The Indicator Value of Vegetation in relation to the Afforestation of Peatland in Northern Ireland

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Introduction.

Peatland in Ireland can be classified into two major groups, Raised bog and Blanket bog; the latter can be further subdivided into low-level and high-level bog, depending on altitude (Barry, 1954). Afforestation of the peatland has been concentrated mainly on areas of blanket bog; in Northern Ireland it has been restricted almost entirely to hill blanket bog (Parkin, 1957) but, in the Republic of Ireland, large areas of low-level bog in the West have been acquired and are being planted (McEvoy, 1954).

Within these two categories of blanket bog, any further subdivision for afforestation purposes must be based on more detailed and precise characters than those on which the original grouping was based. For obvious reasons, the most reliable index of site potential for tree growth is the performance of trees actually growing on the site in question, or at least one very similar to it. Unfortunately, owing to the recent date of most planting on blanket bog, this approach is of little value. Of the limited number of other site characteristics available, the one most used in the past, and that used in current forestry practice, is the vegetation of the site prior to planting (Anderson, 1961; Fraser, 1933; Gimmingham, 1949; Parkin, 1957).

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Factors Affecting the Indicator Value of Peatland Vegetation.

The use of vegetation as an index of the potential of peatland for afforesation involves at least three basic assumptions, namely:—

(1) That peatland vegetation can be described and classified accurately.

(2) That the distribution of peatland vegetation types is related to variation in environmental factors, and that differences in vegetation can thus be used to indicate consistent differences in environmental factors.

(3) That the differences in environmental factors thus indicated can be measured and are significant for tree growth.

In the first part of this paper, some of the principles underlying these assumptions and some of the factors qualifying their acceptance are discussed briefly; in the second part a summary of the results of an investigation dealing with the relation between the vegetation and nutrient content of peatland in Northern Ireland will be presented.

1. *Description and Classification of Peatland Vegetation.*

A criticism often levelled against the use of vegetation as an index of site conditions is that the high level of human interference so modifies the natural vegetation, that the description and subsequent classification of geographically separate areas of vegetation is practically meaningless. This argument has force when the areas concerned have been subjected to essentially different types, or degrees, of human interference. Owing to the poverty of unfertilized peatland, however, its ability to support sustained grazing is severely restricted, and most areas of peatland in Ireland support a uniformly low density of grazing animals. Since the intensity of burning is related to the grazing density, this factor, too, varies little between different areas. The effects of interference on areas of similar vegetation, then, can be regarded as being relatively uniform throughout fairly large regions. Interference is an important factor in modifying peatland vegetation, and must be recognized as such, but it does not invalidate its description and classification.

From the descriptive point of view, interference introduces a complication, but one which can be surmounted without undue trouble. Its most serious effects will be discussed later.

A further difficulty in describing and classifying vegetation arises from the fact that many natural plant communities do not have sharp, well-defined boundaries. More often, the transition between communities is gradual, the variation between them in many cases being continuous. This is particularly true of peatland vegetation with its small flora. Only along lines of flushing is peatland vegetation generally sharply contrasted.

In attempting to describe and classify peatland vegetation, the obvious and most fruitful approach is to concentrate initially on those types of vegetation which show the greatest floristic uniformity throughout the region being studied. Thus, within a region, a number of discrete vegetation types, each readily definable by reference to actual uniform areas, or stands, of vegetation in the field, are recognized, and studied in detail. Types intermediate between the recognized types are noted but not investigated fully. Although the total area occupied by the intermediate types may equal, or even exceed, the area occupied by the main types recognized, their exclusion from the initial classification is justified by the fact that their floristic compostion is so variable that they cannot be adequately defined, nor, therefore, classified. The study of the main recognized types, however, forms the basis of a framework within which the intermediate vegetation types can later be fitted.

It will be noted that in such a scheme of classification there is only one unit—the vegetation type or noda (Poore, 1955). No attempt is made at this stage to establish a hierarchical system of classification.

2. *Relationship between Peatland Vegetation and Environment.*

The vegetation occupying a site is determined by the interaction between the environment of that site and the tolerances of the species capable of reaching it. In general, when the environment changes to the extent that it lies outside the range of tolerance of the species present the specific composition of the vegetation will change. This change in vegetation following change in environmental factors is the principle underlying the use of vegetation as an indicator of environmental conditions. Unfortunately several factors modify, to a greater or less degree, the straightforward plant-environment response.

The effect of such factors is to complicate the use of vegetation as an index of site potential and some of the more important will be discussed below.

(a) *Interference.*

Interference, in addition to being an important factor affecting the classification of peatland vegetation, modifies the relation between peatland vegetation and its environment. However, as has already been mentioned, interference can be regarded as a factor common to similar vegetation types within relatively large areas, so that, other things being equal, similar environments within an area will support similar vegetation types. Different vegetation types, of course, are not subjected to the same degree of interference. The degree of interference depends to a great extent on the 'palatability' and inflammability of the vegetation. *Juncus*—grass flushes are subject to a much greater degree of interference than the poorer *Trichophorum—Calluna* vegetation types; the important point is that the grazing intensity on, for example, *Juncus*—grass flushes is uniform over wide areas, and, therefore, that interference does not disturb the equilibrium between vegetation and environment in different areas.

Probably the most apparent effect of interference on peatland vegetation is the reduction in the total number of plant species. In areas subject to frequent interference, species susceptible to grazing and fire damage are gradually eliminated. The vegetation of the area is then composed of a relatively small number of interference-resistant species, with the result that although there may be little change in the environments of the different sites in the area, the vegetation on them will have changed. In particular the differences between the vegetation on the separate sites will be smaller due to the fewer number of species occupying the same range of site conditions. This effect is made more apparent by the fact that many of the species which are sensitive to environmental change are among those which are lost by interference. Thus, the effect of continued interference with the vegetation of an area is to impair the precision with which vegetation can be expected to indicate changes in environmental conditions.

Although small differences in environmental conditions may not be apparent from the vegetation, larger differences, e.g. those which evoke a response from the less sensitive species, will still be indicated. Although the precision of the method is reduced, its reliability would be affected only if interference had the effect of causing a similar vegetation to develop on basically different sites or *vice versa.* Fortunately there is no indication of this.

It cannot be expected, of course, that the vegetation occupying a site immediately after a major disturbance such as fire, ploughing, fertilization, etc. will provide a reliable indication of the more typical environmental conditions of that site; rather will the vegetation reflect the effect of the recent interference. Such relatively short-term changes in vegetation can be misleading, but fortunately the effects of a recent major interference of the type indicated are easily recognized, and the significance of the subsequent vegetation changes can be interpreted in the light of this knowledge.

(b) *Tolerance of Species.*

The importance of strain or ecotypic differences in forest trees (*Pinus contorta* is an excellent example) in their response to environmental factors has long been realized. It is now known that different ecotypes of a species, e.g. *P. contorta,* will behave quite differently in the same environment. That similar genetic differences do not exist in very tolerant species such as *Calluna* etc. is difficult to believe. Unfortunately it is not at present possible to recognize the different ecotypes of the common native species but until this is remedied the indicator value of such species must remain low.

(c) *Migration Barriers.*

It is perhaps a platitude to state that plants can only grow on a site if first their seed or other means of dispersal can reach it. The existence of barriers to species migration, however, often imposes strict limitations on the actual flora of a region and, although two sites in separate areas may be essentially similar, the vegetation on them may be different owing to the inability of the same species to reach both. Such limitations are unlikely to affect the flora of Irish peatland, but migration barriers such as the English and Irish Channels have undoubtedly had an historical influence on Irish vegetation.

The time required for species migration must be taken into account when considering sudden short term changes in vegetation, e.g. the changes following ploughing and fertilization of different areas, and in studying the colonization of newly-exposed bare ground. For this reason, the absence of a species should not, in itself, be used to evaluate site conditions.

(d) *Compensation Effect.*

The phenomenon by which one factor of the environment apparently compensates for other factors, and can allow a species to exist in an environment normally thought outside its range of tolerance for these factors, has an important bearing on the environmental response of certain species. A compensation effect is often apparent in the extension of a species into an apparently unsuitable climatic region owing to its occurrence on a base rich parent material. Similarly, the altitudinal zonation of vegetation is often modified by compensating edaphic factors.

The occurrence of *Schoenus nigricans,* which is restricted to base rich sites in England and Continental Europe, on the ombrogenous bogs in West Ireland has been quoted as an example of mild climatic factors compensating for adverse edaphic conditions (Bellamy, 1959; Gorham, 1953). The mechanism of this apparent compensation is still in doubt but the mildness of the climate and the high base saturation of the peat, caused by the high salt content of the atmosphere, have both been suggested as causes, and probably both are involved.

The difference in nutrient status of the peat supporting *S. nigricans* in the extreme west and in Loch Navar forest in County Fermanagh might be given as an illustration of compensation and of the dangers inherent in the use of a single species as an indicator of site conditions. At Loch Navar, *Schoenus* is restricted entirely to Ca-rich flush sites, whereas in Mayo it occurs on the open bog plane. The figures shown below indicate the magnitude of the difference in nutrient content, and thus potential for tree growth, between the two areas.

Comparison of Nutrient Status of Typical *Schoenus nigricans* sites in Co. Mayo and in the Lough Navar Area of Co. Fermanagh.

		Total Ion Content (mgs./100 gs. dry wt.)				
Location	*pH*	*Na*	*K*	*Ca*	*P*	*Fe*
* Glenamoy, Co. Mayo (Profile 1)	4.6	58.0	50.0	78.0	22.0	37.0
* Glenamoy (Profile 2)	4.8	80.0	44.0	82.0	18.0	70.0
† L. Navar, Fermanagh	4.6	24.2	62.0	1,301.5	46.7	1,501.3

* The figures from Glenamoy are due to Walsh & Barry (1958).

† The figures from L. Navar represent the mean values from 15 sites.

(e) *Inertial Effect.*

A time lag always occurs between change in environmental conditions and response of vegetation. With some species this interval is greatly extended so that they sometimes continue to exist on a site long after conditions have ceased to be optimal, or indeed 'normal' for their growth. In the sequence of bog development from eutrophic to oligotrophic conditions certain species, e.g. *Phragmites communis* and some *Carex* species, which are characteristic of the early nutrient-rich conditions, occasionally persist through to the later stages of development under a quite different nutrient regime. In such a case the depauperate condition of the persisting species and the vegetation associated with them usually prevents a wrong conclusion about site conditions being drawn from their presence.

Owing to its nature, the relation between peat and the vegetation it supports is very close in certain respects. In contrast with mineral soils, the nutrient status of peat, except where it is influenced by mineral-rich flush water, is largely determined by the mineral constitution of the plants growing on it, and of those which have contributed to its accumulation. The physical characteristics of the peat are similarly conditioned by the vegetation. Several workers have recently shown that the plants growing on peat concentrate and retain large amounts, relative, that is, to the amounts in the peat, of mineral elements within their structure (Goodman and Perkins, 1959; Malmer, 1958; Newbould, 1960). This retention is most marked for the elements Potassium and Phosphorus. Owing to this reservoir of nutrients embodied in the vegetation it would seem useful to regard the peat and its associated vegetation as a unit when considering the nutrient status of peatland in relation to afforestation.

3. *Tree Growth in Relation to Vegetation Type.*

The growth of trees on different vegetation types can be expected to vary in response to two distinct sets of factors—those caused by the direct action of the vegetation *per se* and those environmental factors causing the distribution in the vegetation types, i.e. the factors indicated by the vegetation.

Of the direct effects of the vegetation, one of the more important is undoubtedly the effect of competition between the native vegetation and the trees, although other factors such as litter toxicity, different rhizophere populations etc. must all be considered. Elucidation of the mechanism of this competition effect is not yet complete, but it has been shown that competition for nutrients, in particular for Nitrogen, is a very important aspect (Leyton, 1954; Weatherall, 1953). In this context, the specific composition and degree of vigour of the vegetation must be determined in assessing the potential of the site for tree growth. *Calluna* is one of the more aggressive species in this respect, and its relative abundance and vitality can be critical in the early stages of tree growth.

A vigorous and highly competitive native vegetation may be the most important single factor in the establishment of trees on certain sites, but the relatively poor growth of trees may not be an accurate reflection of the ability of the site to sustain timber production once the competitive effect is overcome. For instance, early tree growth on sites poor in nutrients may be better, due primarily to the absence of vegetation competition, than on sites with a more adequate nutrient supply but more vigorous vegetation. In later years, of course, the position will be reversed.

Since the environment of a site is holocoenotic and reacts as a complex, integrated system, vegetation should strictly be used as an indicator of total environment, not as an idicator of particular, arbitrarily selected factors (of the environment). From this, it is apparent that the only logically correct method of using vegetation as an indicator of site potential for tree growth is to relate the growth of trees directly to vegetation type, i.e. to record the growth of trees on the different vegetation types. Such a method obviously demands long term investigation. It is possible, however, to as it were, short-cut this procedure by relating vegetation to specific environmental factors which are thought to be significant for tree growth on deep peat.

It is now quite clear that the factors of greatest significance to initial tree growth on deep peat are:—

(a) Competition from the native vegetation.

(b) Deficiency of mineral nutrients, particularly Phosphorus.

(c) Deficiency of aeration resulting from excess water.

Any investigation of the indicator value of peatland vegetation should, therefore, be directed towards establishing an association between the vegetation types recognized and those environmental factors indicated.

The results of such an investigation are presented in the second half of this paper.

Relationship between vegetation and peat nutrient content in certain forest areas in Northern Ireland.

During the last few years, an investigation into the relation between vegetation and nutrient content of the peat from certain areas of peatland in the course of afforestation has been carried out by members of the Botany Department of Queen's University, Belfast. Of the forest areas studied, two, Beaghs and Ballypatrick, are situated in North Antrim and one, Lough Navar, is in South-West Fermanagh. All three occur on deep peat.

The classification of the vegetation was based on the detailed examination and description of small areas, or stands, located within the main vegetation types recognized. Transitional types were noted but not examined in detail. At each site described, samples of the peat from immediately below the litter layer were collected and taken back to the laboratory for chemical analysis. In this way, it was hoped to determine some of the factors governing the distribution of vegetation types, and to investigate the value of vegetation in indicating site potential for tree growth.

The detailed results will not be presented here, but some of the conclusions may be of interest.

Altogether, a total of ten distinct vegetation types were recognized in the three areas. Initially, the types were classified into the categories A, B and C depending on whether they occurred on unflushed, slightly flushed or strongly flushed sites. It became apparent later, however, that, although the distinction between unflushed and strongly flushed sites was real, those peats thought to be slightly flushed showed relatively little difference from certain of the unflushed types. Due to the nature of flushing, however, it is very difficult to establish the importance of its influence except when the flushing water is richly charged with mineral ions. When the peat is influenced by flush water of relatively low mineral content, analysis of a sample collected at a particular point in time will not indicate any enrichment effect, even though this weak solution may have an important influence on the nutrient economy on the site over an extended period of time. Thus, despite the fact that the analyses give little indication of it, it is possible that some of the B types benefit from a slight flushing influence.

One fact that the results indicate is that, in general, there is no close correlation between peatland vegetation and the total nutrient content of underlying peat, except in those sites influenced by mineral rich flush water. This is not altogether unexpected, since even if the distribution of vegetation is controlled by the nutritional status of the peat, the availability, rather than the total conent, of nutrients will be the determining influence. This was realised at the outset of the investigation but there are several reasons for determining total nutrient content. In the first place, the concept of "availability" of nutrients was developed mainly in relation to agricultral practices on mineral soils. It has been found over a long period of trial and error, that a rough estimate of the amounts of nutrients which can be utilised by agricultural crops can be obtained by leaching the soil with various reagents and determining the amounts of nutrient elements removed in the leachate. This fraction is classified as 'available'. The method, although giving satisfactory results in practice, is entirely empirical and bears no direct relation to the actual nutrient uptake of the plants.

The relation between the total and available fractions of the nutrient content of peat, however, is much more complicated and the methods used in agriculture are of limited direct value. We know so little of the nutrient release in peat and of the uptake of nutrients by bog plants and trees that a great deal of fundamental research is required before predictions about the relative amounts of total and available nutrients in peat can safely be made. Further, with the establishment of forest conditions and the anticipated decomposition of the upper layers of peat, the total nutrients in the peat may well eventually become available to the trees and thus, in the long term, be the more fundamental criterion of site fertility.

Vegetation and Nutrient Content of Hill Blanket Bog in Northern Ireland.

Despite a general lack of positive correlation between vegetation and total nutrient content of the underlying peat, it is possible to distinguish three broad categories of hill blanket bog between which the differences in total nutrient content are likely to be significant for tree growth.

These three categories of peatland are listed below, while the mean analytical data are presented in the accompanying table (Table 1). The figures in this table represent the mean values obtained for the peat underlying the different vegetation types in each category; the data from the three areas studied have been combined in one overall mean.

Basic Categories of Blanket Bog in Northern Ireland.

A. Areas of very wet, unflushed peat occurring on flat, slightly convex or gently sloping ground.

B. Areas of drier, possibly slightly flushed peat occurring on moderate—fairly steep slopes.

C. Areas of peat strongly flushed with mineral-rich water of telluric origin.

Table I.

Mean Analytical Data relating to Peat from Different Categories

			Mean Ion Content (mgs./100 gs. dry wt.)				
Category	%M	pH	Na	K	Ca	P	Fe
A	90.02	3.37	30.53	26.64	142.27	31.69	88.78
B	89.14	3.18	31.03	28.64	188.41	61.50	140.42
C	84.09	4.62	29.06	72.86	843.28	78.79	2,224.28
Lon Mor	—	—	24.5	42.00	162.5	66.25	—

An interesting comparison can be drawn between the figures shown above for the total ion content of the main categories of blanket bog in Northern Ireland and those quoted by Binns (Binns, 1959) for the Lon Mor experimental area in Inverness-shire. This area is one of the British Forestry's Commission's main centres of experimental work on peatland afforestation and was originally selected as an area of typical deep basin peat of the poorest type. The figures in the last line of Table I. are the mean total ion contents (mgs./100 gs. dry wt.) of the upper six inch layer of an area of unplanted peat adjacent to one of the early F.C. experiments (Exp. 47. P. 28). The high total content of Potassium and Phosphorous in relation to the total content of Irish blanket bog might lead one to expect slightly different responses in this country.

Rather than give complete lists of the species occurring in the vegetation types recognised in the different categories of peatland only the more conspicuous, or those with some special indicator value will be mentioned. The effects of burning and grazing on the specific composition of the types will also be dealt with. The mean values of total ion content of the corresponding peat types are shown, for each type and area separately, in Table II.

Table II.

Mean Results of Analytical Data for Peat from Different Vegetation Types

(Total Ion Content (mgs./100 gs. dry wt.)

Area	Type	pH	M%	Na	K	Ca	P	Fe
Ballypatrick	A2	3.15	91.5	25.71	18.37	129.80	20.08	82.10
	A3	3.18	87.5	33.20	30.69	165.22	56.76	100.64
	A4	3.14	89.13	32.48	21.68	166.11	51.47	103.29
	B1	3.13	89.71	37.10	27.79	176.44	73.24	110.50
Beaghs	A2	3.20	91.64	31.05	20.98	136.80	30.90	124.50
	A3	3.00	89.08	26.28	20.88	190.08	51.16	103.18
	A5	3.15	89.46	29.00	26.50	161.90	46.39	120.66
	B1	2.98	89.69	29.07	29.86	132.31	94.74	148.66
	C1	4.88	80.86	30.57	60.60	679.00	108.40	3,576.30
L. Navar	A1	3.42	88.21	31.75	33.42	161.89	35.07	83.51
	A2	3.72	88.74	33.62	33.80	140.61	40.73	65.00
	B3	3.72	89.38	30.12	43.09	326.83	56.76	295.99
	C1	4.39	83.81	32.42	95.99	549.31	81.23	1,595.23
	C3	4.60	87.59	24.20	62.02	1,301.54	46.74	1,501.30

Category A.

The vegetation characteristic of this category can be divided into two distinct types, separated on a vegetation basis by the relative abundance of *Trichophorum caespitosum,* and on a physical basis by differences in microtopography.

The first type, A1, is one of the most difficult sites to afforest successfully, due both to its poverty of nutrients and to its physical condition. The type occurs on peatland familiarly known as 'quaking bog' or one of the slightly drier phases of this bog type. It is well represented in all three areas studied, although at L. Navar it reaches its greatest development on the flatter areas just outside the forest boundary. A large part of the plateau on the east block of Beaghs forest is occupied by vegetation of this type, which, as a rule, occurs on flat or slightly convex ground. The surface shows a characteristic microtopography of alternating hummocks and hollows, the latter often filled with water, sometimes to a considerable depth. The vegetation forms a mosaic pattern related to the hummocks on which *Calluna, Erica tetralix, Trichophorum* and the small-leaved *Sphagnum* species are prominent. Round the edges of the pools and in the shallower hollows *Eriophorum vaginatum, Narthecium ossifragum, Menyanthes trifoliata* and the submerged and large-leaved *Sphagnums* are the most conspicuous species.

Owing to its extreme wetness this vegetation is seldom burned in its natural state but treading, especially by cattle, can cause damage to the peat structure resulting in a drying out of the surface and increased risk of fire damage. The effects of grazing are seldom severe.

As has been indicated, this type has a very low potential for tree growth but, if the temporary abandonment of an occasional tractor is accepted, and the areas drained, satisfactory growth should be possible given heavy, and probably repeated, application of fertilizer.

The other main vegetation type in this first category is dominated by *Trichophorum* and has been designated A2. The actual cover of *Trichophorum* on any one site is variable, and seems to depend on the wetness of the site and its past history of burning. Several species of *Sphagnum* are often very conspiuous and other associated species are *Eriophorum angustifolium, Erica tetralix* and *Narthecium. Calluna* is nearly always present, but not in a vigorous condition.

Repeated burning of this type appears to lead to the elimination of the *Calluna* and *Erica tetralix* and the establisment of a type of vegetation composed almost entirely of *Trichophorum* and a thick mat of *Sphagnum* species. Grazing seems to have a slight effect. *Carex panicea* is found in this type at L. Navar where it seems to become more conspicuous after interference, an observation which has also been reported for a different type of vegetation (Asprey, 1947). This species is not found in the same vegetation type at either of the North Antrim areas.

The nutrient content of this type is again very low, but the early growth of fertilized trees has so far been promising. This is probably due in some measure to the lack of competition from the native vegetation and it must remain doubtful if the peat is capable of supplying the nutrients required for a complete rotation.

It is interesting to note that the total nutrient content of the peat from both the vegetation types in this first category is considerably lower than the peat from the Lon Mor which Dr. Binns found so deficient after only thirty years of tree growth. Although there is not much difference between the values of Calcium for the two areas, the mean values of Potassium and Phosphorus on a dry weight basis for the Ulster blanket bog are approximately half those of the Lon Mor peat (Table I). Thus it appears certain that supplementary fertilization of the areas in this category will be necessary to secure even one rotation.

Category B.

The second category of peatland bears a number of very diverse types of vegetation. Broadly speaking, however, they can be distinguished by the relative abundance of three species—*Calluna, Eriophorum vaginatum* and *Molinia caerulea.*

The types dominated by Calluna reach their greatest development on the peats of North Antrim. At L. Naver, *Calluna* occurs in a dominant role only on the relatively freely drained, shallow peat on the top of escarpments. *Eriophorum vaginatum* also shows a greater vigour in the drier Antrim areas, but to a lesser degree than *Calluna,* while *Molinia* displays the opposite tendency, being decidedly more vigorous in Fermanagh. Whether this geographic distinction is due to climatic or geological factors cannot yet be confirmed, but probably both factors are involved.

At Ballypatrick and Beaghs the vegetation in which *Calluna* is the dominant species occupies a large area. In the type designated A3, *Calluna* occurs as a strong, bushy plant with a high degree of cover. *Eriophorum vaginatum* is a constant associate, single shoots often protruding above the *Calluna* canopy. *Erica tetralix, Empetrum nigrum, Vaccinium myrtillus* and *Deschampsia flexuosa,* along with *Potentilla erecta* and many of the common hypnaceous mosses are usually conspicuous. *Sphagnum rubellum* and *S. plumulosum* are almost always present, but only become conspicuous when the *Calluna* becomes old and degenerate so allowing a higher light intensity below its canopy.

The factor most likely to limit tree growth on this type is competition from the vegetation, especially for Nitrogen, rather than any nutrient deficiency in the peat.

The M% of the peat is low, the mean of the two Antrim areas being 88.3%. There is very little evidence to suggest that this type is influenced by flushing, in fact the opposite appears to be the case, the vegetation being most vigorous on the tops of ridges and similar situations where drainage is free. From this, it would seem that adequate aeration is the factor primarily controlling the distribution of this type of vegetation. The A3 type does not occur at L. Navar.

The effects of grazing alone are not severe, but burning leads to a radical change in the vegetation, the general effect resulting in a decrease in the dominance of *Calluna* and a consequent increase in the associated species, particularly *Eriophorum vaginatum* and, in certain cases *Trichophorum.*

Several variants of the type occur, and the transition between it and the previously described *Trichophorum* type seems to be continuous. *Eriophorum angustifolium* becomes more conspicuous on the wetter areas and this particular variant has been typified as A4 and A5 at Ballypatrick and Beaghs respectively. The nutrient content of these types is very similar to that of the A3 type and the presence of *Eriophorum angustifolium* does not seem to indicate any particular nutrient conditions, but probably reflects an increased wetness of the site.

Another type found only in the North Antrim areas is that in which *Eriophorum vaginatum* assumes a dominant role. In this type, B1, *E. vaginatum* occurs in tall, dense clumps. The distance between the clumps is variable and seems to be related to the intensity of sheep grazing and treading. Where this is low, the clumps are almost contiguous and the *E. vaginatum* cover consequently high. Associated species are *Calluna* and other Ericaceous species, *Deschampsia flexuosa, Anthoxanthum odoratum* and the herbs *Potentilla erecta and Galium palustre.* High grazing intensity leads to the development of a type of vegetation in which the clumps occur some distance apart. In such areas the proportion of mosses increases, *Polytrichum commune* and several *Sphagnum* species often becoming very conspicuous.

Burning leads to an increase in the dominance of *E. vaginatum* at the expense of the associated species. The relation between burning and the occurrence of the *Eriophorum* dominated and *Calluna* dominated types is obscure, but in intermediate types in which the species are co-dominant, burning appears to lead to the elimination of the *Calluna* and to the formation of a typical B1 type with a high *Eriophorum* dominance. Whether this is an irreversible change is not known.

Tree growth on this type has so far been satisfactory. Its nutrient content is similar to the A3 type except that the Phosphorus content is considerably higher. This latter effect is probably due to the retention of Phosphorus by the *Eriophorum* and its subsequent gradual release, but typical B1 sites may also benefit from a slight flushing influence. Competition between the trees and vegetation is less severe than in the *Calluna* types.

The type of vegetation in which *Molinia* is the most conspicuous species, the B3 type, is confined mainly to L. Navar, although a similar vegetation occurs at a few sites at Beaghs. The *Molinia* is usually accompanied by *Eriophorum vaginatum, E. angustifolium, Calluna* and *Erica tetralix. Carex panicea is* often present and again seems to increase with the severity of grazing and trampling. *Myrica gale* is found occasionally in this type but, although it has been stated that this species is a good indicator of nutrient rich conditions, the data from the Navar samples do not support this contention in that the sites on which it occurs are no richer than the other B3 sites. There may, however, be a flush influence at the sites on which *Myrica* occurs. Two species found, rather unexpectedly, in this type are *Trichophorum* and *Narthecium.* Both are present, however, in an unusually vigorous condition, due, presumably, to the higher nutrient conditions than those under which they are usually found.

The effects of burning and grazing do not appear to be severe and are reflected in the relative abundance of *Carex panicea.*

The Calcium and Iron content of peat from this type is higher than the corresponding types at Ballypatrick and Beaghs, but the content of Phosphorus is lower. Tree growth should be satisfactory.

These three vegetation types, then, form a group whose nutrient content is intermediate between the very poor *Trichophorum/Sphagnum* peat and the nutrient-rich flush peats now to be described. The variation in the vegetation of the group is fairly wide, but most intermediate types can be referred to one of those described above and their potential estimated accordingly.

Although it has been indicated that the types differ with regard to their total content of the various nutrient elements, it seems unlikely, in view of the amounts of the same elements applied as fertilizer, that the differences will be significant for early tree growth. Certain of the differences, however, are statistically significant and may be important during the later life of the tree crop. This may be so with the higher Phosphorus content of the B1 type and the high Calcium content of L. Navar types dominated by *Molinia.*

Category C.

The heavily flushed peats are very different from those already described. This applies equally to their vegetation and chemical characters. The vegetation types in this category found on deep peat are those dominated respectively by *Juncus acutiflorus,* type C1 and *Schoenus nigricans,* type C3. Communities dominated by *Juncus effusus* occur on peat, but usually only where there is an appreciable admixture of mineral particles and the peat is shallow.

These extreme flush types are so readily recognized in the field, and so different chemically from the other types that, despite considerable differences between them, they will be dealt with as a single group.

To illustrate the magnitude of the differences between these and the other peat types some results from the figures of mean total nutrient content shown in Table II. may be quoted. The value for Calcium, for instance, is over ten times greater in the *Schoenus* type than in the A2 *Trichophorum* type and the mean value for Iron is over twenty times that for an unflushed type. Potassium content is two or three times as high in the *Juncus* and *Schoenus* flush types as in most of the others. Only the Phosphorus content fails to show such extreme differences. In the *Juncus* type it is higher than in any other, but the mean Phosphorus content of fifteen *Schoenus* samples is lower than the means of the three peat types in the intermediate category of peat. This fact may be very important for the growth of trees on *Schoenus* type peats, especially in view of the very high Iron content of the peat. Another noticeable feature of the nutrient content of these flush peats is the significantly higher Calcium content of the *Schoenus* as opposed to *Juncus* types.

Apart from the dominants, the species composition of the two types is similar. One very obvious point of difference, however, is the much higher density of vegetation in the *Juncus* type. Consequently, the associated species in the *Schoenus* type are more conspicuous. The common associates of both types are *Molinia, Calluna, Succissa pratensis* and *Prunella vulgaris,* the two latter species being found mainly at L. Navar. The grasses *Deschampsia flexuosa, Anthoxanthum odoratum* and *Holcus lanatus* are commonly present. The moss *Breutelia chryso-*

coma, a recognized indicator of base rich conditions, is found in both types at L. Navar but does not occur in the Antrim areas.

Schoenus nigricans does not occur either at Beaghs or Ballypatrick.

Neither type suffers greatly from burning and grazing. Although the intensity of grazing is as high as on any other type, its effects are not apparent due, presumably, to the fact that the fertility of the site allows the vegetation to recover quickly from grazing damage.

As far as tree growth on the flush types is concerned, the only nutrient element likely to be limiting is Phosphorus. This is particularly true of the *Schoenus* type and fertilization may not overcome this limitation. Owing to the very high Iron content of the peat, the formation of complex Ferro-phosphate compounds may fix the Phosphorus in a form unavailable to the trees.

The competitive effect of *Juncus* and its associated species can complicate the establishment and restrict the early growth of the trees, but, once this is overcome, growth should be good provided an adequate source of available Phosphorus is present.

Peatland Vegetation as a Source of Nutrients.

In view of the peculiar importance of the vegetation in the nutrient economy of peatland, it was decided to investigate certain aspects of the chemical composition of peatland vegetation. The entire aerial portion of the vegetation standing on 1 sq. m. at five sites located in each of the four main vegetation types at L. Navar was clipped and brought back to Belfast in large polythene bags. Separate whole plants were collected for root analysis. The clipping was done in August, i.e. at the time of greatest dry matter accumulation. In the laboratory, the vegetation was separated into species, dried and weighed prior to analysis.

The mean total dry weight varies from approximately 5,000 lbs./acre in the *Trichophorum* type to 9,000 lbs./acre in the *Juncus* type. The value for the *Schoenus* type is relatively low at 5,600 lbs./acre, while the average for the *Molinia* type is 8,000 lbs./acre. These figures may be more intelligible when expressed as being from $2\frac{1}{2}$-4 tons per acre. A preliminary estimate of the dry weight of the *Calluna* dominated vegetation type at Ballypatrick is slightly over 10,000 lbs./acre.

Table III.

Nutrient Content of Four Site Types at Lough Navar, Co. Fermanagh

		Site content of total nutrients (Kgs./Ha.)				
Type	Component	Na	K	Ca	P	Fe
	Peat	43.76	43.52	184.85	53.77	85.01
A2	Shoots	4.81	19.09	11.71	2.44	1.24
	Roots	1.90	12.18	6.11	1.77	0.72
	TOTAL	50.47	74.79	202.67	57.98	86.97
	Peat	38.29	53.86	395.92	72.92	359.01
B3	Shoots	9.07	34.26	15.31	4.04	2.10
	Roots	1.77	31.36	7.60	2.59	0.61
	TOTAL	49.13	119.48	418.83	79.55	361.72
	Peat	57.72	219.36	786.85	147.39	3,795.90
C1	Shoots	25.51	42.68	23.92	6.45	1.17
	Roots	15.60	44.33	24.02	4.98	32.18
	TOTAL	98.83	306.37	834.79	158.82	3,829.25
	Peat	34.69	109.69	1,981.46	65.02	2,148.95
C3	Shoots	2.97	21.98	23.34	3.18	6.54
	Roots	3.41	28.94	19.37	3.19	1.59
	TOTAL	41.07	160.61	2,024.17	71.39	2,157.08

Samples of the vegetation from each type were analysed for total ion content, and the mean values of the nutrient content of both roots and shoots, expressed as Kgs./Ha. are presented in Table III; also included is the nutrient content of the corresponding peat type expressed as Kgs./Ha. to a depth of 10 cms. The total of these values provides an estimate of the Site Nutrient Content, i.e. the total amount of potentially available nutrients contained within the site at any one time. The amount of nutrients present in the site over a period of time will, of course, be greater than this due to the continual supply of nutrients supplied to the site via precipitation, flushing, air-borne particles, etc. and to any amounts added as fertilizer.

Unfortunately, complete results are not available for the North Antrim areas, but there is no reason to suppose that the relation between the nutrient content of the peat and vegetation will be essentially different from that shown for L. Navar forest.

The results in Table III illustrate the significance of the nutrients embodied in the vegetation for the initial growth of trees on peatland. Thus, the amounts of Potassium in the vegetation is approximately equal to the amounts in the upper 10 cms. of unflushed peat. Once canopy closure is attained and the vegetation suppressed, this supply of Potassium will be relatively easily available. Since trees growing on certain peats (Binns, 1959; Wright, 1959) have been shown to be deficient in Potassium content, the release of this element from the vegetation may be an important factor in determining the initial success of a tree crop on unflushed peat.

The amounts of the other elements in the vegetation, though comprising a smaller proportion of the total than Potassium, may be equally important in the early stages of tree growth, since the double layer of vegetation below the plough ribbon is one of the first sources of nutrients to be exploited by the developing tree roots.

It is thus apparent that the natural vegetation has a twofold effect on the establishment of trees on peat. In the first place, there is a direct competitive effect, both in the physical and nutritional sense, between the vegetation and the trees; this can be critical where species such as *Calluna* and *Juncus acutiflorus* are vigorous. Secondly, the nutrients embodied in the vegetation can, when they become available, provide a considerable stimulus to the growth of the trees.

An important source of nutrients available to trees growing on peat is that provided as fertilizer at time of planting. At the present rate of application in Northern Ireland (2 oz. basic slag/tree) the amounts applied are approximately 15-20 Kgs./Ha. of Phosphorus and 40-60 Kgs./Ha. of Calcium. One effect of this fertilization is that the magnitude of the differences between the nutrient content of the peat from different vegetation types becomes proportionately less. When comparing the values of nutrient content of different types this must be borne in mind, for, although the level of statistical significance will remain unaltered since the treatment is common to all types, the significance of relatively small differences to the trees will be reduced.

Summary and Conclusions.

In the first part of this paper, some of the considerations affecting the use of vegetation as an index of site potential for tree growth on peat are discussed. The second part deals with an investigation into the relationship between the vegetation and nutrient of the peat in three forest areas in Northern Ireland. From this, it seems that the peatland in Northern Ireland can be divided into three broad categories on the basis of vegetation and total nutrient content of the peat. The differences between these categories are likely to be significant for tree growth. Within each category, the establishment of trees and their early growth seems likely to be determined by the severity of the competition between the natural vegetation and the trees. From this aspect, successful establishment appears to be inversely proportional to the vigour of species such as *Calluna vulgaris.*

Although there is considerable variation in peat nutrient content between the vegetation types in each category, this may not be significant for early tree growth in view of the relatively large amounts of nutrient elements supplied as fertilizer.

In view of the close connection between the vegetation and the peat in the nutrient economy of the site, it would seem useful to regard the two as a unit and to relate tree growth to this unit, i.e. to site, rather than peat, nutrient content.

Once the vegetation has been suppressed, satisfactory initial tree growth can be expected on all vegetation types, but supplementary fertilization may be necessary to secure economic timber production on certain of the poorer, unflushed types. On the strongly flushed *Juncus* and *Schoenus* types the very high Iron content may lead to a deficiency of available Phosphorus.

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References.

Anderson, M. L., 1961. *The Selection of Tree Species.* 2nd Ed. Oliver & Boyd, Edinburgh.

Asprey, G. F., 1947. The vegetation of the islands of Canna and Sanday, Inverness-shire. *J. Ecol.* **34** : 182-93.

Barry, T. A., 1954. Some considerations affecting the classification of the bogs in Ireland and their peats. Intl. Peat Symp. Dublin, 1954. (in *Irish Forestry,* **11** : 48-64).

Binns, W. O., 1959. The physical and chemical properties of deep peat in relation to afforestation. Ph.D. Thesis, Univ. of Aberdeen.

Bellamy, D. J., 1959. Occurrence of *Schoenus nigricans* on ombrogenous peats. *Nature,* Lond. **184** : 1590-1.

Fraser, G. K., 1933. Studies of certain Scottish moorlands in relation to tree growth. *Bull. For. Comm.,* Lond. **15.**

Goodman, G. T. & Perkins, D. F., 1959. Mineral uptake and retention in cotton-grass. *Nature,* Lond. **184** : 467-68.

Gorham, E., 1953. A note on the acidity and base status of raised and blanket bogs. *J. Ecol.* **41** : 153-56.

Gimmingham, C. H., 1949. Vegetation as an indicator of conditions on hill-land in Scotland. *Scottish Forestry,* **3** (3).

Leyton, L., 1954. *Growth and mineral nutrition of spruce and pine in heathland plantations.* Inst. Pap. For. Inst. Oxf. 31.

McEvoy, T., 1954. Afforestation of peat soils. Intl. Peat Symp., Dublin, 1954. (in *Irish Forestry,* **11** : 65-75).

Malmer, N., 1958. Notes on the relation between the chemical composition of mire plants and peat. *Bot. Notiser,* **111** : 274-88.

Newbould, P. J., 1960. The ecology of Cranesmoor. A New Forest valley bog. *J. Ecology,* **48** : 361-83.

Parkin, K. F., 1957. Afforestation of peatlands in Northern Ireland. *Irish Forestry,* **14** : 111-117.

Poore, M. E. D., 1955. The use of phytosociological methods in ecological investigations. *J. Ecol.,* **43.**

Walsh, T. & Barry, T. A., 1958. The chemical composition of some Irish peats. Proc. *Roy. Irish Acad.,* **59** (B) : 305-28.

Weatherwell, J., 1953. The checking of forest trees by heather. *Forestry,* **26** : 37-40.

Wright, T. W., 1959. Use of fertilizers in the afforestation of deep peat. *J. Sci. Fd. Agric.,* **10** : 645-50.