The Soils beneath the Midland Peats

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SUMMARY

Large areas of raised bog are being cutover for fuel and other purposes in Central Ireland. As a guide to reclamation and development programmes for future land-use systems, surveys have been carried out to determine the type of mineral soils[3] buried beneath approximately 36,000 acres of such bogs. Most of these soils are derived from limestone boulder till and show a variable degree of profile development. Others in the form of marls and glacial clays also occur. All of the soils would present difficulties in reclamation, but to a varying degree.

Amelioration of the soils through incorporation of the overlying peat residues is discussed with reference to experimental work in progress.

INTRODUCTION

The mechanical winning of peat for fuel and other purposes is being carried out by Bord na Mona in a number of localities in this country. The areas are predominantly of the raised bog type and vary from 600 to 20,000 acres in extent with a total area of approximately 130,000 acres involved.

The reclamation of these areas, after peat harvesting is completed, for agricultural, horticultural and silvicultural enterprises, will present several problems. Experiments designed to solve these are in progress at the Peatland Experimental Station, An Foras Taluntais, Lullymore, Co. Kildare and Trench 14, Clonsast Bog, Co. Offaly (Forestry Division, Department of Lands).

In 1963, The National Soil Survey of An Foras Taluntais in conjunction with Bord na Mona, drew up a programme designed to characterise the nature, extent and distribution pattern of the soils underlying certain bogs. Approximately 36,000 acres have been surveyed in detail. Figure 1 shows the location of these bog units.

In recent years afforestation of hand-cutover bog has been quite common. Tree growth on some of these sites has been retarded, probably due to nutritional disorders caused by low nutrient levels and/or, low nutrient availability resulting from root contact with underlying calcareous materials. In such instances, it is desirable that

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[3] In this paper the word "soil" refers to the mineral materials beneath the peat whether or not they show evidence of soil profile development.

foresters have a proper understanding of the resource they are dealing with, to ensure that the proper species and cultural treatment is used.

This paper describes the factors contributing to the development and extent of the various mineral soils delineated in these surveys. Problems associated with the future utilisation of cutover peat are considered with reference to experimental work in progress.

FACTORS OF SOIL FORMATION

Soil properties depend on: (a) the physical and mineralogical constitution of the parent material; (b) the past and present environment, including climate, vegetation and hydrologic conditions, which together regulate the nature and intensity of the soil forming process and (c) the length of time these environmental processes have been in operation, which is conditioned by the geomorphic history of the ground surface concerned. The Central Plain of Ireland has relatively uniform climatic conditions (9) and variations in the nature of the

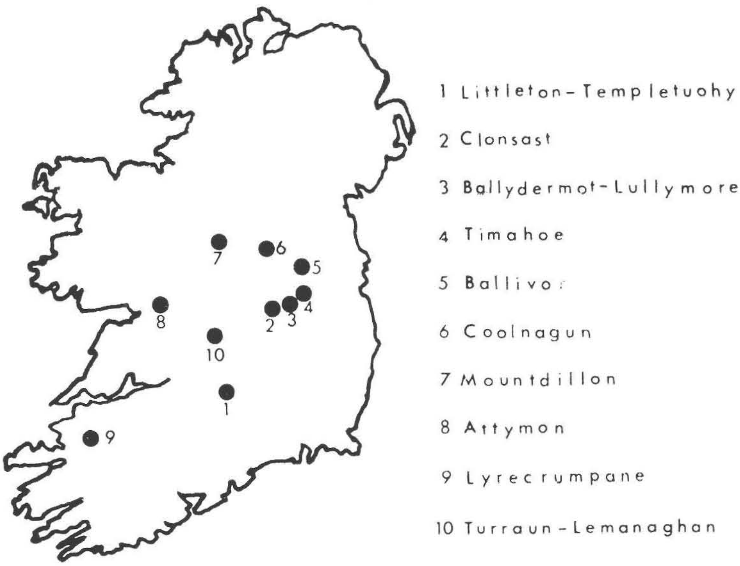

Fig. 1 *Location of bogs surveyed*

soils beneath the Raised Bogs arise chiefly from the integrated effects of parent material and geomorphic factors.

The retreat of the glaciers from the region about 12,000-15,000 years ago, left a gently undulating topography, with many enclosed basins in which Late Glacial inorganic and later organic, lacustrine deposits began to accumulate. Contemporaneously with the filling in of these lakes and ponds and their evolution to fen and woody-fen communities as described by Barry (6) much of the calcareous drift on the surrounding slopes gradually began to support a more arboreal type of vegetation with such species as oak, pine, hazel, alder and occasionally yew. With a deterioration of the climate in the post-glacial *Atlantic* period, tree growth in both community types was retarded, due to a rising watertable, and widespread waterlogging resulted in an increase in paludification and eventually the development of the oligotrophic dominantly *Sphagna* bog.

Hammond, (19), using radiocarbon dating and pollen analyses, has shown that the more depressed areas were covered by peat first and that paludification spread gradually outside the surrounding lagg. Consequently, the more elevated areas were subjected to the forces of weathering for a longer period of time. This factor in combination with the ability of their more highly developed arboreal communities to accentuate the weathering process has resulted in their soil profiles showing more advanced stages of development.

Owing to the relatively uniform nature of the glacial drift beneath the midland peats, it is now apparent that the major variations in the nature and degree of horizon development within the mineral soils are associated with differences in relief. Besides being the major cause of variations in profile development relief has also affected the extent and occurrence of superficial materials, such as marls, clays and silts. Such materials usually occur in the more low-lying areas beneath the peat.

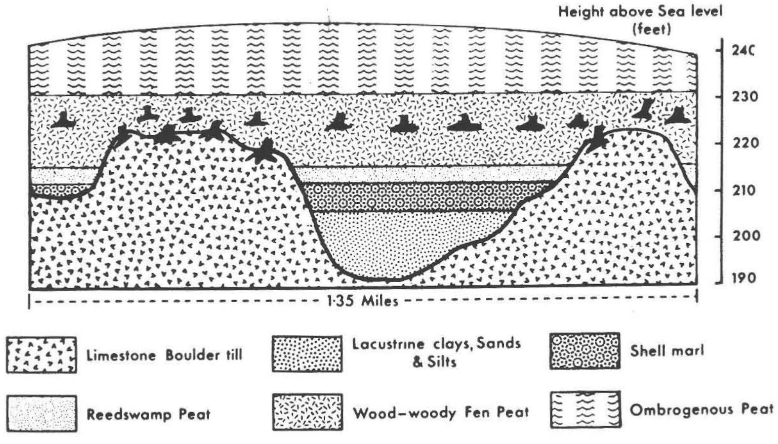

Fig. 2. *Schematic section across a Raised Bog in County Westmeath before peat harvesting. The ombrogenous and some of the more eutrophic peat is usually removed.*

The more important characteristics of the various categories delineated will now be described.

NATURE OF THE MINERAL SOILS

The nine different soils delineated in the surveys may be divided into two broad groups: —

(1) Those derived from glacial drift

(2) Those derived from superficial sands, silts, clays and marls, deposited over the glacial drift.

Different criteria have been used for further classification within these two broad groups. The degree of profile development is used to classify group (1) into more homogeneous units. Three degrees of development are recognised; (a) Well Developed, (b) Moderately developed and (c) Undeveloped. In Group (2) the texture and depth of the superficial deposits of sands, silts and clays are used as classification criteria. Marls are treated separately.

Group 1

Well Developed Relict Soils

These occur on the higher elevations of the bog floor and exhibit the maximum expression of profile development. Although found beneath all the bog areas surveyed, they vary considerably in their extent of occurrence. The most extensive areas are at Ballivor, Co. Meath (9), Clonsast, Co. Offaly (15) and Timahoe, Co. Kildare (18). Derived from calcareous limestone glacial drift, they are characterised by their upper horizons being leached and decalcified to an average depth of approximately 10 to 12 inches. They are usually greyish in colour, although the upper leached horizons generally display lighter colours than the underlying illuvial B horizons, which exhibit brownish colours, due to accumulation of sesquioxides. Yellowish red to yellowish brown mottles frequently occur particularly in the B horizon in the vicinity of old root channels. These soils have sandy loam textures in their surface horizons. The underlying B horizons, show heavier, clay loam textures. They have poor structural properties and tend to be rather compact. The upper leached horizons are moderately acid, but a sharp rise in pH and total neutralising value occurs once the lower calcareous C horizons are encountered. Fossil roots of grasses, sedges and trees frequently penetrate the B horizons and occasionally the calcareous C horizons. For example, fossil roots of Scots pine *(Pinus sylvestris L.)* have been observed *in situ* in the calcareous C horizon of these soils beneath both Littleton and Templetuohy bog. Fossil roots of oak, *(Quercus sp)*, alder, *(Alnus sp)*, hazel *(Corylus avellana L.)* and yew *(Taxus baccata L.)* also occur.

The level of plant nutrients, including trace elements, are low throughout with the exception of calcium and magnesium.

The well developed relict soils show many affinities with the Grey Brown Podzolic soils described by Ryan (29), which occur extensively in the midlands. Differences between the two are due mainly to the longer period of time that the latter have been exposed to weathering and anthropogenic influences.

Moderately Developed Relict Soils

These soils show a moderate degree of development intermediate between the well developed category described above and the undeveloped category described below. They are leached and decalcified to a depth of about six to eight inches. Their colour and structural properties are similar to the well developed category. Texture varies from sandy loam at the surface, to slightly heavier loam in the underlying B horizons. The surface horizon is usually slightly acid bu pH increases with depth and they become moderately alkaline in the lower calcareous C horizons. Nutrient status shows similar trends to the well developed category.

Although these moderately developed soils occur at all the areas surveyed, they are most common at Clonsast, Lullymore, Timahoe and Ballivor bogs, (15, 17, 18, 9). Sharp changes in topography such as occur at Coolnagun, Littleton and Mountdillon are not conducive to this type of profile development.

Undeveloped Relict Soils

This category includes soils derived from limestone boulder till, showing little evidence of profile development due to their occurrence on the relatively low elevations of the bog floor. They are characterised by the presence of free calcium and magnesium carbonates, at or within three inches of the surface, (peat/mineral junction) and have high pH and total neutralising values. Levels of essential plant nutrients are low throughout with the exception of calcium and magnesium. They differ from the more developed categories in having fewer fossil roots.

Undeveloped soils occur beneath all the bogs surveyed, but are particularly common at Littleton-Templetuohy, Attymon and Ballivor (9). They are also commonly found beneath parts of Timahoe bog (18), but their close association with other types precluded their delineation into separate areas.

The three soils derived from glacial drift and described above are seldom encountered in the field as discrete entities with clearly defined boundaries. Rather the boundaries between them tend to be gradual extending over variable distances depending on the rate with which topography changes. Their separation is made all the more difficult by the presence of the overlying peat. Together, they represent 60 per cent of the total area included in these surveys. The undeveloped category account for half of this.

Some analytical data for the three are presented in Table 1. Data from an upland Grey Brown Podzolic soil also derived from calcareous limestone boulder till is included for comparison. The main difference is the average depth to the calcareous C horizon. This decreases as one goes from the Grey Brown Podzolic soil to the Undeveloped Relict soils. Corresponding increases in pH values and levels for free calcium and magnesium carbonates also occur.

Table 1

Average Data for Relict soils derived from Glacial drift with corresponding data for an upland Grey Brown Podzolic soil.

Soil	Average depth to C horizon (inches)	Horizon	Texture	pH	T.N.V.**
Grey Brown		A	Sandy loam	7.5***	0
Podzolic	20-23	B2t*	Clay loam	6.8	0
(Upland soil)		C	Sandy clay loam	8.1	29.0
Co. Longford					
Relict soil		A	Sandy loam	6.1	0
(a) Well	10-14	B2t	Clay loam	6.9	0
developed		C	Sandy loam	7.8	38.0
Relict soil		A	Sandy loam	6.1	0
(b) Moderately	5-7	B	Loam	6.7	0
developed		C	Sandy loam	7.9	31.0
Relict soil	0-2	A	sandy loam/loam	7.4	3
(c) Undeveloped		C	Sandy loam/loam	8.1	31.0

*B2t = horizon showing increase in the finer textural components, clay (and silt).

**T.N.V. = Total Neutralising Value

***High surface pH due to liming.

Group 2

This group comprises three main categories which generally occur in the more lowlying basin situations of the bog floor. These include superficial deposits of (a) silty clays or silty clay loams; (b) marls, shell marls and chalk muds; (c) sands and sandy loams. Categories (a) and (b) are more common than category (c).

Category (a) — Silty clays, silty clay loams

These soils known locally as "glacial clays" and "blue clays" are characterised by their heavy texture, massive structure, sticky consistence, absence of gravels or stones and dark grey to grey colours. Their content of silt plus clay frequently represents over 90 per cent of their less than 2 mm fraction. This factor, together with their low permeability and poor structural properties engenders poor drainage conditions. They are generally, but not always, calcareous to the surface with pH values ranging from 7.0 to over 8.5. Their nutrient status is low, although high levels for certain trace elements e.g. molybdenum, have been recorded. This latter feature is probably related to their sedimentary origin.

Both shallow and deep phases of these soils have been delineated in the field. They frequently show evidence of varving with layers of fine sand, silt and clay occurring down the profile at varying intervals. The most extensive deposits occur beneath the Mountdillon group of bogs near Lanesborough, Co. Roscommon (7, 8). This region was greatly influenced by the River Shannon before peat accumulation began, this had resulted in approximately 2000 acres of peat being underlain by deep deposits of silty clays. They also occur commonly beneath the peat at Turraun and Lemanaghan, Co. Offaly. In some instances, they are overlain by deposits of marl — see below. Such is the case at Coolnagun bog, Co. Westmeath (9). At other areas, they are overlain by reedswamp peat. At the Mountdillon Group of bogs they are overlain by deposits of organic mud known as sapropel and gyttja, (5, 7, 8).

Category (b) — Marls and chalk muds

Included in this category are deposits of marl, which usually contain shells, and chalk muds. These materials may occur either immediately above category (a) or above undeveloped boulder till-relict soil 3 above. They vary from less than 1 inch to about 4 feet in depth. They also occur occasionally as layers of variable thickness, within deposits of peat.

These marls and calcareous muds were formed in lime-rich post glacial freshwater lakes through the precipitation of calcium carbonate by *Potamogeton* and species of *Characeae*. Such plants became coated with calcium carbonate and on their death and decay, the calcareous material accumulated on the lake bottom. Freshwater shells, the remains of species such as *Bythinia, Planorbis* and *Limnae* (10) may or may not be present. The chalk muds contain variable amounts of organic matter and because of this are usually darker in colour than the whitish coloured marls. Marl normally contains over 90 per cent calcium carbonate and is generally of moderate alkalinity. Levels of plant nutrients are always low.

Although deposits of marl occur beneath all of the bogs surveyed, their extent of occurrence varies greatly. The two largest areas so far encountered are beneath Ballydermot bog, Co. Kildare and Coolnagun bog, Co. Westmeath. At Ballydermot, deposits of shell marl extend over an area of more than 1,000 acres (17). More than eighty per cent of Coolnagun and Milkernagh bogs are underlain by deposits of this nature (9). It is apparent from observation in the field that deposits of marl occur beneath many areas of peatland not being worked by Bord na Mona. One example of this is to be found just north of Littleton bog, Co. Tipperary, where a large deposit of shell marl lies beneath shallow handcutover bog. This area has been afforested in recent years.

Category (c)—Sands, sandy loams.

These also form under alluvial or lacustrine conditions. Their light sandy texture, high permeability and low water-holding capacity favour excessive drainage, should the watertable be lowered sufficiently. They seldom show any worthwhile degree of development and are usually calcareous to the surface (with high pH values). However, in some areas, the surface horizons have undergone a moderate degree of leaching. Levels of plant nutrients are usually low. Both fine and coarse sandy deposits of varying thickness have been delineated. They seldom occur to any worthwhile extent.

APPLICATION OF SURVEY RESULTS

These surveys have shown that considerable variation exists in the mineral soils beneath the midland peats. In addition, the cutover peat surveys being carried out by Barry (2, 3, 4, 5), show that similar variation exists in the overlying peats. More recently, Barry *et al* (7) and Hammond (19) have demonstrated the strong correlation between peat type and underlying mineral soils. In designing future land-use policy cognisance must be taken of some problems associated with both the peat itself and the underlying soils. For the latter these include low biological activity, poorly developed and compact soil structure and low levels of essential plant nutrients. In some cases the highly alkaline nature of the upper layers also presents difficulties; free calcium and magnesium carbonates, very high pH, interference with plant nutrient uptake (including trace elements) and the restriction of the plant rooting system. The peat over-burden will present problems with regard to low levels of plant nutrients, high acidity, low permeability and shrinkage.

Before embarking on any reclamation programme involving forestry it would first be necessary to establish the effect of mixing the peat with the underlying mineral soil. Tree roots are unlikely to penetrate unless (a) soil is ameliorated through mixing with the peat by cultivation, (b) nutritional disorders are corrected (c) fertilizers are incorporated more deeply than at present. Excavation by the senior author of 10 years old roots of *Larix leptolepis* and *Pinus contorta* growing on shallow (6-9 inches deep) well drained cutover peat at Lullymore Experimental Station, underlain by a moderately developed soil showed that only about 2 per cent of the roots had penetrated below the peat. These trees are likely to be subject to windblow in future years.

Incorporation of the peat with the underlying mineral soil would alter the physical, chemical and biological properties of the medium resulting in many complex physico-chemical and biological interactions the nature and intensity of which would be greatly influenced by the type of peat and mineral soil concerned. The process involved in such organic — inorganic reactions are as yet little understood as evidenced by the reviews of Greenland (13) and Whitehead (34). The former, however, points out that the interactions of mineral soil and organic matter in addition to influencing the biological and physico-chemical properties of the soil results in decreased decomposition of the organic matter due to adsorption of organic molecules by clay minerals. The degree of adsorption depends to a large extent on the type of clay mineral concerned and also on the nature of the organic matter. Greenland, quoting others, states that such adsorption may in certain cases increase bacterial activity and decomposition of the organic fraction.

The improved aeration, permeability and aggregate stability resulting from the addition of organic matter to mineral soil, all accentuate the development of a more active biological flora in the latter. Dickenson and Dooley (11) have shown that cutover peat is not rapidly colonised by micro-organisms. These workers were concerned however, with acid anaerobic peat. As shown by Zverkov (36) and Nepomilev *et al* (23), suggested by Dickenson and Dooley *(loc. cit.)*, and concluded by Pessi (26), reclamation of peat (cultivation and fertilisation) results in a much improved micro-flora. Van Heuveln *et al.* (31) and Pons (27) in discussing soil formation and classification of reclaimed peat soils respectively referred to physical, chemical and biological "ripening" as the initial processes involved when drainage and nutrient status are satisfactory. More recently, Wieringa (35) has shown that treatment of acid "garden peat" with lime and fertilisers results in a marked improvement in its properties as a microbial medium. The addition, therefore, of material such as peat with this potential for improvement to the sterile mineral soils beneath should result in increased biological activity in the latter with all its associated improvements in fertility. Van Dijk *et al.* (32) have shown that the addition of horticultural peat to mineral soils results in increased availability of phosphate due to a reduction in fixation. This is especially important on calcareous soils. The beneficial effect of organic acids on the availability of insoluble sources of phosphorus and certain trace elements (34) also encourages the incorporation theory. Therefore, present evidence indicates that forest trees, when planted on shallow peat should grow and survive better if the peat is mixed with the underlying mineral soil before establishment. Further, Handley and Ridgman (14) showed that claying a light fen peat soil increased the yields of argricultural crops and although the presence of the clay might have an initial effect on nutrient supply they pointed out that in the long term it was desirable due to plant-soil moisture relationships. Results reported by O Carroll (25) also supports this hypothesis — see below. The presence of large fossil tree stumps *in situ* in some of the soils indicates that forest trees grew satisfactorily on such areas in the past. The presence of large Scots pine roots embedded in calcareous horizons is particularly interesting in view of the fact that this species is usually looked on as being a calcifuge. Perhaps a colder climate in early post glacial times favoured the growth of the species on such a medium. In this respect the findings of Tkachenko in the sub-arctic Archangelsk province of Russia as quoted by Iyer and Wilde (21) are particularly interesting. Under arctic conditions Tkachenko found that Scots pine grew much faster on calcareous than on acid soils. Wilde has also shown that the cooler the climate the more beneficial is soil alkalinity (36).

SUMMARY OF RELEVANT EXPERIMENTAL WORK TO DATE

The first experimental work concerned with the production of forest crops on cutover peat commenced at Trench 14, Clonsast Bog, Co. Offaly, in 1955 when Bord na Mona leased an area of 15 acres to the Forestry Service, Department of Lands. Peat types at Trench 14, as described by Barry (2) vary considerably in woodiness and depth. The peat is underlain by well developed and moderately developed relict soils (15). A pocket of deep silty clay occurs at the north end of the Trench, more or less coincident with Barry's reedswamp peat. Although not replicated the experiment is in many ways a classic and it shows that a wide range of conifers can be established successfully on Sod Peat cutover bog. Production figures of 220 cubic feet per acre per annum have been recorded. The presence of moderate amounts of calcareous mineral matter in the vicinity of the roots of *Larix leptolepis* improved growth (25). It was found that phosphate application was necessary where the remaining peat cover was greater than about two feet in depth. Where the peat is shallower or absent, other factors such as the nature of the mineral soil become dominant (25). In experiments at the Lullymore Peatland Experimental Station, potassium was found to be a limiting factor for coniferous tree growth on cutover peat (1). O Carroll (24) has also diagnosed pottassium deficiency on two species of conifer on a peat soil in the midlands. These findings are not surprising in view of the exceedingly low levels of potassium present in such situations. (7, 33). This factor in addition to the capacity of the mineral soils to fix potassium in relatively unavailable forms suggests that a shortage of potassium is likely at Clonsast or other areas where similar conditions prevail. In view of possible low nitrification in Irish peats as shown by Kuster and Gardiner (22) nitrogen may be a limiting factor as the trees get older.

The work at Trench 14 was extended in 1966 to study how the addition of mineral soil* to cutover peat might effect the growth of Sitka spruce. This involved four levels of application: 0, 60, 100 and 120 tons per acre of mineral soil. Each level was applied to four plots, two of which were cultivated, thereby mixing in the mineral soil with the peat and two which were not cultivated thereby leaving it spread on top of the peat. The control plots although receiving no mineral matter had two plots cultivated and two undisturbed. Results after the first season's growth showed that plant mortality increased with increasing

* The soil used was of the moderately developed type. In some cases it appears that the lower calcereous C horizons were used despite attempts to use only the leached horizons.

level of mineral soil applied. In the second year, cultivation significantly increased leader growth whether mineral soil was applied or not and irrespective of the amount applied.**

Another experiment on the N, P and K requirements of Sitka spruce and Contorta pine on cutover Sod Peat bog was laid down at Timahoe Bog, Co. Kildare by An Foras Taluntais in 1965. This has shown that potassium application increased the height growth of both species, phosphate application in excess of 2 oz. per plant had no effect while nitrogen adversely affected establishment (1). Similar trends but better growth rates were obtained with the same species in another trial on shallow cutover milled peat at Lullymore (1).

Further research is needed to investigate the rate, type and time of application of fertilisers. In addition to the major plant nutrients, micro-nutrients also deserve attention. Low levels of copper, boron, manganese and in some cases, molybdenum, zinc, cobalt and iron are a feature on both the cutover peats and their underlying mineral soils (7, 8). Hewit (20), has described deficiency symptoms in trees, due to abnormally low levels of most of these elements. The calcareous nature and high pH levels of some of the mineral soils beneath the peat will also merit attention in tree nutrition. In this respect, the demonstration by Richards (28) that *Pinus taeda* showed iron deficiency chlorosis in soils when the pH was raised above 7.5 is relevant as is the control of lime-induced chlorosis in Scots pine growing on a calcareous site by Schonhar (30) by injection of ferric sulphate into the trees. Further research is also needed to show whether it is best to plant trees on shollow peat *in situ* or on shallow peat mixed in with the underlying mineral soil and if so particular attention might be given to the mechanics of such an operation. The research being carried out at the Arthur Rickwood Experimental farm in the Fenlands in England (38) is particularly interesting in this respect. The performance of forest trees on all other peat types including the deep virgin raised bog types also needs further investigation from a biological, hydrological and nutritional point of view.

CONCLUSIONS

To plan a land use policy that will make the best use of cutover areas a thorough knowledge of the soil resources is most important. This information is being compiled as a result of these surveys. Then the best amelioration processes, the ideal cropping systems, the most desirable manurial and management practices to give optimum returns must be worked out. Research already in hand is providing some of the answers but many aspects have still to be investigated. The factors such as water, oxygen and nutrients limiting the achieve-

** Grateful acknowledgement is extended to the Research Branch, Forest Service, Dept of Lands for the information on its experiment.

ment of potential timber production are within man's control but the level to which each should be adjusted under the environmental conditions concerned in order to reduce the potential/actual production ratio to a minimum is not yet known. Therefore, from a forestry viewpoint the potential timber production in these areas might first be investigated and then a research programme implemented, designed to assess what combination of adaphic and other limiting factors within the control of management, such as tree species or provenance, would take one nearest to that potential. The costs involved in such operations would also need consideration to ensure optimum economic returns on capital invested.

Finally, when the time comes for making land-use decisions for these cutover areas, in addition to considering the economic role played by silvicultural, agricultural and horticultural crops, the high recreational value associated with forests and the scarcity of visually attractive features in these midland areas might be given consideration. Similarly other alternative uses of land resources such as the provision of artificial lakes for wildfowl and other recreational needs might also be considered. Only in this way can the various forms of land-use be brought together in such a way as to serve best the economic and social interests both at a local and at a national level.

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