soil.

The amount of intercepted water depends on the kind and amount of the precipitation and its frequency. Interception is influenced mainly by (a) the amount of water required to saturate the canopy surfaces (b) the size of individual showers, especially if the showers are too light to saturate the canopy surface and (c) the evaporation between showers, creating dry surfaces and allowing the interception of subsequent showers (Rutter, 1963 : Aranda and Coutts, 1963). Rutter (1963) found that 32% of the annual precipitation was intercepted by the crowns of a 16 year old stand of Scots pine. Norway spruce has been reported as intercepting 26% of the annual rainfall, and beech 7.5% (Eidmann, 1959).

After a swamp has been drained surface evaporation will decrease and one experiment in Finland (Multamaki, 1942), in Heikurainen, 1964) showed that evapo-transpiration on a drained bog was only two thirds of that on an undrained bog. After drainage, however, the growth of the trees normally improves and thus total transpiration increases. Another Finnish work indicated that evapo-ttranspiration from a wooded strip was more than twice that from an open strip (Huikari, 1959, in Heikurainen, 1964). In Russia a straight-line relationship was found to exist between the volume of water transpired and the current annual increment of stands of Aspen (Smirnov and Odinokova, 1954).

A study of oak, beech and Norway spruce stands on similar soils in Denmark showed that during the growing season oak lowered the watertable by 205 cm., beech by 115 cm. and Norway spruce 75 cm. The lowering of the watertable under the beech and spruce occurred over 3-4 months but under the oak the lowering took place in less than 6 weeks (Holstener-Jorgensen, 1959). It has been shown for some agricultural crops e.g. wheat, maize and beet that transpiration during the short rapid growth stage which normally lasts about 30-40 days accounted for 70-85% of the annual water consumption (Kállay, 1966).

The transpiration of individual trees varies with crown size, crown shape, and between light and shade trees. Under Danish conditions birch, oak and poplar have much lighter transpiration rates than ash, alder, beech and sycamore. The estimated daily water consumption in June for a stand of 25-30 year old beech having 1381 stems per hectare was found to be as follows:— On a sunny day with an air humidity of 60-70% and a temperature of 20-25°C the consumption was 40,000 litres per hectare. This dropped to 20,000 litres per hectare on a dull day with air humidity 85-90% and air temperature 13-16°C. In wet weather the water consumption was found to be negligible. When soil moisture is high, water consumption evidently depends mainly on light intensity and air humidity, less on air temperature in the range 10-20°C, while wind strength has a slight effect (Ladefoged, 1956).

The volume of water transpired varies with species. Birch was found to be a heavy transpirer in Denmark (Ladefoged, 1956) and other Scandinavian work also showed that it transpired more than Scots pine or Norway spruce (in Heikurainen, 1964). There are also numerous reports on transpiration differences between provenances of the same species. In Europeean larch northern and lowland provenances transpire more on cool days than southern and Alpine provenances. The northern and lowland provenances conversely transpired less on warm days. Polish provenances had the lowest total transpiration and restricted their transpiration most under conditions of reduced moisture (Kral, 1962). A Russian study of oak also showed the existence of provenances whose transpiration rates differed by up to 37% (Sütjaev, 1964).

The amount of available moisture influences the water uptake of trees. In America evapo-transpiration was found to be nearly 3.5 inches greater in swamps having a high stable watertable than in nearby swamps where the rooting zone dried out (Satterlund, 1961). Studies of 23 year old oak/ash stands in Russia showed that ash had the greater ability to adapt its water uptake to the water supply. It was better able to limit it in dry weather and was able to increase it sharply when sufficient moisture was available (Krasulin and Pankratova, 1957). Thus in suitable climatic conditions where large quantities of soil water are available transpiration will be heavy.

The amount of evaporation which can take place from a bare soil is limited. Evaporation at the soil surface sets up a suction gradient and at the same time the soil permeability is decreased. This limits the amount of water which can be lost from the soil surface (Penman, 1963). Apparently this is also true of peat. In any case the amount of evaporation which can take place from the soil surface under forest is severely limited.

From time to time the view has been expressed that a vigorously growing tree crop would help to dry out the peat on which it was standing. It was stated earlier in this paper that evaporation from a wooded area could be divided into:—

(1) Evaporation of intercepted water.

(2) Transpiration.

(3) Evaporation from the soil.

It has been pointed out that evaporation from the soil under a tree crop will be limited. This means that transpiration and the evaporation of intercepted water will be the main agents in this drying out. Investigations into the relationship between evaporation of intercepted water and transpiration showed that under the same atmospheric conditions the evaporation of intercepted rainfall was greater than the transpiration rate. This was due to the diffusive resistance of the stomata and a boundary layer of still air at the leaf surface (Anon. 1962). A Russian study also showed that water intercepted by the crowns of trees could reduce the water lost by transpiration (Rahmanov, 1958).

The relationship between transpiration and the evaporation of intercepted rainfall is important, but both are dependent on one factor: a supply of energy to transform liquid into vapour. It takes approximately 590 calories at ordinary air temperature to vaporise a gram of water and the amount of energy available, which is initially supplied by radiant sunshine, is limited and can not be increased.

If it is hoped that forests will help to dry out peat then full use must be made of the limited amount of energy available for evaporation. This could probably best be done by (1) planting species e.g. birch, and provenances of species which transpire heavily and (2) by developing large crowns on the trees to present as large a surface for evaporation as possible thus making full use of the available enrgy. The importance of this is seen from figures for Glenamoy, Co. Mayo which indicate that out of a total rainfall of about 55 inches only 20 inches are evaporated, leaving an annual surplus of 35 inches.

The optimum depth of the watertable has been determined for different agricultural crops but no comparable data exists for trees. In Norway Thurmann-Moe (in Heikurainen, 1964) concluded that the ground water level should be at a depth of 30 cm. In Estonia it was considered that 40-50 cm. was the optimum. In Latvian swamps Sabo found the following ground water depths to be adequate:

Pine 18 cm. Norway spruce 29 cm. Birch 42 cm. (in Heikurainen, 1964).

Other investigators have found that Birch and Scots Pine were less sensitive to poor drainage than Norway spruce (Orlov, 1959: Meshechok, 1963). However, Yeatman (1955) concluded that tree roots will only freely exploit soil that is porus and well aerated.

It has been frequently stated that the root systems of swamp trees are shallow. This applies even to tree species which normally have a deeply penetrating tap root. On peat these species either have no tap root or at best, it is very poorly developed (Heikurainen, 1964). This was found to be the case with Scots Pine growing on sphagnum peats in Russia. Here, although the watertable was 50-60 cm. below the surface the trees had an entirely superficial root system (Ogievskij, 1958). One comparative study of seedlings of aspen, birch pine and spruce indicated that Scots pine had the greatest root development under wet conditions (Jarvis, 1963).

Heikurainen (1955) investigated the root systems of Scots pine stands on Finnish bogs and reached the conclusions that (1) the greater the mean annual increment the greater the root system (2) 85-90% of the roots were in the top ten centimetres of peat and even on effectively drained peats few roots penetrated below 20 cm. (3) the quantity of long roots found was large, the total length of roots often exceeding 1 km/cu.m. of soil. It was also found that 85% of the roots were greater than 1 mm. in diameter.

A detailed study of a 65 year old Scots pine stand gave the following figures:—

70% of the roots were in the top 5 cm.

20% of the roots were in the 5-10 cm. layer.

8% of the roots were in the 10-15 cm. layer and

2% of the roots were in the 15-20 cm. layer.

A correlation was also found to exist between the average ground water level and the depth of the root system. A drop of 10 cm. in the ground water level during the growing season meant a difference of about 1 cm. in the average depth of the root system (Heikurainen, 1964).

Another Finnish study indicated the existence of a correlation between drain spacing and average root depth. With a drain spacing of 80 metres the average rooting depteh was 4.7 cm., with drains 40 metres apart the rooting depth increased to 5.4 cm. and when the drains were only 5 metres apart rooting depth increaesed to 6.8 cm. (Paavilainen, Heikurainen, 1964).

Hence, it would appear that even under Finnish conditions increased drainage does not greatly increase root depth. It has been stated that the advantages of a deep rooting system are more related to water supply than to nutrient supply and it has also been stated that there is no inherent need for a tree to have deep roots (Anon., 1960). Consideration of this evidence indicates (1) that the advantages of deep rooting are more connected with stability than with growth and (2) that the surface rooting of Sitka spruce under our conditions is only to be expected and does not indicate that growth will suffer because of shallow rooting.

This literature survey has indicated that under Irish conditions the following points are, at least, worth considering:—

(a) The effectiveness of any drainage system depends on the permeability of the material being drained. In view of the low permeability of most peats, especially in the deeper more humified layers, the value of deep drains is limited. The actual depth of drain which should be aimed at will vary with the type of peat and is, in any case, open to debate but deepening beyond three feet will apparently serve no useful purpose.

(b) Many forests are situated on areas endowed with surplus water. This is self evident as surplus water is essential for the formation of blanket bog. Any drainage system should aim at getting rid of as much surplus water as possible. On the Irish Grass Meal Company's farm at Gowla, Co. Galway which is situated on a raised bog the bog surface between the drains is cambered so that all surplus water is got rid of as soon as possible. Any drainage system on blanket bog should be designed with the same object in view.

(c) As was suggestel previously full use must be made of the energy available for evaporation and, accordingly, the aim should be to develop large crowns on the trees to present as large a surface for evaporation as possible. If these crowns have a low centre of gravity the stability of the trees will improve,, an advantage in view of the shallow rooting on blanket bog.

TABLE I

"Experiments with Afforestation on Peatland in Norway"
By B. MESHECHOK

International Peat Congress, Leningrad, 1963

Ditch intervals for different ditch depths for various, assumed drainage norms: the precipitation June-September = 300 mm.

Drainage norm (i.e. mean distance from peat surface to ground water level) in cm.	Ditch depth in cm.					
	40	50	60	70	80	90
	Ditch intervals in meters					
	For ombrogenous peatland :					
20	21	30	38	46	53	61
25	13	21	28	35	41	47
30	7	14	21	27	33	38
35	3	9	15	21	26	31
40		6	11	16	21	25
	For soligenous peatland :					
20	29	41	53			
25	20	30	39	49		
30	13	21	30	38	46	
35	7	16	23	30	36	43
40		11	18	24	30	35

It is pointed out that the figures in the table are valid under conditions existing in the soil with precipitation in June-September being 300 mm. As normal precipitation varies greatly for various localities, it was useful to try to find a method for making corrections. From the material the following, simple, empirical formula was obtained :—

$$E_N = E_{300} \times \frac{300}{N}$$

where E_N = effective ditch interval in metres for normal precipitation N for each specified place (for June-September).
E_{300} = effective ditch interval with precipitation June-September = 300 mm which was chosen for the ditch depth specified in the above table.
300 = constant precipitation in mm. assumed for this table.
N = normal precipitation during June-September for the area under investigation.

That formula may be used fir corrections in places with normal precipitation of about 200 to 500 mm during June-September.

TABLE II

Vertical Permeability Values (*Sarasto,* 1963)

The values are in litres per hour from samples having a basal area of 100 cm^2 and a height of 5 cm.

	Degree of humification (*von Post,* 1922)							
Sample	1	2	3	4	5	6	7	8
Sphagnum peat	14.9	9.4	2.1	0.9	0.7	0.2	0.2	0.1
Sedge peat	—	9.3	4.5	0.9	0.7	0.5	0.3	0.2

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