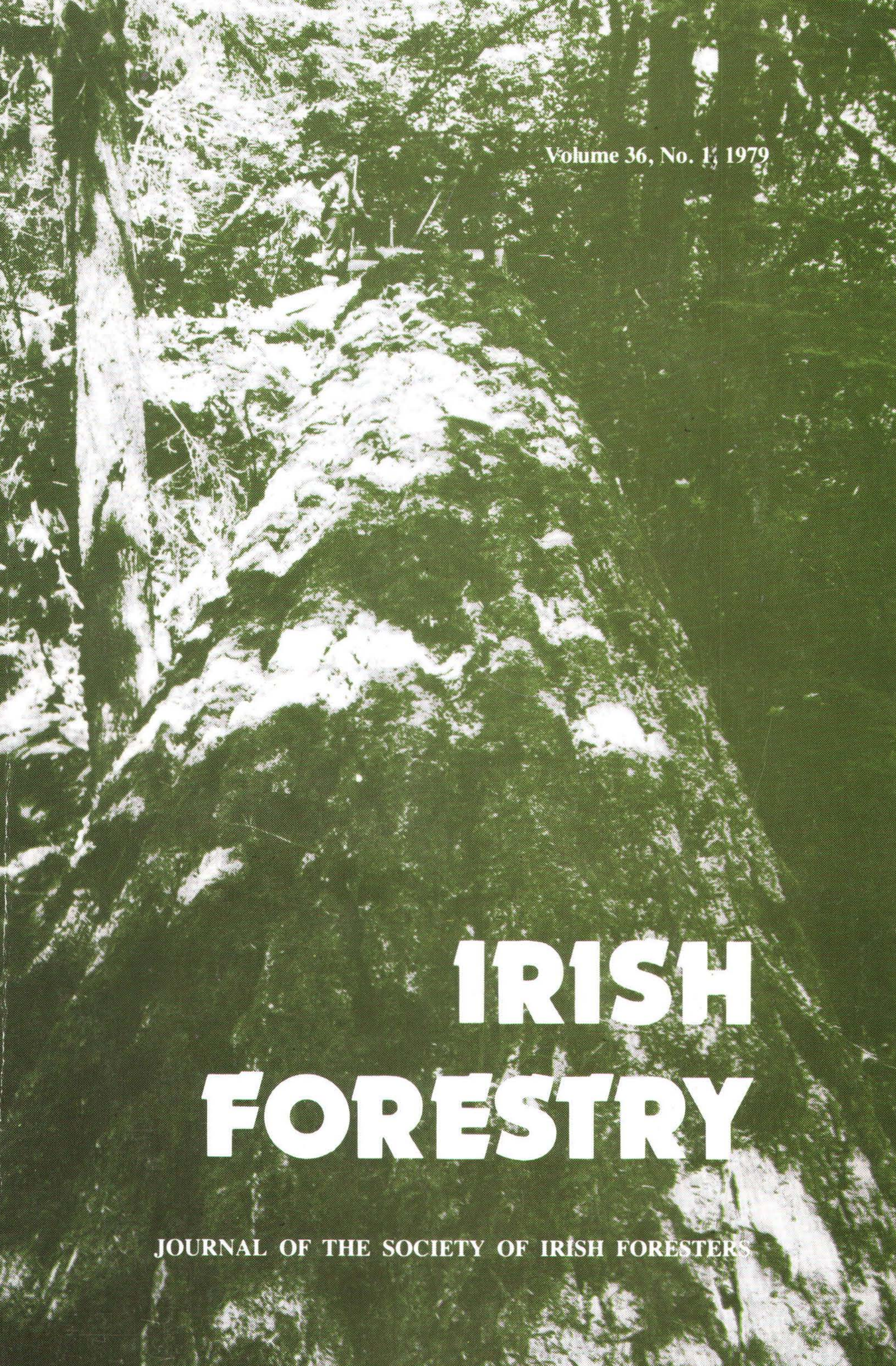

Volume 36, No. 1, 1979

IRISH FORESTRY

JOURNAL OF THE SOCIETY OF IRISH FORESTERS

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JOURNAL OF THE SOCIETY OF IRISH FORESTERS

1979, Volume 36, No. 1.

Published twice yearly. Price £2.

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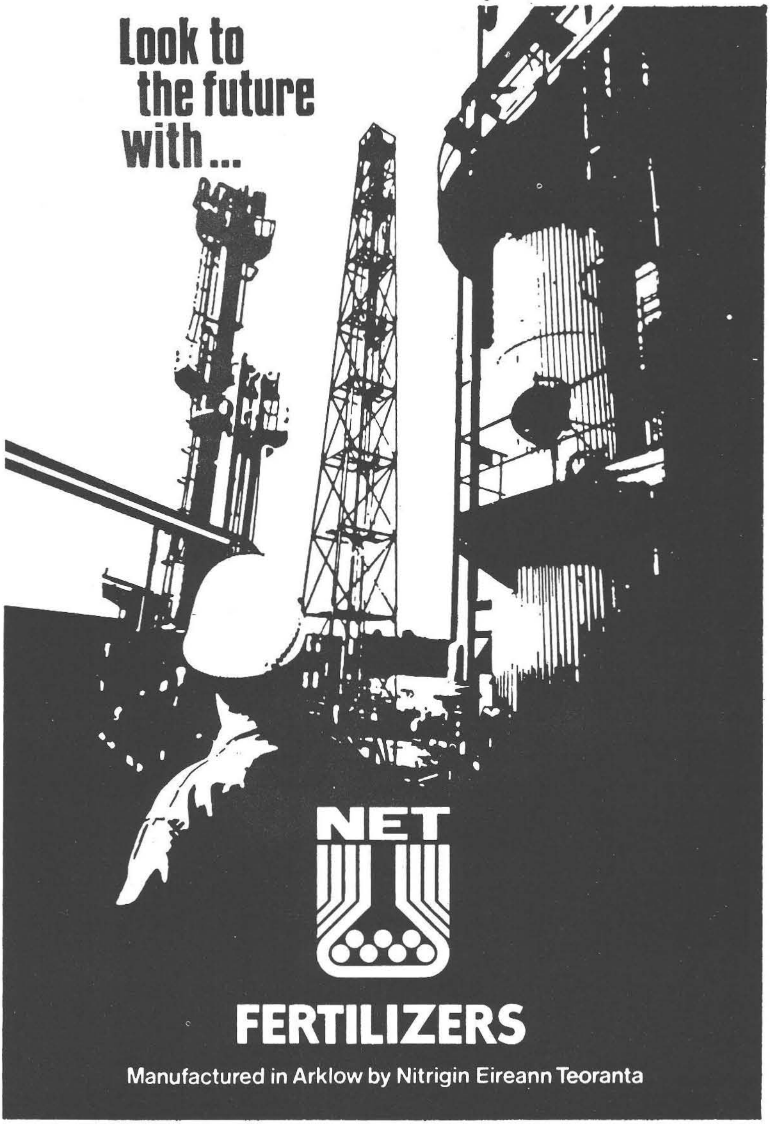

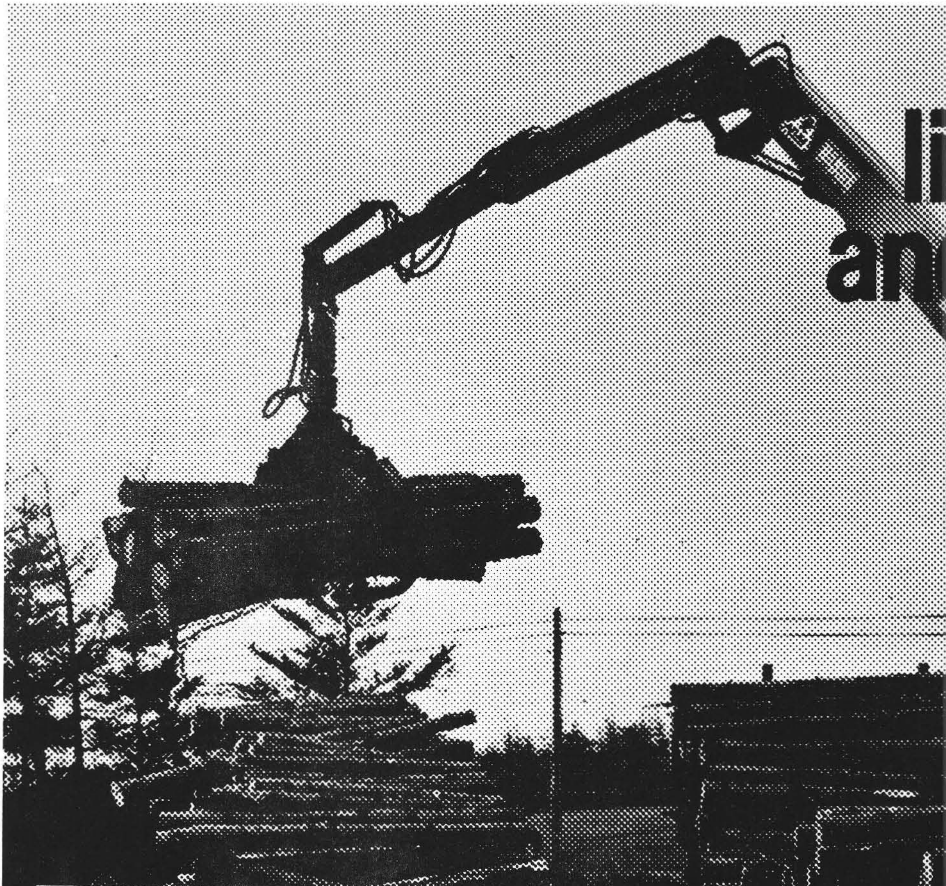

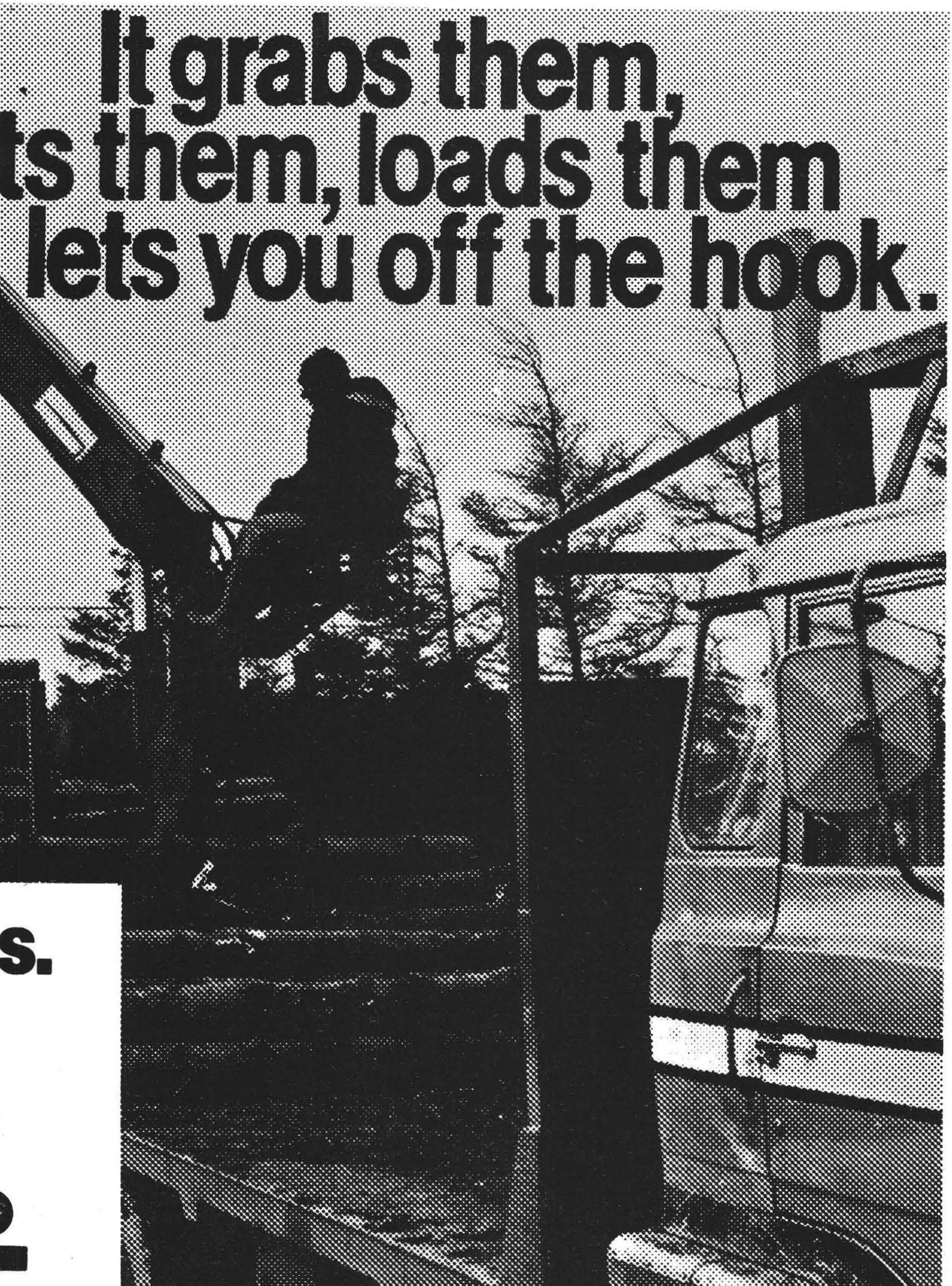
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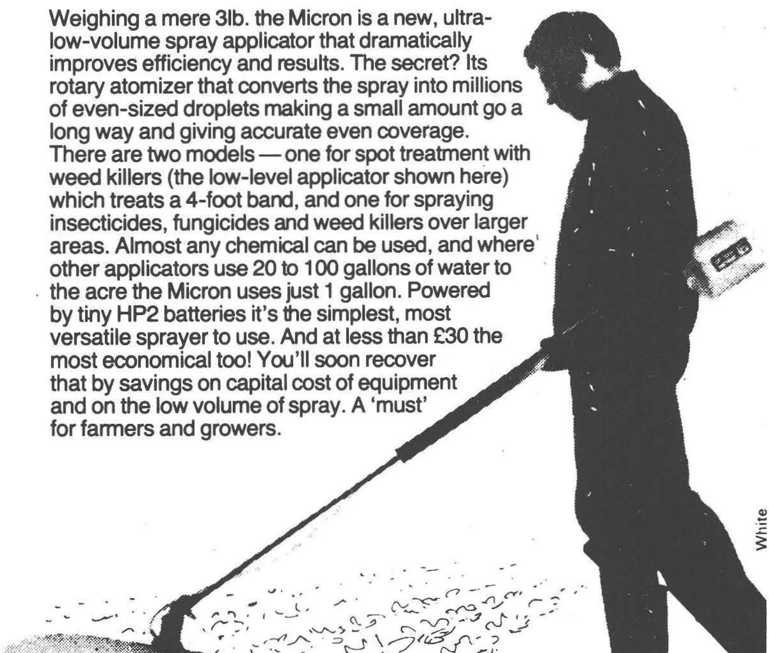

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IRISH FORESTRY

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1979, Volume 36, No. 1.

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1. Two copies of each paper should be submitted, in typescript, with double spacing and wide margins.

2. Diagrams and illustrations should be clearly drawn in black ink on good quality paper. The approximate position of diagrams and illustrations in the text should be indicated in the margin.

3. Tables should not be incorporated in the body of the text, but should be submitted separately at the end (one table per page). Their approximate position in the text should be indicated in the margin.

4. Nomenclature, symbols and abbreviations should follow convention. The metric system should be used throughout.

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Contents

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Cover: Looking the length of a fallen Douglas-fir tree which measured 3.1m diameter on the stump. Wind River Ranger District, Carson, Washington, U.S.A. Total length was more than 45m. Workmen in picture are about half way along the tree. (Photo: U.S.D.A. Forest Service)

Printed by the Elo Press Ltd., Dublin 8, Ireland

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EDITORIAL

Wood for the Burning

Time was when the only energy source available to man was wood, burned to provide heat. True, the water wheel comes to us from the time of the Babylonian Empire, the ancient Chinese developed the windmill and, in the sailing ship, a single use of wind power has, in a very real sense, shaped the history of the world. Nevertheless, it is estimated that in 1800 more than 90% of man's energy consumption came from wood. Although the advantages of coal were already known, it was only with the development of underground mining in Britain in the 18th century that coal production soared and with it came the Industrial Revolution. Wood fell from its dominant position and its use as fuel has continued to decline, so that today, Swedish farmers with more ready cash than foresight are replacing their wood-fired stoves and furnaces with oil-fired boilers and allowing the waste wood of their own forests around them to rot on the ground. It is then, perhaps surprising to learn that an estimated 2,300 million tonnes of wood is consumed as fuel, every year. The tragedy is that this is mostly in very poor countries, where the disappearance of these forests, so vital for the survival of the inhabitants, is occurring at an alarming rate and the daily search for fuel is becoming almost as important and as time-consuming as the search for food.

It is in the developed countries that the idea of growing trees in order to provide an energy source is gaining most prominence. Still at an early stage of development, these schemes aim to achieve the maximum possible rate of dry matter production on the site. They are a far cry from conventional forestry but they are worthy of the attention of foresters. They represent a serious effort to utilise solar energy in a manner which has the potential to contribute significantly to our energy supplies. However, it is vitally important that in the production of energy forests inputs be kept to a minimum. There is little point in achieving an energy yield of 125,000kWh* per hectare per annum if the energy inputs in terms of fertilisers, harvesting, transport, etc. amount to 150,000kWh. The trouble is, that the sums involved here are not easy and call for some rather sophisticated energy accounting. Unless *all* the inputs are taken into account, and this can be very difficult, the calculated benefits may be illusory and the entire operation a waste of time . . . . and energy.

* 1kg plant dry matter has an energy content of 5kWh approx. The corresponding figure for petroleum is slightly less than 12kWh per kg.

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The Society of Irish Foresters was founded in 1942 to advance and spread in Ireland the knowledge of forestry in all its aspects.

The main activities of the society centre around:

(a) Annual study tour

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(c) Production of two issues annually of Society's journal "Irish Forestry"

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Submissions to the journal will be considered for publication and should be addressed to: Dr. E. P. Farrell, Editor, Irish Forestry, Department of Agricultural Chemistry and Soil Science, University College, Belfield, Dublin 4. The attention of contributors is drawn to "Notes for the Assistance of Contributors" on page 2.

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The Energy Potential of Forest Biomass in Ireland

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Sidmonton Place, Bray, Co. Wicklow.

ABSTRACT

Wood has several important advantages over other biomass sources for energy production. Vigorous juvenile growth, low moisture content and the capacity to coppice are the ideal characteristics of species grown for this purpose. The Forest and Wildlife Service is participating in an EEC Energy Project with the aim of investigating the energy potential of forest biomass. The first phase of this project, consisting of growth trials of a range of woody species at four representative forest sites (western blanket bog, midland raised bog, old red sandstone podzol and drumlin-gley) was established in 1977. Plant spacing was narrower than that used in conventional forest management practice in order to increase productivity per unit area. Early results of plant survival and dry matter production from the growth trials indicate that, of the species being investigated, lodgepole pine, Sitka spruce and *Eucalyptus* are performing best. Above average forest land is required for satisfactory growth of species capable of coppicing and, of the four sites, only the drumlin-gley appears to fulfil this requirement. The possibility of direct seeding reducing the establishment costs of the successful, though non-coppicing conifers, is being tested. Preliminary results from these trials, of seedling emergence, are encouraging. Yields of forest biomass ranging from 25-40 tonnes dry matter/ha/year have been obtained on productive forest lands in the United States; this is a productivity almost competitive with coal at 1974 prices. Similar yields are possible in Ireland on comparable sites. Estimates of the possible energy contribution of forest biomass, as waste materials and as pure energy plantations, are made. It is postulated that the energy import demands of this country could be reduced by 27% based on 1977 imports and **assuming the equivalent of half the total forest area were managed on a 20 year rotation.**

IRISH FORESTRY, 1979, Vol. 36, No. 1: 7-18.

INTRODUCTION

The dramatic quadrupling of oil prices in 1973 had an alarming effect on the economy of most oil-importing nations. The Irish economy in particular suffered since we have a heavy dependence on imported oil, importing 75 percent of our energy requirements in the form of oil.(1) It is widely accepted that the 1973 crisis was no passing phenomenon; in other words, cheap oil is a thing of the past. Furthermore, the world's supply of oil is predicted to run out in the next 50 years. Other non-renewable sources of energy, such as coal and natural gas, also have limited reserves available.

Recognition of these harsh realities has activated urgent research into the use of alternative renewable sources of energy. Three options have been proposed in order to meet the energy shortage expected through unavailability of formerly plentiful and cheap sources of energy: (i) nuclear energy — this option is the subject of conflicting opinions on a worldwide scale; (ii) increased imports of coal — the disadvantage of this option for this country would be that it would again be placing an undue reliance on an imported source of energy, thus putting itself at the mercy of the whims of influences outside its control; (iii) renewable resources — included amongst this option would be such possibilities as solar and geothermal energy, wind and wave power, and biomass.

Renewal resources have considerable advantages: (i) renewability, (ii) abundance, and (iii) economy, and presumably this economy will become increasingly apparent as the non-renewable resources come nearer to full depletion and become economically inaccessible. Further discussion in this paper will be centred on the renewable resource biomass and specifically forest biomass.

THE FOREST BIOMASS CONCEPT

The term "biomass" refers to plant material and industrial waste, including forest wastes* and plantations grown specifically for the production of energy. (The latter are often referred to as "energy plantations").

The types of energy that can be derived from biomass include (i) direct heat, (ii) electricity generation, and (iii) liquid fuels. Forest crops have several advantages over agricultural crops for biomass purposes: (i) they can be put to other uses besides energy, (ii) they can be harvested throughout the year, (iii) they can be grown on poor or infertile sites, (iv) deterioration in storage is slow, (v) their fertiliser requirements are relatively small. It could also be said — and this also applies to some biomass sources other than wood — that the technology, workforce and materials are available for the development of this resource.

The main disadvantage of forest biomass is its bulky nature and therefore its high cost of transport. However, this might be offset by having the source of energy near to where it will be utilised.

* Wastes refer to tree stems less than 7cms in diameter, branches and needles.

The ideal species for use in biomass production would have the following characteristics: (i) it would be high-yielding in its early years of growth, (ii) it would have a low moisture content, and (iii) it would be capable of coppicing or sprouting. As regards the last it is unfortunate that the conifers in general do not fulfil this requirement. In addition, and perhaps more seriously, conifers at conventional spacings are not high-yielding in their early years, and rotations of at least 15 years would appear to be necessary for conifers if present spacings are to be used. Assuming continuance of the present trend in land use and the availability of only poorer land types for forestry, conifers are likely candidates for forest biomass. However, an awareness of the necessity for extensive forest biomass production may increase in the future to such an extent that land types normally denied to the forester may well be made available. If that is the case coppicing hardwoods would probably be the preferable species for biomass production. It behoves us therefore to have answers as to what species yield most on different land and soil types. In addition, research is needed to investigate the intensity of cultural practices required to maximise dry matter production. It is appropriate therefore that the Forest and Wildlife Service is participating in an EEC Energy Project which has these goals amongst its aims.

EEC Energy Project

Many bodies, such as the EEC, were prompted into major energy, research and development programmes following the oil crisis in 1973. Thus, the EEC initiated a wide-ranging programme in 1975 in which solar energy was to be one of the subjects for research. The Forest and Wildlife Service has undertaken involvement in the solar energy project entitled "Photosynthetic production of organic matter — choice and development of the most suitable energy crops for the different regions of Europe"(2). Our concern therefore will be the use of short rotation tree crops and forest wastes for the production of energy. The following are the objectives of the project: (i) to ascertain the likelihood of commonly grown species giving an economic yield on representative forest sites, (ii) to make projections as to the extent to which yields could be increased in order to obtain the maximum utilisation of solar energy, (iii) to determine the maximum output of utilisable energy per hectare and the proportion of national needs that will be supplied in this way.

The first phase of this project consists of a series of growth trials. These were established in Spring 1977 at four locations on representative forest sites (Table 1), that is western blanket bog (Ross Forest), midland raised bog (Tullamore Forest), drumlin-gley (Swanlinbar Forest), and old red sandstone podzol (Kilfinane Forest).

Table 1 — Site characteristics of growth trial locations

	Forest			
Characteristic	Kilfinane	Swanlinbar	Ross	Tullamore
Aspect	South	North	East	Nil
Elevation (m)	290	240	100	100
Slope	7°	3°	0.5°	Nil
Rainfall/yr (mm)	1000-1500	1,600 (Ca.)	1,250 (Ca.)	750 (Ca.)
Geology	O.R.S.	Carbonif. Sst.	Granite	Carbonif. Lst. Sst. and Shale
Great Soil Gp.	Podzol (Discont. iron pan)	Drumlin-gley	Blanket bog	Raised bog
Peat depth (m)	0.1-0.3	0-0.15	2.6	3.0 (Ca.)
Vegetation	Calluna-Molinia	Grass-Rush	Calluna-Molinia	Calluna-Eriophorum

Before planting, the sites were prepared to conform as much as possible to the normal forest management requirements (Table 2). At each of the four sites a range of species was planted (Table 3).

Table 2 — Site preparation for growth trials

Forest	Ploughing	Fertiliser
Kilfinane	Clarke S.M.B. tine plough (D6 tractor) — complete	500kg C.R.P. (14.5% P)/ha.
Swanlinbar	Clarke S.M.B. tine plough (D4 tractor) — complete	None
Ross	Cuthbertson S.M.B. (drainage) at 1.5m — Fiat 805	500kg C.R.P./ha.
Tullamore	Cuthbertson S.M.B. (drainage) at 2.0m — Fiat 655	500kg C.R.P./ha +250kg KC1 (50% K)/ha.

Table 3 — Species composition of growth trials

Species	Common Name	Age
Pinus contorta Doug. ex Loud.	Lodgepole pine	1+1
Pinus radiata D. Don	Monterey pine	1-year seedlings
Picea sitchensis Bong. Carr.	Sitka spruce	2+1
Alnus rubra	Red alder	1+1
Betula verucosa	Silver birch	1 u, 1
Eucalyptus johnstoni	Eucalyptus	1-year potted
Populus trichocarpa	'T' (Fritzi Pauley)	0+1
Populus tacamahaca x *trichocarpa*	'TT (32)	0+1
Castanea sativa Mill.	Spanish chestnut	1+1
Salix aquatica gigantea		
Salix dasyclades	Willow	Cuttings
Salix viminalis		

Planting was completed before the end of April 1977 at Ross and Tullamore and by mid-May 1977 at Kilfinane and Swanlinbar, apart from the *Eucalyptus* plants which were planted at the end of June 1977. The slit method of planting was used except in the case of the poplars (pit method), *Eucalyptus* (semi-circular spade method) and willows (unrooted cuttings were inserted directly into soil by hand).

Plant spacing was decided somewhat arbitrarily in the absence of guidelines (Table 4). However it was assumed that spacing narrower than that used in normal management practice would achieve better results in terms of dry matter production. The unavailability of suitable machinery to plough any closer than 1.5-2.0m on the peat sites dictated to some extent the spacing at Ross and Tullamore; that is, it would have been desirable to have the plough ribbons (i.e. the continuous sod removed to produce the furrow and upon which the trees are planted) closer than 1.5-2.0m in order to be able to plant at a narrow spacing across the ribbons. To make up for the plant number deficit across the ribbons extra plants were planted along the ribbons.

Table 4 — Plant spacing at growth trials (m)

Forest	Conifers, Eucalyptus	Willows	Other Hardwoods
Kilfinane	0.8 x 0.8	0.5 x 0.5	1.2 x 1.2
Swanlinbar	0.8 x 0.8	0.5 x 0.5	1.2 x 1.2
Ross	1.5 x 0.5	1.5 x 0.3	1.5 x 1.0
Tullamore	2.0 x 0.3	2.0 x 0.3	2.0 x 0.8

A randomised block design was used on the mineral sites and a completely randomised design on the peat sites. Plots were replicated three times except for *Eucalyptus* and willow at all sites and poplar and Spanish chestnut at the peat sites. The plant density of each species at the four sites are shown in Table 5.

Table 5 — Plant density of growth trials (plants/ha)

Species	Kilfinane	Forest Swanlinbar	Ross	Tullamore
Lodgepole pine	15,625	15,625	11,033	10,206
Monterey pine	15,625	15,625	11,033	10,206
Sitka spruce	15,625	15,625	11,033	10,206
Eucalyptus	15,625	15,625	11,033	12,022
Alder	6,400	6,400	5,785	5,897
Birch	6,400	6,400	5,651	5,405
Poplar 'T'	6,400	6,400	5,785	5,897
Poplar 'TT'	6,400	6,400	5,785	5,897
Spanish chestnut	6,400	6,400	5,785	5,897
Willow	34,225	34,225	19,354	18,144

Results and Discussion of Growth Trials Two Years After Establishment

Estimates of dry matter production two years after establishment of the various species at each site have been made (Table 7). These have been based on the number of surviving plants (Table 6) and a sampling of three trees per plot. The three sample trees were selected to represent (i) the mean height tree, (ii) the mean height tree plus one standard deviation, and (iii) the mean height tree minus one standard deviation.

It is clear from the survival assessments (Table 6) that several of the species, such as the poplars and willows, find the conditions of soil and/or climate unfavourable. The drumlin-gley site alone bears consistently high numbers of surviving plants. In general the species surviving best are: lodgepole pine, Sitka spruce, alder, birch and *Eucalyptus*.

Table 6 — Plant survival at growth trials (%)

Species	Kilfinane	Forest Swanlinbar	Ross	Tullamore
Lodgepole pine	98	89	99	95
Monterey pine	86	55	50	68
Sitka spruce	98	98	98	97
Eucalyptus	79	96	20	96
Alder	97	97	100	78
Birch	92	97	90	94
Poplar 'T'	92	100	10	0
Poplar 'TT'	94	100	70	0
Spanish chestnut	98	97	100	86
Willow	0	100	0	0

Table 7 — Above ground dry matter two years after establishment at growth trials (tonnes/ha)

Species	Kilfinane	Forest Swanlinbar	Ross	Tullamore
Lodgepole pine	0.82	0.17	0.64	1.37
Monterey pine	0.13	0.14	0.03	0.23
Sitka spruce	0.77	0.44	0.87	1.22
Eucalyptus	1.08	0.89	0.21	3.60
Alder	0.14	0.68	0.13	0.16
Birch	0.15	0.28	0.18	0.37
Poplar 'T'	0.37	3.79	0.03	0
Poplar 'TT'	0.33	1.08	0.21	0
Spanish chestnut	0.07	0.06	0.11	0.20
Willow				
S. aquatica gigantea	0	0.84	0	0
S. dasyclades	0	0.82	0	0
S. viminalis	0	0.65	0	0

Since these survival counts were conducted, severe frosts occurred in early January 1979 and wreaked havoc on the *Eucalyptus* in particular. It is uncertain if the plants will recover although some have been observed to have sent out shoots to take over from the damaged main shoots.

Whilst it is still too early to make projections as to the potential dry matter productivities of the various species it is apparent which species are likely to be in the forefront. Lodgepole pine and Sitka spruce are prominent at all sites except the drumlin; their relatively poor growth on the drumlin is surprising but they are expected to recover and may even grow very well on this site. *Eucalyptus* performed well on all but the blanket bog but it remains to be seen if this species recovers from the frosts mentioned above. If a frost-hardy *Eucalyptus* species were selected it seems that it would be a very promising candidate for biomass production. The poplars and willows succeeded only on the relatively fertile drumlin soil and where exposure was not excessive. The failure of the willows on all but the drumlin site might appear to be a severe indictment of the species. However, the willow species were the only ones that were planted as cuttings; perhaps survival and dry matter production would have been better if rooted plants were employed. Furthermore the planting of the willow cuttings was done later than desirable and they probably suffered as a consequence.

To the agriculturist the dry matter data of even the most successful species may not appear high. However, this is to be expected since forest trees in general are not productive in their initial growth. The mean annual increment (MAI) at normal spacing does not reach a maximum till after at least 15 years. Acceptable levels of biomass production might be achieved using rotations somewhat shorter than the age at which maximum MAI is reached. Dry matter production can be increased substantially by such devices as decreasing the spacing which would therefore allow a considerable shortening of rotations.

Given that only the drumlin site would be regarded as fertile it is not surprising that the coppicing species have not produced as much dry matter as the non-coppicing species on the other sites. Coppicing species, generally hardwoods, require fertile, unexposed sites and so favourable results could not realistically be expected for the hardwoods on the infertile sites. This is unfortunate since planting is one of the costliest items in stand establishment. In view of the relative success of the non-coppicing species, lodgepole pine and Sitka spruce, and assuming they have a potential for biomass production on the poorer forest sites, it was decided to investigate the possibility of reducing the establishment costs of these species by direct seeding. Accordingly, direct seeding trials were laid down at each site. Seeds of lodgepole pine and Sitka spruce were sown directly on to the ground surface in Spring 1978. The only site preparation carried out prior to sowing was the removal of coarse vegetation. The density of sowing was heavy, being similar to that used in forest nurseries, and so survival of even 25% of the emerging seedlings might be considered satisfactory for biomass production. More exact tolerable levels of seedling survival will not be known until more information is obtained about the plant spacing required for maximum yields. Preliminary results of seedling emergence are encouraging.

YIELD PROSPECTS FROM FOREST BIOMASS

The EEC energy trials described above are not yet at a stage where we can answer the questions posed by the objectives of the project. The only conclusion that can be drawn from the trials so far is a tentative choice of the best species for each site. The big question is: Will productivity reach levels that will provide reasonable hope for further increases in yields through experimentation on fertilisation, spacing, species selection, etc.? Experience on some fertile sites in the U.S. has been that it is possible with present technology and expertise to increase yields from 10 to 15-fold through practice of short rotation forestry(3).

The viability of forest biomass as an alternative energy source can be gauged from experimental evidence gained in southeastern and northwestern U.S. where yields ranging from 25-40 tonnes/ha/year of above ground dry matter have been achieved so far(4,5). This level of productivity was almost competitive with coal in terms of 1974 coal prices(6). Given the spiralling increases in coal prices since 1974 it would be reasonable to assume that wood at such yields would now hold its own at least with coal and presumably will become increasingly competitive in time.

Is it possible for us in Ireland to achieve comparable yields? Conventional long rotation forests are composed of trees spaced too far apart, even in the most productive of our plantations, to give yields comparable to those reported in the U.S. In the absence of spacing trials (these are proposed for inclusion in the second phase of the EEC Energy Project) we are not in a position to be specific as to what yields are possible. However, reasonable estimates of potential yields are possible based on investigation of two small plantations of Sitka spruce. The first plantation is situated on a peaty gley in Drumkeeran Forest, Co. Leitrim and consisted of a bed of plants spaced 12cms apart both between and along rows. The yield of above ground dry matter reached 48 tonnes/ha after only three years following transplanting. The second plantation occurred in a private nursery on an acid brown earth in Carnew, Co. Wicklow, and the Sitka spruce plants here had been planted at a 27cm x 6cm spacing. The yield of above ground dry matter was more spectacular at this site reaching 88 and 90 tonnes/ha after only three and four years respectively following transplanting. Apart from the high yields obtained an interesting point about these data is that very little additional production is gained by waiting the longer time period. Perhaps these yields could be increased still further by utilising the best combination of resources available such as fertilisers and lime, weed and pest control, irrigation and even a different spacing. It has to be admitted that the yields mentioned above were obtained on above average forest sites and it may well be that energy plantations will require land of a quality not at present available to the Forest and Wildlife Service.

ENERGY PROSPECTS FROM FOREST BIOMASS

1. Forest Wastes

In 1978 total fellings (thinnings plus final fellings) amounted to about 1,055,000m^3, of which about 205,000m^3 represented waste material. Assuming a 50% moisture content (fresh weight basis) and 0.35 tonnes/m^3 dry material, forest wastes for 1978 amounted to about 36,000 tonnes dry matter. This is equivalent to about 18,000 tonnes oil equivalent or 26,000 tonnes coal equivalent, which would have represented about 0.3% of oil imports in 1978 or 3% of coal imports in 1978.* If total fellings for 1978 were used solely for energy purposes they would have been equivalent to 1.2% of oil inports or 12.6% of coal inports. National felling forecasts indicate substantial increases in volume of fellings each year rising to over two million m^3 by the year 2000(7); therefore it is possible to decrease our reliance still further on imported energy by utilising forest wastes, provided of course our energy requirements stayed relatively constant.

2. Energy Plantations

The present total forest land area in Ireland is about 330,000 ha. Let us assume an equivalent area to be managed on a 20 year rotation, capable of producing 10 tonnes dry matter/ha/year or 200 tonnes dry matter over the rotation. The area of forest due for harvest annually would be 330,000 ha ÷ 20 years = 16,500 ha. Therefore the amount of dry matter available annually would be 16,500 ha x 200 tonnes/ha = 3.3 million tonnes dry matter/year. This would be equivalent to 1.6 million tonnes oil equivalent (MTOE) which represents 27% of the nation's energy import demand for 1977.

Whether this substantial reduction in energy imports could be sustained in the long term is unknown. It would depend on many factors, most of which would not be directly related to forest biomass production. Foremost amongst these would be the future energy demands of the country. It is estimated that the energy import demand will rise from 6.0 MTOE in 1977 to 16.0 MTOE in

* The conversion factors used were: 1 tonne wood = 0.49 tonnes oil equivalent and 1 tonne wood = 0.72 tonnes coal equivalent.

1990(1). If the projected contribution from forest biomass as stated above were to stay constant at 1.6 MTOE then this would represent 10% of the energy import demand for 1990, a considerable drop from the 27% envisaged for 1977. Thus the significance of the contribution of forest biomass to our energy requirements may well hinge on how people will respond to energy conservation measures they probably will be asked to adopt in the future.

SUMMARY AND CONCLUSIONS

The idea of using wood to produce energy does not meet with unanimous approval. However, with the costs of oil and coal escalating at a rate in excess of that for wood, the economics of the proposition should become more attractive in time.

The problems of disposing of timber products in periods of poor demand might be eased greatly if the product affected, say pulpwood, were diverted for energy production.

The growing of forests is a relatively efficient way of capturing and storing solar energy. The efficiency is increased if the lands suitable for the practice of intensive short rotation forestry using coppicing species are available.

There are two ways of producing forest biomass, firstly as forest wastes and secondly as pure energy plantations. A system of dual usage could be employed in which forests could be a source of conventional products such as sawlog, boxwood and pulpwood and also as a source of energy. This might be the best course of action on exposed and/or infertile forest lands. This would ensure maximum utilisation of the species that are likely to grow best on these sites, namely the non-coppicing conifers. Pure energy plantations would meet with greater success on more productive lands since these would support a wider range of species, including the highly desirable coppicing hardwoods.

Direct combustion may not be the most appropriate form of energy to produce from forest biomass. With continued improvements in chemical technology becoming available perhaps con version to other forms of energy, especially liquid fuels, might make a more substantial reduction in imported energy costs.

It is clear that much research and development work needs to be done before the full picture of the potential of forest biomass emerges.

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Intensive forest management is a much used term here in Western North America. In Irish forestry we have been practicing intensive forest management for decades for without it we would not have the ever expanding forest resource that we now have. In the Pacific Northwestern States of Oregon and Washington much of the virgin old growth native forest has been logged, and the importance of intensive forest management has increased in the past decade.

For Irish forestry the home of silviculture and management is Avondale Estate, Co. Wicklow. Here in the great forested region of the Pacific Northwest, the home of silviculture and intensive forest management is Wind River.

The Gifford Pinchot National Forest is situated in south central Washington State. It is one of 19 national forests in the Pacific Northwest, and it is subdivided into 5 forest districts one of which is the Wind River District. The offices for the district are situated in Hemlock some 97km east of Portland, Oregon, and 16km north of the Columbia Gorge in Skamania County. The total area of the district is 102,000 hectares of which 97,000 is classified as "commercial forest land".

Situated on the western slopes of the Cascade Range, the Wind River District is characterised by steep slopes and gentle rolling plateaus. The fast flowing rivers, the Wind River and the Lewis River drain the district and flow into the Columbia River. Elevation ranges from 150m to 1524m.

The climate is typical of the western slopes of the Cascades. Winters are cold and wet with temperatures often below 0°C, and the summers are hot and dry with temperatures often in excess of 21°C. The annual precipitation on the district ranges from 130cm on the eastern side to 310cm on the western side. The average winter snowfall at the higher elevations is more than 6m, and is usually less than 0.5m at the lower elevations.

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The geology of the forest area is primarily intrusive and extrusive volcanic material, however some small isolated pockets of bedded sediments do occur. The major soil groups are derived from volcanic ejecta, which includes ash, pumice and cinders from the now dormant snowclad volcanic cones of Mount St Helens, Mount Adams and Mount Hood. These soils tend to be unstable and harvesting limitations have been placed on all soils that are highly erosive.

A diverse natural flora exists on the forest which includes many of the economically important tree species of Western North America. The predominant commercial timber species on the district are in order of importance, Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), Pacific Silver Fir (*Abies amabilis* (Dougl.) Forbes) and Western hemlock (*Tsuga heterophylla* (Raf.) Sarg.). Other species of importance are Western red cedar (*Thuja plicata* Don.), Noble Fir (*Abies procera* Rehd.), Grand Fir (*Abies grandis* (Dougl.) Lindl.), Lodgepole Pine (*Pinus contorta* Dougl.) and Western White Pine (*Pinus monticola* Dougl.). Some of the typical ground cover vegetation includes the beautiful Vine Maple (*Acer circinatum* Pursh.), Bigleaf Maple (*Acer macrophyllum* Pursh.) and Oregon grape (*Berberis aquifolium*). Other species common to the region are Red alder (*Alnus rubra* Bong.), *Alnus oregona* Nutt., huckleberry (*Vaccinium spp*), salal (*Gaultheria shallon*) and Bracken fern (*Pteridium aquilinium pubescens.*).

Avondale is to Irish forestry what Wind River is to forestry in the Pacific Northwest, for it was here that the early American Foresters came to be trained as far back as 1912. Wind River is known internationally for its fine bare rootstock nursery, which covers 49 hectares and produces some 30 million seedlings annually, primarily Douglas-fir. This district is also the location of the oldest arboretum in Western North America. It was established in 1912 with the primary object of testing the suitability of exotic tree species from all over the world. The arboretum covers 4.5ha and no less than 641 seedlots and planting stock have been planted out here. Some of the exotic tree species have survived but the most productive species proved to be the native tree species in the case of the Pacific Northwest. This region of the world is the place from which many of the seeds came that were planted in Avondale many decades ago. Some of the native species of this region have become the cornerstone of many planting programmes in Western Europe including Ireland. Some 480ha of "old growth" timber has been set aside as the Wind River Natural Area. In 1933, 4,400ha were set aside as the Wind River Experimental Forest. This is one of several experimental forests dedicated to serve as a centre for testing various silvicultural techniques, including spacing and fertilization trials. Studies on forest protection, ecology, forest harvesting and slash disposal are also carried out in this designated area.

The professional staff of the Wind River District consists of five assistants one for each of the following areas, Resources, Timber Sales, Silviculture, Fire Management, and Engineering. Each assistant is responsible to the District Ranger and all hold university degrees. A brief outline of the responsibilities of each assitant is given below.

The Resource Assistant is responsible for fish and wildlife management, watershed management, recreation, special use permits and all mining exploration on the district. In 1972 the Gifford Pinchot National Forest had more than one million visitors. The Wind River Ranger District has 87km of nature trails, two toll campsites and four tollfree campsites. The famous Pacific Crest National Scenic Trail which stretches some 3,800km from Canada to Mexico passes through the district. A wildlife biologist is working as part of the Resource staff and his primary responsibility is the monitoring of the turbidity of water samples taken before, during and after logging on "class one" streams. A class one stream is one in which anadromous fish are found, and/or a stream which is used as a domestic water supply. The changes in turbidity of the water samples allow foresters to schedule harvesting and road construction operations to times when the minimum damage is done to the fish populations. The wildlife biologist also has the responsibility of big game management, which includes hunting and the maintenance of a sustained forage supply. Natural meadows, ponds, nesting sites and other niches are protected. The deer hunting season spans three weeks and the elk season two weeks. During the 1977 five week season, 500 deer and 70 elk were harvested on this district alone.

The Timber Sales Assistant is responsible for all timber sales on the district. The sustained nondeclining evenflow allowable cut for the district is estimated at 168,000m^3 annually. The average annual revenue from timber sales in recent years has averaged £9.6 million — 75% of this revenue is retained by the U.S. Government, and the remaining 25% is returned to the county in which the timber was cut. Half of the revenue given to the county is allocated to schools, and the other half to road construction and maintenance in that county. In this way the people benefit directly from the revenue of timber sales in their county. In Skamania county in 1972, the yield supported three local sawmills, and four plywood mills which employed 720 people and the annual payroll amounted to £3.7 million.

The Timber Sales Assistant is also responsible for the layout and extent of clearfellings. Clearfelling has long been a controversial issue in the Pacific Northwest. Today as always, clearfelling is the most widely used harvesting system on the district but strict limitations have been placed on the size and location of clearcuts. Clearcuts average 6ha in size, and range from 1 to 50ha, depending on soil conditions, topography, accesibility and value of the timber. Most of the harvesting on steep slopes is done by highlead, or skyline,

Douglas-fir, butt end 3m diameter. Counting rings showed it to be 524 years old. On Baker Highway, National Forest, Washington.

with some tractor skidding on the flatter sites. Some loggers leave vast quantities of "unmerchantable material" behind as slash. The amount of slash left on the forest floor ranges from 14 to 580 tonnes per ha. The gross standing volume ranges from 175 to 760m^3 per ha. Much of the timber cut is "oldgrowth" Douglas-fir which is often over 500 years old.

The Silviculturalist is responsible for reforestation, spacing, fertilisation and precommercial thinning. Intensive forest management is only in its infancy here in Western North America, because with such an abundance of "oldgrowth" many people thought it to be almost inexhaustible. These "oldgrowth" stands are rapidly disappearing (Fig. 1) and being converted into young vigorous "second growth" stands through the application of intensive forest management. The Silviculturalist on the district is keenly aware of the importance of intensive forest management to maintain and boost current yield. This is achieved by having all stands fully stocked and growing at their optimum rate throughout their rotation, which for Douglas-fir averages 120 years. Full stocking and precommercial thinning are prerequisites to maximising the economic return over the rotation. A great deal of research has been carried out in the Wind River Experimental Forest on the effect of spacing on volume production by Dr Donald Reukema. Many of the recommendations of Dr Reukema have been applied to large areas in the district. Fertilisation of stands has also been researched, but as of yet no extensive use of fertilisers has been made in the district. It should be mentioned that although the Wind River Ranger District is one of the most intensively managed publically owned districts in the entire Pacific Northwest Region, in comparison with intensive management in Ireland this district has still a long way to go.

Fire management is the sole responsibility of the Fire Management Assistant. Each summer a fire crew of 60 men and women are hired for fire prevention and fire fighting. During the summer months fire is prevalent and if the fire hazard becomes too high all logging operations are closed down. The Fire Management Assistant can call upon regional firefighting equipment such as aeroplanes carrying liquid fire retardnt, smoke jumpers, and extra manpower if climatic conditions and the size and intensity of a forest fire deem it necessary. A highly trained and well organised team of smoke jumpers can be parachuted into the scene of a forest fire within a very short time of the fire being reported. These men work to contain the fire with the help of the district fire crew and the aircraft support.

The Engineering Assistant has the responsibility of transportation planning, road layout, and all other engineering tasks on the district. Roughly 50km of road is constructed annually and all roading is designed to facilitate harvesting and intensive management. The engineering staff work in close contact with the Timber Sales staff. At the present time the district has 1000km of forest road.

Finally, the overall responsibility for the Wind River District lies with the District Ranger. He coordinates the efforts of his staff into what is a blend of many disciplines and background experiences. The policy and decision making responsibility for the district rests with the District Ranger. Environmental Analysis Reports are produced for all major management projects. These reports state clearly what the anticipated impact the proposed management activity will have on the environment. If the impact of a management activity is potentially great, then an Environmental Impact Statement is prepared for the planning unit in question. This Environmental Impact Statement is based on the management alternatives open to the District Ranger. Public input and criticisms are invited on all Environmental Impact Statements. Eventually a Final Environmental Impact Statement is published which outlines the alternatives open to the District Ranger and the preferred alternative, which is usually a multiple use alternative, and the consequences to the environment of its implementation.

ACKNOWLEDGEMENTS

I am deeply indebted to Mr Robert D. Tokarczyk, Forest Supervisor; Gifford Pinchot, National Forest, Washington; Mr Harold P. Lange, District Ranger; and all those who were so kind and helpful to me during my stay on the Wind River Ranger District, Washington.

Biomass, Nutrient Content and Distribution in a Stand of Sitka Spruce*

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ABSTRACT

The annual uptake of nitrogen, phosphorus and potassium by an unthinned 33 year old crop of Sitka spruce was estimated by destructive sampling of eight trees. Extrapolation of their nutrient contents to the total crop gave estimates of 81kg N, 4kg P and 15kg K. Although the stemwood and bark accounted for half of the total dry matter production they only contained 17, 14 and 36 *per cent* of the total quantities of N, P and K present in the crop and forest floor, the main bulk of the nutrients being in the needles and branches.

INTRODUCTION

The rising cost of fertilisers in recent years, together with the extension of afforestation on to increasingly difficult site types, and a trend towards more complete-tree harvesting systems (Young 1974, Keays and Hatton 1976), has focused attention on both the biomass production and nutrient accumulation patterns within forest crops. Although results from many studies have been published none of these refer to Sitka spruce (*Picea sitchensis* (Bong) Carr.), a native of Western North America and now the most important forest tree in Ireland (Purcell 1977) and Britain (Pearse 1976). This study was carried out in a polestage crop of Sitka spruce. The objects were:

1. to measure the total dry matter (DM) production by the crop and to determine its distribution between the different crop components;
2. to measure the total nitrogen (N), phosphorus (P) and potassium (K) contents of the crop and to determine their distribution patterns;

* Based on part of a larger study carried out by the Senior Author at University College Dublin, Ireland.

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3 to estimate the gross annual production of organic matter and the gross annual uptake of N, P and K;

4 to quantify the extra drain on the nutrient budgets that would result through the implementation of more complete tree harvesting systems.

METHODS

Field

The crop was planted in 1941 at Glenmalure forest (National Grid ref. Glenmalure T 06 94) on a soil transitional between a peaty gley and a blanket peat — peat depth 80cm — over shallow glacial drift comprised of mica schist and granite. No cultivation or fertiliser treatments were imposed on the site other than the fact that the trees were planted on mounds. No silvicultural operations had been carried out apart from brashing of dead branches in 1973 which were left on the forest floor. As a result the crop was considerably overstocked (Table 1) relative to the normal management tables for the species (Bradley, Christie and Johnston, 1966).

Table 1 — Crop and site characteristics.

Age	Top Ht.	Yield Class	Basal Area	Stems	Elevation	Mean Annual rainfall	Mean Annual temperature
(Yrs)	(m)	$m3\ ha^{-1}$	$m2\ ha^{-1}$	ha^{-1}	(m)	(mm)	^{o}C
33	15.9	14	74.7	3,760	350	1,800	10

Eight trees were selected at random for destructive sampling using the following procedure: three square 0.1ha plots were located randomly within the stand which had a total area of 7ha. The diameter at 1.30m from the base of all trees (a small proportion of which was dead) in the three plots was measured to the nearest 0.1cm. The total population for the plots, 735 trees (diameter range 7.0-28.9cm), was divided into eight equal number classes based on the diameter distribution and the sample trees were randomly allocated within these, the only restriction being that at least two samples should fall on each plot. Each sample tree was felled on to a large P.V.C. sheet and separated into the following components for determination of fresh weights and subsampling for moisture content and chemical analyses; dead branches (including bark), live coarse branches, live fine branches, bole timber and bark and coarse and fine roots (greater and less than 1cm diameter), the stump being included with the coarse root fraction. That part of the

Table 2 — Concentrations of N, P and K in the different components on each sample tree. (% D M).

Tree Component		Sample tree number 1	2	3	4	5	6	7	8	$\bar{X}$	Std. Error
Dead branches	N	.80	.84	.76	.87	.87	.87	1.00	1.06	.88	.035
	P	.0560	.0500	.0545	.0585	.0480	.0520	.0550	.050	.0522	.0012
	K	.067	.050	.050	.060	.050	.055	.092	.045	.059	.005
Live coarse branchwood	N	.11	.11	.13	.16	.13	.13	.13	.14	.13	.005
	P	.0090	.0082	.0130	.0207	.0115	.0110	.0147	.0125	.0125	.0013
	K	.075	.067	.095	.100	.050	.085	.107	.090	.084	.006
Live coarse branch bark	N	.98	.92	1.32	1.25	1.07	1.08	1.01	1.31	1.12	.054
	P	.0900	.1000	.1600	.1100	.110	.1400	.1500	.1400	.1237	.0090
	K	.390	.545	.725	.480	.362	.690	.580	.565	.542	.045
Live coarse branch needles	N	1.86	1.59	1.66	1.66	1.66	1.66	1.52	1.59	1.65	.035
	P	.1300	.1100	.1400	.1900	.0700	.1500	.1200	.1300	.1300	.0121
	K	.845	.725	.690	.840	.327	.850	.670	.545	.687	.063
Live fine branchwood	N	1.24	1.04	1.24	1.73	1.24	1.52	1.11	1.45	1.32	.080
	P	.1100	.0800	.1100	.0900	.0800	.1600	.1200	.1200	.1087	.0087
	K	.250	.260	.330	.460	.190	.450	.380	.260	.323	.035
Live fine branch needles	N	1.73	1.99	1.99	1.73	1.86	1.92	2.12	1.86	1.80	.047
	P	.1100	.0800	.1100	.1900	.0800	.1600	.1200	.1200	.1212	.0132
	K	.900	.725	.580	.660	.635	.500	.710	.860	.696	.047
Bole timber	N	.19	.14	.19	.12	.11	.19	.18	.12	.16	.012
	P	.0030	.0025	.0035	.0040	.0050	.0030	.0030	.0040	.0035	.0003
	K	.050	.050	.067	.062	.045	.067	.062	.067	.059	.003
Bole bark	N	.92	.89	.91	.71	.81	.65	.74	.79	.80	.035
	P	.0700	.0620	.0700	.0820	.0670	.0650	.0870	.0900	.0741	.0037
	K	.250	.330	.240	.400	.205	.400	.410	.400	.329	.030
Coarse roots	N	.16	.20	.14	.16	.24	.23	.18	.20	.19	.012
	P	.0108	.0083	.0075	.0097	.0202	.0222	.0137	.0126	.0131	.0054
	K	.132	.095	.072	.112	.127	.185	.132	.107	.120	.0117
Fine roots	N	.78	1.59	1.11	1.04	.84	.90	.78	1.11	1.02	.094
	P	.0520	.0540	.0500	.0600	.0550	.0800	.0560	.0750	.0620	.0039
	K	.177	.225	.172	.440	.272	.590	.282	.385	.318	.051

main stem less than 7cm diameter was included with the coarse branch category. The branch components were chopped up into approximately 15cm lengths to facilitate subsampling. Ten discs were taken at equal distance along each bole in order to determine the ratio between bole timber and bark and their moisture contents and nutrient concentrations. Although many fine roots were observed at 100-110cm the overall excavation of the root systems proved easy due to the aid of a block and chain which was suspended from a specially constructed heavy frame. Recovery of roots appeared to be in the order of 95-98 *per cent.*

Laboratory

Dry weights were determined on duplicate samples by drying at 105°C for forty eight hours. Samples for chemical analyses were dried at 70°C for the same period. Subsamples of the live coarse branches were further separated into branch timber, branch bark and branch needles. For the live fine branches a separation was made between root timber and root bark. All samples were ground in a Glen Creston mill before chemical analyses were carried out (in duplicate). Total nitrogen was determined using a micro-Kjeldahl method after Jackson (1958). Phosphorus was determined colourimetrically using the molybdenum blue method, ascorbic acid acting as the reductant after Alexander and Robinson (1970). Potassium was measured by flame emission spectrometry. The results from the chemical analyses are presented in Table 2.

Statistical

The moisture contents and nutrient concentrations were used to determine the dry matter and nutrient contents of each sampling component on each of the sample trees; the total dry weights and contents of N, P and K present being obtained by addition. A series of simple linear regression equations relating the sample tree dry weights and their nutrient contents to independent variables such as basal area, mid-diameter, volume and total height was then calculated. These showed that basal area was more closely related to the dependent variables than any of the other variables, the r^2 values in each case being 0.94 or more (Table 3). Because it is also an easily measured stand characteristic it was used for prediction purposes. Further, as the r^2 values were sufficiently high it was not deemed necessary to use any alternative models.

Table 3 — Coefficient of determination for the equations relating DM, N, P and K of the sample trees to certain tree parameters.

Dependent variables	Basal Area	Volume	Independent variables DBH	Mid-Diam.	Total Height
Total DM	.97	.94	.88	.90	.27
Total N	.94	.90	.88	.86	.18
Total P	.95	.90	.90	.88	.24
Total K	.94	.92	.88	.85	.32

Separate regression equations were calculated in order to provide a breakdown of the distribution of DM and nutrients within the crop. Basal area was again used as the independent variable due to its reasonably close relationship with the dry weights and nutrient levels of the different crop components. (Table 4). The dry weights and nutrient contents of the component parts were converted to a unit area basis. Examination of the crop estimates (Table 4) shows that while the confidence intervals are quite variable in some cases, the prediction of the larger components together with the total are quite satisfactory (±12% for total DM). This would seem to indicate that improvements in the accuracy could be attained by estimating the dry weight and nutrient contents of the whole tree by chipping and sub-sampling rather than splitting into subjective components. Certain estimates are very unreliable e.g. live coarse branch needles, mainly because it's not an easily described component.

Results and Discussion

The basal area, volume, total height, dry matter distribution and total N, P and K contents for each of the sample trees are shown in Table 5. Table 6 shows the DM, N, P and K contents for the crop, and the forest floor based on earlier work (Carey and Farrell 1978).

The total DM and nutrient contents were determined by addition of the data for crop and forest floor and the figures on gross annual accumulation were obtained by dividing these by the age of the crop, 33 years. These figures do not take account of losses of organic matter from the site through decomposition, respiration or root death. However these are likely to be small in view of the dense nature of the crop and the fact that no silvicultural treatment other than brashing had taken place.

The relatively large quantities of organic matter and nutrients, particularly N and P, in the forest floor are a reflection of the very dense nature of the crop. This resulted in an unusually high fall of litter (Carey and Farrell 1978) and at the same time probably contributed to slow rates of decomposition. The small quantity of potassium present in the forest floor relative to that in the crop is a reflection of the high mobility of this nutrient compared with N and P and is in agreement with results found by other investigators (Cole *et al* 1967).

Table 6 indicates that the crop has produced in excess of thirteen metric tons of organic matter per hectare per annum and in doing so it has taken up an average of 81kg N, 4.4kg P and 15kg K each year. The figure for organic matter, although within the range given in the literature for coniferous trees, is nevertheless high bearing in mind that the timber production is less than the national average for Sitka spruce in Ireland (Purcell 1977). However it still only represents forty three *per cent* of the figure given by Curran (1968) for maximum production potential of organic matter in the country.

Table 4 — Regression equations and coefficients of determination, crop estimates and confidence intervals for dry matter and nutrient level by components and for the complete tree.

		Intercept		Slope		R^2	Crop Estimate (kg/ha)	95% Confidence Intervals (kg/ha)±	% of mean±
Dead branches	DM	3.66119	NS	419.89087	NS	.46	45,131.9	23,408.8	51%
	N	.00415	NS	5.01476	*	.65	390.2	186.3	48%
	P	.00227	NS	.20756	NS	.40	24.0	13.1	55%
	K	.00228	NS	.24287	NS	.30	26.7	19.0	71%
Live coarse Branch Bark	DM	–0.5264	NS	69.03462	***	.91	3,177.4	1,094.3	34%
	N	– .00845	NS	.89814	***	.88	35.3	16.7	47%
	P	– .00097	*	.10302	***	.92	4.0	1.5	36%
	K	– .00342	NS	.40567	***	.91	17.4	1.6	9%
Live coarse Branch Wood	DM	–1.40251	NS	309.89868	***	.90	17,876.0	5,192.0	29%
	N	– .00273	NS	.44714	***	.92	23.1	14.8	64%
	P	– .00710	*	.41585	*	.68	4.4	14.6	332%
	K	– .00196	NS	.30056	***	.86	15.1	5.1	34%
Live coarse Branch Needles	DM	–0.13781	NS	12.14865	**	.72	389.3	390.1	100%
	N	– .00203	NS	.18844	*	.69	6.4	6.4	100%
	P	– .00017	NS	.01565	**	.71	.5	.5	100%
	K	– .00050	NS	.06528	*	.68	3.0	2.2	73%
Live fine Branch Wood	DM	–3.08226	*	343.68433	***	.92	14,083.9	5,147.1	37%
	N	– .04862	*	4.89276	***	.94	182.7	63.0	34%
	P	– .00433	*	.43340	***	.90	16.1	7.5	47%
	K	– .00722	NS	.99259	**	.81	47.0	24.6	52%

Live Fine Branch Needles	DM	–5.48316	**	467.53687	***	.89	14,308.3	8,295.4	58%
	N	– .10219	*	8.87506	***	.89	278.7	162.0	58%
	P	– .00663	*	.57251	***	.91	17.8	9.3	52%
	K	– .05194	*	3.93288	**	.84	98.5	87.8	89%
Bole Timber	DM	–0.01790	NS	2,700.71729	***	.91	201,676.3	42,650.8	21%
	N	.01438	NS	3.51416	*	.59	316.6	150.0	47%
	P	– .00021	NS	.10488	***	.95	7.0	1.2	17%
	K	– .00426	NS	1.84652	***	.89	121.9	32.3	26%
Bole bark	DM	0.48120	NS	213.58185	***	.94	7,763.9	2,785.9	16%
	N	.00678	NS	1.54186	***	.89	140.7	27.0	19%
	P	– .00119	NS	.21906	***	.86	11.9	4.5	38%
	K	– .00333	NS	.96207	***	.87	59.3	21.0	35%
Coarse roots	DM	–0.59856	NS	749.08325	***	.96	53,705.9	8,157.3	15%
	N	– .00312	NS	1.55764	***	.86	104.6	32.3	31%
	P	– .00021	NS	.11112	**	.70	7.5	3.7	49%
	K	– .00034	NS	.90113	**	.83	66.0	21.0	32%
Fine roots	DM	0.58190	*	12.26289	NS	.30	3,104.0	959.7	31%
	N	.00330	NS	.18602	NS	.50	26.3	9.5	36%
	P	.00024	NS	.01214	*	.61	1.8	.5	28%
	K	.00104	NS	.02544	NS	.44	9.5	4.4	46%
TOTAL	DM	–6.52438	NS	5,297.8393	***	.97	371,216.9	43,634.7	12%
	N	– .13869	NS	27.12363	***	.94	1,504.6	352.8	23%
	P	– .01828	*	2.19340	***	.95	95.1	25.6	27%
	K	– .06969	*	9.72180	***	.94	464.2	121.5	26%

Table 5 — Basal area, volume, total length, dry matter distribution (kg) and total N, P and K contents (kg) of sample trees.

Tree characteristics	Sample tree number							
	1	2	3	4	5	6	7	8
Basal area (m^2)	.00849	.01227	.01690	.02010	.02406	.02835	.03365	.05147
Volume to 7cm diam (m^3)	.04863	.07286	.09657	.11889	.14668	.23905	.23816	.36272
Total length (m)	12.7	14.6	11.9	13.8	11.5	15.6	15.9	14.6
Tree component								
Dead branches	3.47	6.43	24.22	7.89	12.91	9.67	22.35	24.35
Live coarse branch wood	3.06	3.61	3.11	4.10	4.79	5.46	9.07	16.10
Live coarse branch bark	0.47	0.51	0.48	0.84	0.69	1.17	1.76	3.35
Live coarse branch needles	0.11	0.05	0.07	0.09	0.02	0.12	0.18	0.63
Live fine branch wood	1.40	2.34	2.15	1.89	3.67	5.88	9.93	15.20
Live fine branch needles	0.60	2.43	2.61	2.75	2.21	5.29	10.73	20.82
Bole timber	20.14	29.01	37.55	59.22	56.67	88.25	111.10	125.34
Bole bark	2.34	4.31	3.67	4.07	5.35	6.51	8.57	11.34
Coarse roots	5.22	11.11	10.33	12.55	21.31	18.97	23.28	38.73
Fine roots	0.74	0.36	0.68	0.94	1.38	0.81	1.08	1.06
Total dry weight	37.55	60.16	85.09	94.34	109.00	142.13	198.06	256.94
Total N (g $tree^{-1}$)	139	243	401	295	382	557	907	1271
Total P (g $tree^{-1}$)	8	12	25	20	23	37	56	83
Total K (g $tree^{-1}$)	40	72	84	111	100	197	293	441

Table 6 — Total DM, N, P and K contents of crop and forest floor (kg ha^{-1}) and gross annual accumulation patterns (kg ha^{-1} $year^{-1}$).

	DM	N	P	K
Crop	371,217	1,505	95	464
Forest floor	60,212	1,174	51	36
Total	431,429	2,679	145	500
Annual	13,073	81	4.4	15

The figures on gross annual uptake of N, P and K in Table 6 do not necessarily indicate the actual quantities necessary to sustain the growth rate achieved at this particular site nor do they represent the actual quantities taken up each year. Nutrient uptake by forest trees is known to vary considerably with age (Switzer and Nelson 1972) and uptake of nutrients in excess of actual requirements, termed "luxury consumption", is also a well established phenomenon (Tamm 1964). If the data by Rodin and Bazilevech (1965) are applicable, then the figure for nitrogen uptake found here would appear to be well in excess of actual requirements. They estimate that the annual growth of organic matter in these islands requires 10-20kg N, 1-3kg P and 6-10kg K ha^{-1} $annum^{-1}$. The fact that the nutrient levels in the newly formed foliage on the crop (N=2.05%, P=0.20%, K=0.80% are well in excess of what are considered threshold levels for conifers (Tamm 1964) also suggests that tree growth at this site is not limited by lack of available nutrients. This has recently been demonstrated for phosphorus in that the application of phosphate fertiliser to the crop in 1975, although it resulted in increased P levels in the trees in the following years, has had no effect on their diameter growth so far (Carey 1977, unpublished data).

Despite the shortcomings associated with the estimates on nutrient uptake the figures are nevertheless reasonably comparable with those published elsewhere for certain other coniferous species. For instance Ovington (1961) gives figures of 61, 3 and 18kg for N, P and K respectively for *Picea abies* while Miller and Miller (1976) in their studies on *Pinus nigra* estimated the uptakes per hectare associated with a steady growth rate of YC 16 were 69, 6 and 28 for the three nutrients. The result for nitrogen found here is particularly high when compared with corresponding figures for other conifers in some American and Scandinavian studies (Cole *et al* 1967, Melkonen 1974).

A breakdown of the distribution of organic matter and nutrients within the crop and forest floor is presented on a percentage basis in Table 7. The bole timber and bark represent just over half of the total production, the remainder being distribution between the

Table 7 — Percentage distribution of DM, N, P and K within the crop and forest floor.

Component	DM	N	P	K
Dead branches	10.5	14.6	16.4	5.4
Live coarse branch wood	4.1	0.8	2.7	3.0
Live coarse branch bark	.7	1.3	2.7	3.4
Live coarse branch needles	.1	0.2	0.7	0.6
Live fine branch wood	3.2	6.8	11.0	9.4
Live fine branch needles	3.3	10.4	12.3	19.6
Bole timber	46.7	11.8	4.8	24.4
Bole bark	4.1	5.3	8.2	11.8
Coarse roots	12.4	3.9	5.4	13.2
Fine roots	.7	1.0	1.4	2.0
Forest floor	14.0	43.8	34.9	7.2
Total	100.0	100.0	100.0	100.0

roots (13%), the branches and needles (22%) and the forest floor (14%). The striking feature with regard to the data in the context of existing forest harvesting systems is the fact that only about half of the total production is usable. This explains the growing interest in complete tree harvesting systems in forestry in recent years (Keays and Hatton 1976, Young 1974).

Although the stemwood and bark account for half of the total dry matter production these components only contain 17, 13 and 36% of the quantities of N, P and K present in the crop and forest floor. As expected the main proportions of the nutrients are present in the needles and branches which account for 34, 46 and 41% of the quantities present. The high concentration of nutrients in these components illustrates the increased drain on the nutrient budget that would arise should complete tree utilisation systems be adapted. However, this crop is by no means mature or indeed representative of the way in which Sitka spruce is normally managed and considerable redistribution of both nutrients and organic matter can be expected as it is thinned and gradually matures (Madgwick 1977, Webber 1977). Further studies need to be carried out in more mature crops on the distribution of nutrients and organic matter in order to determine the real inpact on nutrient budgets of more complete tree harvesting systems.

ACKNOWLEDGEMENTS

Acknowledgement is made and grateful thanks extended to the Forest and Wildlife Service, Department of Fisheries and Forestry for financial support, and to Prof. D. M. McAleese and Dr. E. P. Farrell *in whose Department the study was carried out. Also to Mr. W. B. Luddy for assistance in field measurements and to Miss Rachel Reid for assistance in the laboratory.*

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Juvenile Instability in Planted Pines

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SUMMARY

Planted pines often require a number of years to achieve a firm anchorage. In this, they differ from naturally established trees which, at least to begin with, are usually quite stable. This difference is due to the effect of the usual methods of raising and planting forest tree seedlings on root morphology. One way to eliminate this effect is to plant seedlings while they are very young and still retain the capacity to initiate first order lateral roots. Another, is to use planting stock raised in containers coated with a root growth inhibitor to prevent the elongation of lateral roots until after planting. With both methods, planted trees can be obtained having a symmetrical array of primary lateral roots comparable in form and mechanical function to the roots of a naturally established tree.

INTRODUCTION

Planted pines often require a number of years to achieve a firm anchorage during which time they may easily be blown over by the wind or weighed down by snow (Bergman, 1976; Bell, 1978; Booth and Mayhead, 1972; Chavasse, 1978; Clarke, 1956; Edwards, Atterson and Howell, 1963; Moss, 1971). Trees thus affected are not uprooted and so continue to grow. However, they acquire a geotropic stem curvature or sweep which, under present or foreseeable market conditions, greatly reduces their value (Moss, 1971).

On approaching maturity, planted pines frequently become unduly susceptible to windthrow (Bergman, 1976; Irvine, 1970; Moss, 1971) and there is evidence to suggest that this development has some relationship to instability during the juvenile phase (Moss, 1971).

Thus, in the plantation culture of pines, the instability of young trees is a matter of considerable practical significance.

IRISH FORESTRY, 1979, Vol. 36, No. 1: 36-47

In this article the cause and consequences of juvenile instability in planted pines, and also possible means to prevent it, are examined with particular reference to experience with lodgepole pine (*Pinus contorta* Dougl.) in British Columbia.

THE CAUSE OF JUVENILE INSTABILITY

In some cases, instability in planted pines may be the result of a species or a provenance having been planted on a site to which it is not well adapted. In support of this interpretation it has been suggested that the instability of radiata pine (*P. radiata* D. Don) in

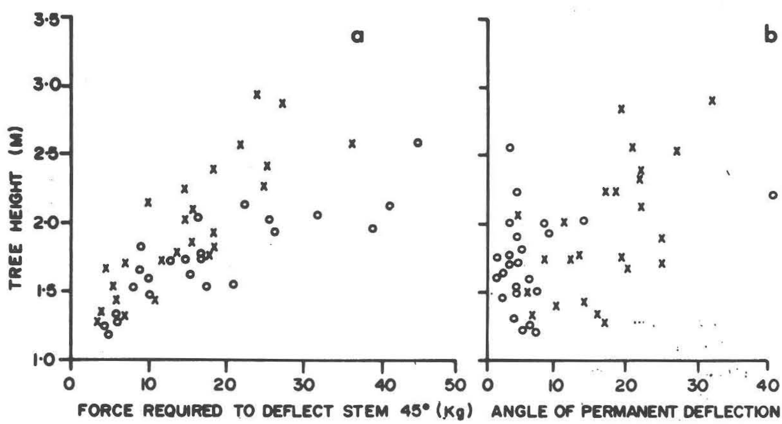

FIG. 1. A comparison of the stability of planted and naturally established lodgepole pine in a plantation near Quick, B. C.

(a) The resistance of planted (x) and naturally established (o) trees to being pulled over to an angle of 45° as measured with a spring balance attached to the stem approximately 30cm from the base. (Note. The data sugest an increasing difference in stability between planted and naturally established trees with increasing tree size. This interpretation is not justified, however, since the rigidity of the lowermost part of the stem increases with tree size. Thus, although all of the trees were pulled over to the same angle, a greater part of the deflection was accomodated by bending in the stem below the point at which the deflecting force was applied in the small trees than in the large ones. As a consequence, observations made on trees of different heights are not directly comparable.)

(b) The extent to which trees were permantly deflected from their original posture after being pulled over to an angle of 45° to the vertical and then released.

certain parts of New Zealand is due to the shallowness of the soil which prevents the development of the deep root system necessary for a firm anchorage in this species (Wendelken, 1955). Likewise, it is thought that instability in lodgepole and other species of pine planted in the United Kingdom is often due to frequent soil water-logging which prevents the development of a deeply penetrating root system (Busby, 1965).

However, when Clarke (1956) investigated the effect of a severe storm on young radiata pine in the Australian Capital Territory he found a large proportion of planted trees had been flattened while naturally established trees of a similar size were unaffacted. Similarly, it has been observed in British Columbia that, where planted and naturally established lodgepole pine seedlings occur together, the former are usually much less well anchored than the latter as judged either by the force needed to pull the trees over to an angle of 45° to the vertical, or by the extent to which trees are permantly deflected after being subjected to such a pulling test (Figs. 1a and b).

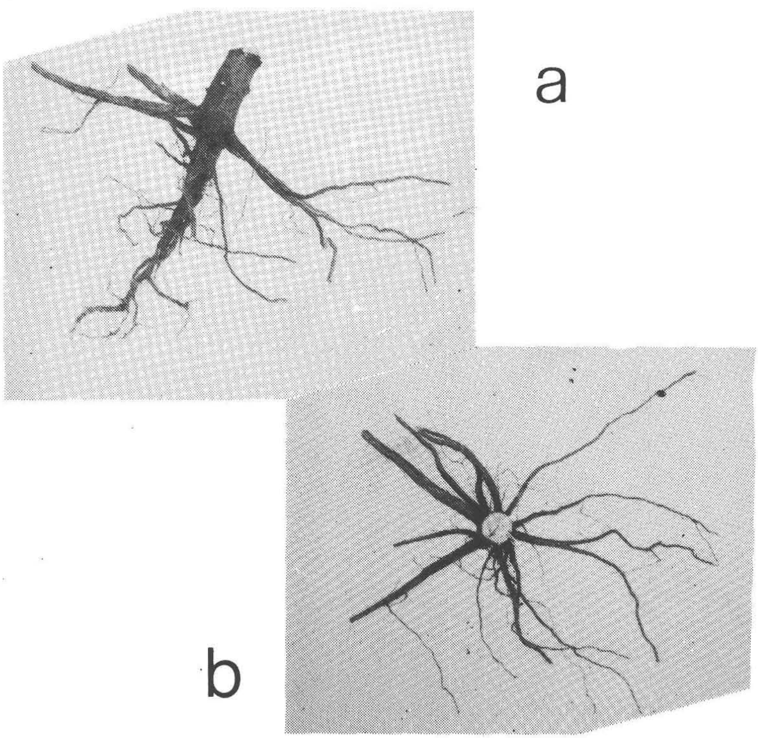

FIG. 2. The root of a 10 year old, naturally established lodgepole pine in profile (a) and from above (b). As with most naturally occurring lodgepole pine in British Columbia, this tree was growing in a well drained and relatively coarse textured mineral soil. The length of the tap root is approximately 30cm.

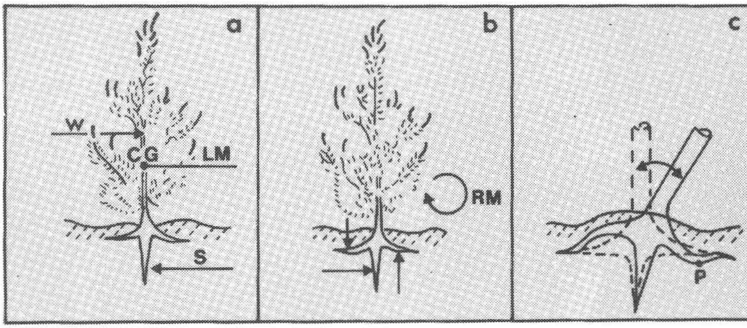

FIG. 3. The acquisition of, and resistance to, a turning moment by a pine seedling.

(a) A lateral force (W) acting on the crown, imparts to the tree a tendency to linear motion such that its centre of gravity (CG) moves in a line (LM) parallel to W. This tendency is opposed by forces in the soil (S) acting on the root in the direction opposite to that of the force W. Through the joint action of S and W the tree acquires a tendency to rotate about a point near the base of the stem.

(b) The arrow shows the direction and point of action of the main forces opposing a clockwise rotational moment (RW).

(c) Deformation in the root of a tree having a clockwise rotational moment. Because the soil above the left-hand lateral is more easily lifted than the soil underneath the right-hand lateral is compressed the tree tends to pivot about the point, P; the exact position of this point depends on how far along the root appreciable flexure occurs.

Thus, it appears that, at least in young planted pines, instability is mainly due to the fact of their having been planted.

The reason for the relative instability of planted trees becomes evident upon consideration both of the effect of planting, including that of nursery culture, on root form, and the relationship between the structure and function of a pine root system.

The lodgepole pine illustrated in Fig. 2 has a form which is typical of most naturally established pine seedlings (Aldrich-Blake, 1930; Bishop, 1962; Horton, 1958; Porter and Lamb, 1974; Preston, 1941). It has a well developed tap root which subtends an array of sturdy laterals orientated in the horizontal, or an oblique, plane.

Such a root is highly effective as a mechanical support as is attested by the firmness with which most naturally established pine seedlings are anchored. An indication of why it is effective may be obtained by reference to Figs. 3a, b and c.

Fig. 3a shows how the wind or any other force acting on its aerial portion imparts to a tree a tendency to rotate about a point near the base of the stem (except when the force acts on a line passing through the base of the stem — e.g. gravity). Tension in the windward-side lateral roots opposes this moment. Some rotation in the root system occurs, however, because of stretching in the windward-side laterals. This rotation is resisted by forces in the soil acting on the upper surface of the windward-side laterals, the windward-side of the tap root and the lower surface of the lee-side laterals (Fig. 3b). However, these forces are unlikely to provide a young tree with much support owing to the flexibility of its roots. Instead they will simply cause bending in the roots and deformation of the soil (Fig. 3c). Thus, the mechanical stability of a naturally established pine seedling with a root of the normal form is likely to depend primarily on the tensile strength of its lateral roots.

Tree pulling experiments support the conclusion that lateral roots of a young pine act as stays on the tap root main stem axis. For example, in the experiment of which the results are illustrated in Fig. 1b, the tree that was permanently deflected from its original posture to the greatest extent after being pulled over to an angle of 45° was a naturally established seedling that, on excavation, was found to have no lateral roots on the side opposite to that from which it was pulled. In other experiments it has been found that naturally established lodgepole pine seedlings lacking a tap root are also prone to acquire a leaning posture after being pulled over to an angle of 45° from the vertical, even though they possess a symmetrical array of lateral roots.

In contrast to that of a naturally established seedling, the lateral roots of a planted tree are not, at the outset, so disposed in the ground that they will necessarily be placed under tension by a turning moment acquired by the tree.

A bare root tree, for example, if it is well planted, has a bilaterally compressed root (Schantz-Hansen, 1945; Sutton, 1969). Thus, if a deflecting force is applied to the crown in the plane at right angles to the planting slit it will be opposed only by the very slight bending resistance of the roots.

And if not well planted, as is often the case, the roots of a bare root seedling may be unilaterally distributed in relation to the base of the stem (a so-called hockey-stick root), or they may simply be balled up in a planting hole that is too small for them (Gruschow, 1959; Hay and Woods, 1974; Wibeck, 1923). It is not to be expected that a root of either type will serve effectively as a mechanical support.

When first planted, the lateral roots of a container grown or mudpacked seedling (the latter having roots encased in a cylindrical mass of peat and clay or other material so that it may be dibble planted) are also ineffective in supporting the tree since they lie parallel to, or circle around, the tap root rather than extending out from it in the horizontal plane.

Thus, all the most common planting methods modify the form of a pine root system in a way that tends to reduce its effectiveness as an anchorage. What is more, the effect of planting on root morphology in lodgepole and other species of pine can persist for many years, if not throughout the life of the tree (Bergman, 1976; Gruschow, 1959; Hay and Woods, 1974; Schantz-Hansen, 1945; Sutton, 1969; Wibeck, 1923).

Besides influencing tree stability directly, there is some evidence that the effect of planting on root morphology can reduce stability indirectly. Reportedly this occurs when roots that have been balled together in planting, or which have come to encircle one another while growing in a container, restrict one another's growth as they increase in diameter (Bergman, 1976). It seems unlikely that such root strangulation occurs often, since contact between the roots of the same tree or species usually results in a graft being formed. And when this happens, there is a cessation of cambial activity where the roots make contact so that there is no tendency for the roots to grow into one another (Van den Driessche, 1958; Eis, 1972). Thus, it has been found in British Columbia that in the case of lodgepole pine and other species grown in small containers (Styro 2 containers — Sjoberg, 1974) the mass of roots forming the root plug graft together quite readily within several years of planting (author's unpublished observations).

However, there is at least one documented instance of tap root breakage in pot grown pines due, apparently, to a restriction of the growth of the tap root by a band of encircling laterals (Harris, 1978). Perhaps the explanation of this, and similar occurences, is that the trees were raised in relatively large containers so that by the time the tap root made contact with the lateral that had grown around the container wall, the roots had formed a relatively thick epidermal layer which delayed or prevented the formation of a graft.

THE SIGNIFICANCE OF JUVENILE INSTABILITY

Juvenile instability in planted pines is clearly of practical significance insofar as it causes trees to lose their upright posture, since trees that lean, or topple, develop a crooked stem. In some plantations the incidence of toppling can be very high. Besides Clarke's report (Clarke, 1956) of planted radiata pine seedlings in the Australian Capital Territory being flattened by a storm, there are reports (Booth and Mayhead, 1974; Edwards, Atterson and Howell, 1963) of a very high frequency of toppling in Scottish plantations of lodgepole, Corsican (*P. nigra* Arn.) and Scots pine (*P. sylvestris* L.) while, in New Zealand, basal bowing has occurred with a very high frequency in plantations of maritime (*P. pinaster* Ait.) (Sweet and Thulin, 1962), lodgepole and radiata pine (R. G. Brown, personal communication).

The number of trees in a plantation that develop a basal sweep depends, however, on the soil and weather conditions that prevail before the tree achieves a firm anchorage. An indication of the variation to be expected is provided by experience with lodgepole pine planted in the interior of British Columbia during the last 11 years.

In a provenance test plot established with transplant stock at Clucultz Lake near Prince George in 1972, the majority of trees had lost their upright posture by the spring of 1977 (K. Illingworth, personal communication). (Virtually all provenances were affected, although observations to be made in this plantation are expected to confirm Moss's report (Moss, 1971) of an effect of provenance on juvenile stability). Yet in a plantation at Genevieve Lake, less than 100 miles distant, only about 15% of the trees were found to have a basal sweep when examined in 1974. Furthermore, it appeared that, by then, the trees had become quite firmly rooted so that no further toppling is likely to have occurred there.

In all of the more than 40 other bare root lodgepole pine plantations in British Columbia that have been examined by the author between 3 and 8 years after establishment, many trees were found to be quite poorly anchored compared with naturally established trees of the same size. However, most, and in some cases all, of the trees in these plantations were standing upright at the time of observation. Thus, if soil and weather conditions remain favourable during the interim, it is probable that these trees will, like the majority in the Genevieve Lake plantation, achieve a firm anchorage without first developing a crooked stem.

In an examination of 7 of the province's oldest plantations established with container grown stock, great variation in the incidence of toppling was also observed. In a plantation on a deep organic soil near Boston Bar in the Vancouver Forest District, which was established in 1973, three quarters of the trees were leaning when the plantation was visited in the spring of 1977; one quarter of them, at an angle of more than 45° to the vertical. However, in the other 6 plantations established between 1970 and 1972 on mineral soils in the central interior of the province, the incidence of toppling averaged no more than about 10%.

But while most planted pines eventually become quite stable as a result of the processes of root elongation, branching, diameter growth and fusion they may not necessarily remain firmly anchored until maturity. In general, trees become less stable as they increase in size. Thus, if the effect of planting on the form and structure of a pine root persists throughout the life of the tree it may make the tree unduly susceptible to windthrow as it approaches rotation age.

Experience with lodgepole pine in British Columbia provides no basis for determining whether this is the case. However, Moss (1971) found that windthrow in different provenances of lodgepole pine in a 29 year old plantation at Wykeham in England tended to be correlated with the incidence of basal bowing. No investigation as to the cause of this relationship has been carried out. It seems possible, though, that asymmetry in the distribution of lateral roots which leads to toppling in young trees may result in windthrow later on. However, if this is the correct interpretation it is likely that it is the absence of, or lack of rigidity in, the lee side laterals which make for instability in older trees (Busby, 1965; Wendelken, 1966), rather than the absence of, or lack of strength in, windward side laterals as in young trees.

The Prevention of Planting-Induced Instability

Perhaps the only means of eliminating the adverse effects of planting on tree stability is to use planting methods which cause no persistent modification in the natural pattern of root morphogenesis.

One way of doing this would be to plant young seedlings which still have a capacity to initiate first order lateral roots. In the case of Corsican and lodgepole pine, if not of other species, this would mean planting seedlings no more than a few weeks old, since, in both cases, the capacity to initiate first order laterals is lost during the first season (Aldrich-Blake, 1930; authors unpublished observations). Whether adequate survival could generally be obtained using bare root stock of such an age is uncertain; although it is of interest to note that Anderson and Williamson (1974) observed quite high survival in freshly germinated coulter pine (*P. coulteri* D. Don) seedlings planted on a very dry site in southern California.

Instead of planting them as bare root stock, very young seedlings can be injection- or dibble-planted in a container. However, if satisfactory root development is to occur after planting, it is necessary to use a container that does not impede root development. In this respect, the split Styrene tube developed in Ontario may be less than satisfactory, although it is reported that, under certain circumstances, tubed pine seedlings develop a deeply penetrating root system with a well distributed array of laterals (Low and Oakley, 1975). Paper pots can also interfere with root growth after planting, although this might be largely prevented by the use of a paper pot that decomposes rapidly after planting (Segaran, Dojak and Rathwell, 1978).

The first bullet container developed for injection planting constitutes an extremely serious impediment to root growth (Anon., 1975; Waters, 1968). However, Walters has recently developed a perforated, 4-piece, plastic bullet, designed to come apart as the root system grows, that may prove to be more satisfactory (Anon., 1975). Another bullet design that may be suitable for planting very young pine seedlings is shown in Fig. 4. Consisting of a piece of wood having a pair of longitudinal slits at right angles to one another, it provides a central cavity for the tap root surrounded by 4 full length slots to permit egress of the lateral roots that will be initiated after planting.

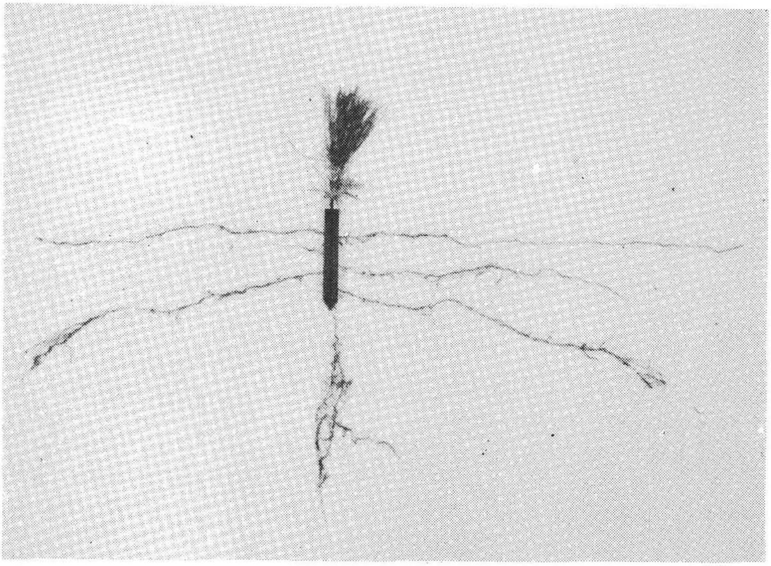

FIG. 4. A lodgepole pine seedling 12 weeks after planting in a slit-sided, wooden bullet. The seedling was planted 2½ weeks after emergence, just as the tap root reached the botom of the container. The elongation of lateral roots did not occur until after planting. Dimensions of the bullet are 1.2cm x 1.2cm x 9cm long.

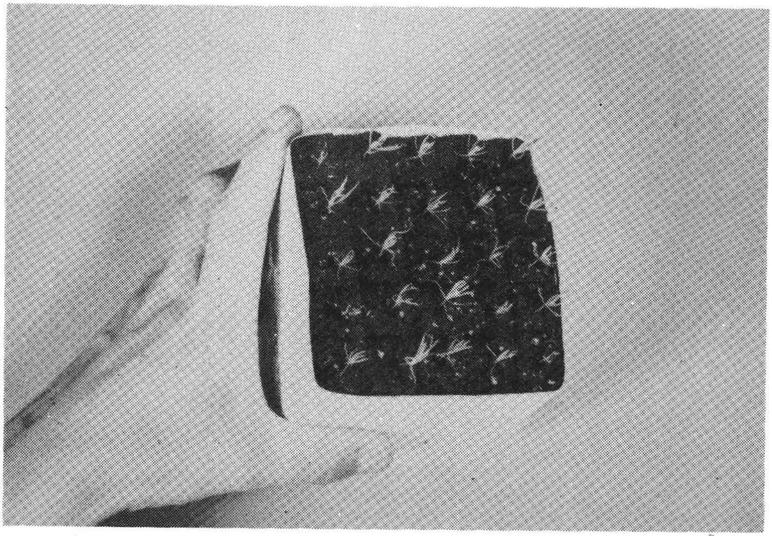

FIG. 5. Three week old lodgepole pine seedlings growing in peat blocks. Lateral root initiation in these seedlings has not yet begun. The blocks were manufactured by the author. However, a number of commercial concerns supply blocks of various materials for raising tree seedlings.

A different method of planting young seedlings is to raise them in blocks of a coherent rooting medium which can be dibble planted (Fig. 5). Several studies in the United States indicate that good survival can be obtained with 2 to 8 week old pine seedlings planted in this way (Barnett, 1975; White and Schneider, 1972).

If larger stock must be used, it may be possible to obtain a well formed root system by dibble planting seedlings that have been raised in containers coated with a root growth inhibitor to prevent lateral roots growing down and around the container walls (Furuta, Jones, Humphrey and Mock, 1972). In a trial with lodgepole pine seedlings raised in Styro-containers (Sjoberg, 1974) that had been dipped in exterior latex paint containing 0.1kg/l of basic cupric carbonate, the elongation of lateral roots was completely inhibited after contact had been made with the container wall (Burdett, 1978). However, the inhibited laterals resumed growth very quickly after planting. Consequently, the trees soon acquired an array of plagiotropic laterals growing straight out from the tap root like those of a naturally established tree (Fig. 6).

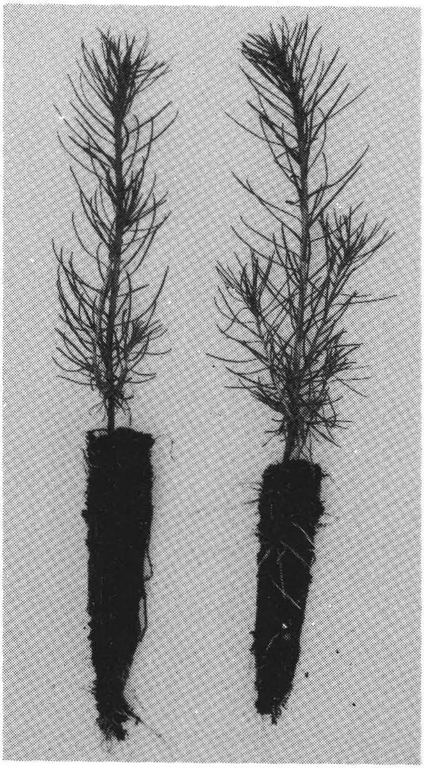

FIG. 6. Seedlings from copper painted (right) and unpainted containers one week after planting under warm, long-day conditions. The root plugs are approximately 11cm in length.

In contrast, root growth in seedlings from untreated containers was largely restricted to the elongation of lateral roots that had grown down the container wall to the tip of the root plug (Fig. 6).

If bare root stock must be planted, it is doubtful whether some persistent effect of planting on root form can be altogether avoided. However, studies in New Zealand with radiata pine indicate that box pruning of lateral roots to a length of approximately 5cm yields seedlings which are much less prone to toppling than are bare root trees produced in the usual way with lateral root pruning confined to one direction (along the length of the drills) only (Chavasse, 1978).

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Rate of Weight Loss of Small Round Timber

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INTRODUCTION

In certain markets for small round wood, purchase by weight is preferred to purchase by solid or stacked volume. Where produce is sold by weight it is desirable to know the relative green weights of different species and also how weight, for a given volume of timber, changes with time as this can influence prices.

Among the relatively limited information on this subject for Northern Irish conditions, Jack (1966), working with Sitka spruce, showed that the rate of weight loss over a 20 week period was linear and was likely to remain so up to the time the material reached a density of about 550kg/m^3. He found large variations in the rate of loss according to the time the material was felled, ranging from 2.7kg/m^3 per day for material felled in April to 0.99kg/m^3 per day for material felled in November. Small sized material lost weight about 50 *per cent* faster than larger sizes. There were small differences in the rate of weight loss of produce from different forests and of different yield classes.

EXPERIMENTAL METHODS

A total of up to 9 billets of timber each 2m long, were cut from two randomly selected trees of each of the 16 species listed in Table 1, in the vicinity of Newcastle, Co. Down, on 9 July 1975, 12 November 1975 and 14 April 1976.

Each piece was weighed on the day it was felled to the nearest 100g and then two and four weeks after felling, and subsequently every four weeks up to the end of about 35 weeks. Billets of all species cut on any one date were stacked parallel to each other in random sequence so that they did not necessarily occupy the same place in the pile after each weighing. They were piled under the shade of some large trees and did not receive any direct sunlight.

The mid-diameter over bark of each billet was recorded to the nearest 0.1cm and its true volume calculated. In subsequent calculation, results were expressed as weights, weight losses, etc. per

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cubic metre of timber. The volume at the time of first measurement was used throughout; it was not recalculated at each reweighing because mid-diameters, checked on a sample of billets on several occasions, never varied, indicating that over the 35 week period the timber did not dry below fibre saturation point. Small quantities of bark were lost with time from some of the billets but these losses were negligible.

In total, 428 individual pieces of timber were dealt with (16 species x 9 pieces (approximately) x 3 felling times). The average mid-diameter was 16.1cm with a standard deviation of 2.33cm. Thus, over 99% of all the samples had a mid-diameter of the mean $\pm$3 standard deviations. They were therefore within a range of 9.1 — 23.1cm mid-diameter. No piece had a mid-diameter of less than 7cm.

RESULTS

The main results of the work described in this paper are summarised in Table 1. Before discussing them in any detail, it should be noted that the design of this experiment makes it unlikely that differences between species will be particularly consistent, unless they are very large. It is known, for example, that at least among some species, timber properties can vary significantly not only betwen trees from different sites but also within sites, and between, and within provenances. Properties can also vary according to the rate at which a tree grows, the part of the tree from which the timber is cut, and other factors (Elliot 1970). Since only about 9 pieces of timber were used in this experiment from each species at each time of cutting and no regard was taken in the design to account for possible variations of this kind, fairly large variations would be expected.

Density at time of felling[1]

Table 1 shows the green density[2] of the material for the different times of felling in kilograms per cubic metre. It can be seen that on average the timber cut in November had a slightly greater density than that cut in April or July, a finding which is consistent with Jack's (1966) work on Sitka spruce (*Picea sitchensis* (Bong.) Carr). This is not however true of all 16 species. For example, Scots pine (*Pinus sylvestris* L.) scarcely varied at all and European larch (*Larix decidua* Miller), beech (*Fagus sylvatica* L.) and birch (*Betula spp*) were denser in April while lodgepole pine (*Pinus contorta* Dougl.) was denser in July.

1. Samples of sycamore (*Acer pseudoplatanus* L.) were included with the material cut in November and April. Its green density and rate of weight loss were similar to birch.
2. The "green density" figures given in this paper were calculated by dividing the weight, at the time of felling, by the volume at the time of felling. The values obtained by this method are naturally much higher than conventional values for density which are calculated by dividing oven dry weight by volume.

TABLE 1 Summary of Green Densities and Rates of Weight Loss for 16 Species

SPECIES	JULY CUT MATERIAL 1 Green density kg/m³	2 Weight loss per day kg/m³	3 Weight loss in 4 weeks %	NOVEMBER CUT MATERIAL 4 Green density kg/m³	5 Weight loss per day kg/m³	6 Weight loss in 4 weeks %	APRIL CUT MATERIAL 7 Green density kg/m³	8 Weight loss per day kg/m³	9 Weight loss in 4 weeks %	OVERALL MEANS 10 Green density kg/m³	11 Weight loss per day kg/m³	12 Weight loss in 4 weeks %
SPRUCES												
Norway Spruce	876	1.15	3.51	1 032	1.46	4.21	994	1.76	5.16	976	1.46	4.29
Sitka Spruce	867	1.34	4.10	1 012	1.53	4.49	932	1.59	4.78	937	1.49	4.46
PINES												
Corsican Pine	917	0.79	2.36	927	0.71	2.03	917	0.64	1.97	920	0.71	2.12
Lodgepole Pine	956	1.01	2.98	870	1.13	3.30	855	0.94	2.75	894	1.03	3.01
Scots Pine	972	0.93	2.91	978	0.74	2.22	980	0.59	1.90	977	0.75	2.34
LARCHES												
European Larch	808	0.85	2.43	899	0.68	2.00	940	1.13	3.37	879	0.89	2.60
Japenese Larch	809	0.95	2.81	838	0.90	2.65	819	1.36	4.04	822	1.07	3.17
OTHER CONIFERS												
Douglas Fir	867	0.95	2.83	900	1.14	3.40	845	1.19	3.59	871	1.09	3.27
Noble Fir	958	1.06	3.21	991	1.06	3.09	951	1.27	3.85	967	1.13	3.38
Western Hemlock	894	0.79	2.36	895	1.30	3.95	809	1.32	4.10	866	1.14	3.47
HARDWOODS												
Alder (Common & Grey)	843	1.02	3.07	848	0.95	2.83	804	0.99	2.85	832	0.99	2.92
Beech	1 112	0.59	1.92	1 046	0.76	2.36	1 177	0.61	1.92	1 112	0.65	2.07
Birch	837	0.78	2.26	893	0.71	2.11	953	0.55	1.66	894	0.68	2.01
Eucalyptus SPP	1 092	0.62	1.98	1 096	0.88	2.61	1 045	1.07	3.17	1 078	0.86	2.59
Oak (Sessile)	1 076	0.54	1.74	1 159	0.18	0.94	1 091	0.34	1.26	1 109	0.35	1.31
Poplar (Hybrid)	765	0.88	2.55	769	0.98	2.88	748	0.88	2.52	761	0.91	2.65
Sycamore	—	—	—	845	0.64	2.11	920	0.91	2.76	883	0.77	2.43
MEANS	916	0.89	2.69	946	0.94	2.82	929	1.01	3.06	930	0.95	2.85

Standard errors:		*Species*	*Month*	*Species x Month*	*Residual of*
	Green density (kg/m³)	15.7***	6.8**	22.2***	380
	Weight less/day (kg/m³)	0.078***	0.34*	0.135*	378
	Weight less/4 weeks (kg/m³)	0.227***	0.099*	0.393*	378

Note: **In the analyses of variance for weight less per day and % weight less in 4 weeks the data were adjusted according to the volume of each billet and its fresh weight: these variables were used as convariates. Data for sycamore were not included in any statistical analyses.**

In cases where comparisons are possible, the average green densities found in this experiment (Table 2) are reasonably close to those quoted by Hamilton (1975). Five of the species, including the spruces, are within 2% of Hamilton's figures, 4 are within 4% and a further 5 range between 6 to 8%. The last group includes Corsican and lodgepole pines (*Pinus nigra* Arnold var *calabrica* Schneid.), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and beech. The density shown for Sitka spruce is also within 3% of Jack's (1966) average figure.

Table 2 — Green densities averaged over all dates of felling in descending order of magnitude.

Species	Average Green density (kg/m^3)	Figures from Hamilton (1975) — kg/m^3
Beech	1,112	1,030
Oak	1,109	1,060
Eucalyptus	1,078	—
Scots pine	977	1,020
Norway spruce	967	960
Noble fir	967	930
Sitka spruce	937	920
Corsican pine	920	1,000
Lodgepole pine	894	950
Birch	894	930
Sycamore	883	830
European larch	879	900
Douglas fir	871	870
Western hemlock	866	930
Alder	832	—
Japanese larch	822	830
Poplar	761	—

Changes in density with time after felling

Calculations for individual pieces and means show that for all practical purposes linear regressions satisfactorily differentiate rates of weight loss over the time periods examined (Fig. 1). For this reason, the regression coefficients for each billet, which represent the weight loss in kilograms per cubic metre per day, were used in an analysis of variance. Means and some statistical details are summarised in Table 1. The relationships between green density and rate of weight loss are also illustrated more simply in Fig. 2. The

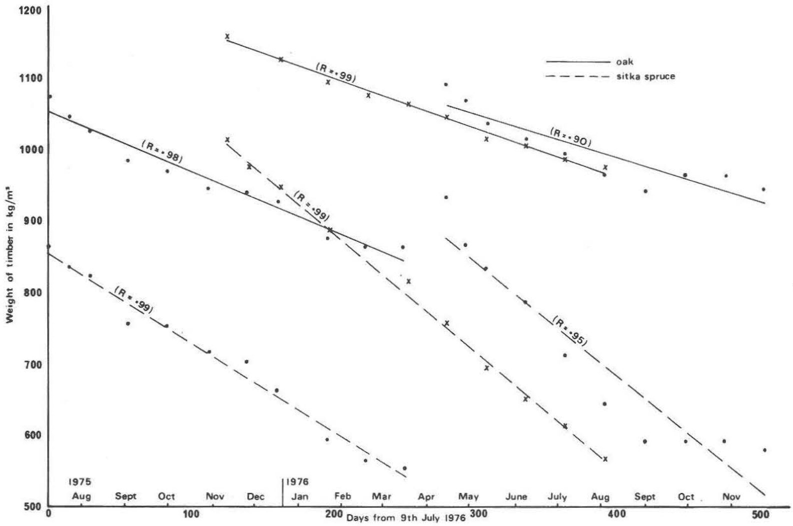

FIG. 1. Rates of weight loss with time and date of felling for Oak and Sitka spruce.

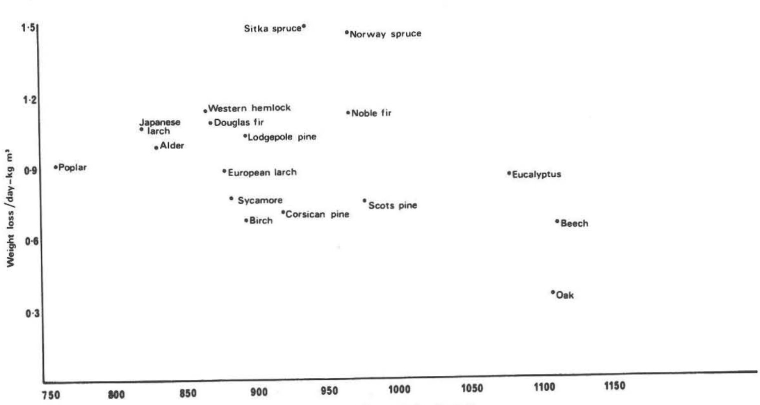

FIG. 2. Relationship between green density and weight loss per day for different species.

average rate of weight loss of the spruces was significantly greater than all other species and oak (*Quercus petraea* Matt.) was significantly slower, based on least significant differences.

Several of the remaining species were reasonably consistent in relation to each other in their rates of drying. However a few anomalies should be noted, one of the most obvious is western hemlock: July cut material dried out significantly more slowly than material cut in the other two periods. The billets of the pines and birch cut in April dried out more slowly than those cut in July or November whereas the overall trend indicated that the reverse should have been true. Similarly, if the July and November cut material is compared, the overall trend indicated that species lost weight more quickly (though not significantly so) in November where as with several species this was not so. These include Corsican and Scots pine, the larches, alder (*Alnus* spp.) and oak. The reasons for these variations are not obvious, but could be associated with variation in the individual trees from which the billets were cut.

The differences in drying rates for the different times of felling are not as great as might have been expected from Jack's (1966) work. His mean figures for weight loss of Sitka spruce were 1.91kg/m^3 per day for July felled material, 0.99kg/m^3 for November and 2.75kg/m^3 for April, representing a maximum difference between July and April of 64%. In this experiment the figures for similar periods were 0.89kg/m^3 per day for July cut material, 0.94kg/m^3 for November and 1.01kg/m^3 for April indicating a maximum difference of only 12%. It is not known why results of the two exercises differ so much, but differences could be associated with variations in climate during the years in question and also the ways in which cut produce was stored.

Differences in the rates of drying are obviously caused by variations in temperature, humidity, wind, precipitation etc, at different times of year and between years. Perhaps the easiest of these climatic variables to record is rainfall and Fig. 3 shows that there was a reasonably good relationship between the average rate of weight loss of all Sitka spruce samples and precipitation during the 28 day period of weight loss, recorded in a rain gauge placed adjacent to the experimental site.

Percentage weight loss with time after felling

For some purposes it is more useful to express rates of weight loss with time as a percentage loss from the original green densities. The percentage loss for each species over 4 week periods are accordingly shown in Table 1. From these data it seems reasonable to group the species as shown in Table 3.

The spruces tend to lose a significantly greater percentage of their weight with time than all other species, and oak loses significantly less. Based on least significant difference calculations, the remain-

Table 3 — Grouping of species according to relative rates of weight loss.

Group	Species	% Weight Loss Per Month
1	Sitka spruce	4.46
	Norway spruce	4.29
	Western hemlock	3.47
	Noble fir	3.38
2	Douglas fir	3.27
	Japanese larch	3.17
	Lodgepole pine	3.01
	Alder	2.92
	Poplar	2.65
	European larch	2.60
	Eucalyptus	2.59
3	Scots pine	2.34
	Corsican pine	2.12
	Beech	2.07
	Birch	2.01
4	Oak	1.31

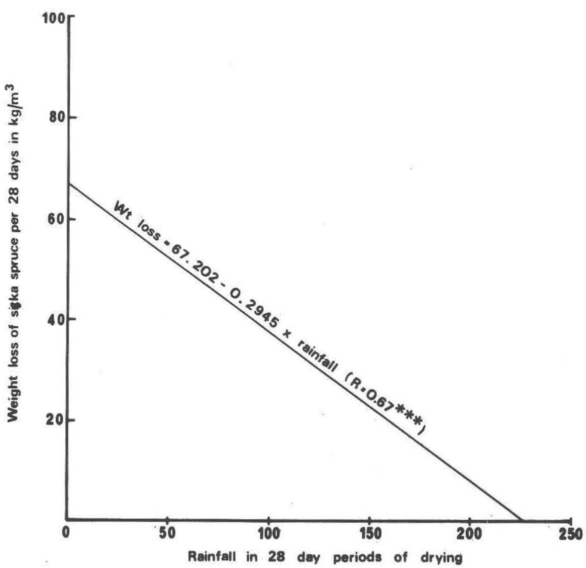

FIG. 3. Relationship between weight loss of Sitka spruce timber and rainfall in preceeding 28 days.

ing 13 species can be divided broadly into 2 groups. Western hemlock, Noble fir, Douglas fir, Japanese larch, lodgepole pine and alder all tend to lose rather a higher proportion of their weight with time than the remaining seven species.

Table 1 shows that material cut in July does not dry out at a significantly greater rate than that cut in November while April cut material dries significantly faster than that cut in either of the other periods. It is probably reasonable to suggest therefore that only two main time periods are likely to cause major variations in the drying rates of timber. The first might include the bulk of the summer months, March — August, and the period September — February is the one when drying is likely to be slower.

Effect of size of material on rate of weight loss

The average billet used in this experiment had a mid-diameter of 16.1cm with the majority of pieces ranging between 9.1 and 23.1cm. It would be reasonable to expect the small diameter pieces which have a large surface area in relation to volume to dry more quickly than large diameter pieces.

To illustrate this, the percentage weight losses per month of each piece of Sitka spruce and oak were computed and regressions against mid-diameter calculated. The results are shown in Fig. 4.

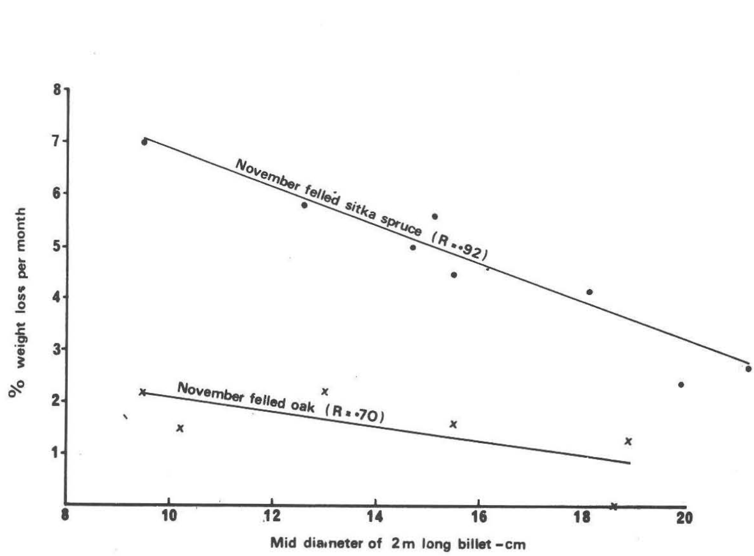

FIG. 4. Relationship between size of billet and rate of weight loss per month.

Linear regressions once again satisfactorily explain differences within the size range of material being examined. With these 2 species of material cut in November, the greatest difference was found with Sitka spruce where 10cm diameter billets lost weight at a rate of 6.8% per month while 20cm diameter material lost it at 3.2% per month. The smallest difference was with oak where, for the same sizes, losses were 2.2% and 1.1% respectively. However, regardless of the percentage weight loss, the 10cm material of both species lost weight at twice the rate of 20cm material.

DISCUSSION

The experiment described here has provided some data for Northern Ireland conditions to show the rates at which small sized timber loses weight according to species, season of cutting and size of material. The rate of weight loss is linear over the period examined and can vary between over 5% per month to less than 1%, depending on the species.

The fastest weight losers are the spruces, which at present form the bulk of all timber which is being produced, with the most common species being Sitka spruce which loses weight faster than Norway spruce.

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Notes and News

Photographers please take note . . . .

Have you noticed that *Irish Forestry* has a new printer. We look forward to a long and happy association. Apart from improvements in the appearance of the journal, it will now be possible to use black & white or colour transparencies as copy material for the cover photograph. If you have a slide that you feel might make a good cover photograph, have a print made from it and send it to the editor for consideration. It will be returned to you in good condition, whether or not it is used.

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Impact of Intensive Harvesting on Forest Nutrient Cycling

Dr. Al Leaf, who addressed the society during a visit to Ireland in June 1976, is one of the organisers of a symposium entitled "Impact of Intensive Harvesting on Forest Nutrient Cycling" to be held at Syracuse, New York, August 13 to 16, 1979. Topics to be discussed include the energy potential of wood, nutrient removals through intensive harvesting and the amelioration of nutrient losses. Guest speakers will include Professor Carl Olof Tamm, Swedish Agricultural University, Uppsala and Dr. Earl Stone, Cornell University, Ithaca, New York. Details from Dean J. M. Yavorsky, College of Environmental Science and Forestry, State University of New York, Syracuse, New York, 13210, U.S.A.

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IUFRO All-Division 5 Meeting

An All-Division 5 Meeting of IUFRO will be held in Oxford, 8-22 April, 1980. There will be meetings of most of the subject groups and project groups and sessions of the whole division. Further information from Secretariat, IUFRO All-Division 5 Meeting 1980, 142 Oxford Road, Cowley, Oxford, OX4 2DZ, Great Britain.

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A word of thanks

The editor wishes to thank most sincerely Dr. Niall O Carroll, former editor of the journal who contributed a great deal to the production of *Irish Forestry* Vol. 35, during the editor's absence in Sweden.

Book Reviews

MANAGING SMALL WOODLANDS
Forestry Commission Booklet 46. H.M.S.O. 40 pages Price 90p

This booklet has been written primarily for the woodland owner: Its purpose is "to provide the basic information for the establishment and management of small woods emphasising ways and means of modifying forestry practice to adapt it to their needs". It is not a booklet on the classic foundations of forest management; it follows a much more practical approach dealing with the type of problems with which the woodland owner, who is not a trained forester, must cope in the day to day management of his property.

Chapter 1 deals with what might be termed the objects of management emphasising the need to draw up a plan which will take into account the potential of the woods and integrate proposals for woodland management into the plans for the property as a whole. The benefits available are outlined: Timber growing, Landscaping, Nature conservation, Sport and shelter. A short chapter on woodland types and possible courses of action gives some advice on how to handle over-mature woodland and coppice. This is followed by an equally short chapter on species selection with an Anderson type table on site classification and recommended species. Chapter 4 on crop establishment is mainly silvicultural as is chapter 7 on thinning. There is no attempt in either chapter to depart from what is generally considered to be the conventional approach to silvicultural operations. Planting espacement of 2 metres between rows and 2 metres between plants is recommended except where mechanical weeding with a tractor may be feasible. Then, it is suggested that a wider spacing between rows and a closer spacing between plants can be effected, giving the required 2,500 plants per ha. Line-thinning is recommended as the simplest form of first thinning, without comment on its possible association with windthrow on certain sites. Second and subsequent thinning can be "selective" thinnings. The use of average distance between trees expressed as a percentage of top height is recommended as a thinning index. This index, proposed variously by Hart and Becking in Holland and by Hummel in Britain deserves greater recognition as a simple and effective easily measured approach to thinning.

Chapter 5 gives an outline of protection measures against fire, animals and weeds as well as insects and fungi. It is noted that farm stock, particularly sheep, can cause serious losses and that pigs, horses and goats are liable to strip bark. Maintenance opeations such as drainage, cleaning, brashing and pruning are dealt with briefly and it is interesting to note that the use of 2, 4, 5 — T is recommended as a stump treatment prior to planting, despite the opposition of many conservationists. The final chapter gives a brief description of the grant aid available in Britain. The source of this financial aid will vary with the objectives of planting. To qualify for a Forestry Commission grant timber production must be one of the primary objectives. Aid for amenity planting is available from the Countryside Commission and grants for shelterbelt planting come from the agricultural departments. Two schemes are available to the woodland owner; the Small Woods Scheme for areas less than 10ha and the Dedication Scheme — Basis III for areas over 10ha. information on both schemes is just adequate to give the owner a brief outline of what is involved.

The booklet is written in a simple, lucid style eminently suitable to woodland owners with a minimum knowledge of forestry. Although the content is limited in scope, a number of references at the end of relevant paragraphs will provide more detailed information for the reader who wishes to develop his interest. A complete list of references is also provided. In a sense the booklet might be looked at as a posthumous tribute to H. Eldin who had written two chapters before his death and had prepared notes for others. His colleagues completed the booklet and the editor has done a fine job in achieving a consistent style and treatment. At 90p it is excellent value for the woodland owner.

P. M. JOYCE

INVENTORY OF OUTSTANDING LANDSCAPES IN IRELAND
An Foras Forbartha, 1977. Price 75p. Soft back. 64 pages. One map.
20 Black & White landscape pictures.

Why produce such a report? The stimulus came from the International Union for the Conservation of Nature and National Resources (I.U.C.N.). Ireland was chosen as part of a pilot programme and was asked to prepare an inventory of outstanding landscapes which would eventually be world-wide and complementary to the U.N. List of National Parks and Equivalent Reserves and to the World Directory of National Parks and other Protected Areas. The I.U.C.N. requested that ten areas be submitted from each country. This inventory under review contains all the landscapes of Ireland out of which the best ten were chosen.

This report, to my knowledge, is the first comprehensive assessment of the better landscapes of this island. The authors freely admit to its limitations and do not make any claims that it is the definitive work on this subject.

The difficulties of selecting and evaluating landscapes are acknowledged. If landscapes are selected on a county basis then areas in a scenically dull county may rate highly where as the same landscapes in a county blessed with great beauty would not register at all. That landscapes were assessed on a regional basis is of great merit here.

Human curiosity, being what it is, I would have liked to know which ten areas were selected for the international inventory.

No doubt there were lenghty deliberations on defining 'Outstanding Landscapes': The introductory comments are however thin in this regard. Indeed this is my only criticism of the book. One area designated as such is part of the Wicklow/Dublin mountain range. The area is 102,400ha. It stretches from Saggart to Stepaside to Baltinglass. Within this area there are certainly jewels (Glendalough?) worthy of the classification 'Outstanding Landscapes' but it is questionable if the whole mountain range should be so classified.

A most useful reference book for anyone involved in planning or development of the countryside. The descriptions under 'Landscape Type' and 'Distinctive Features' for each landscape will prove of special value.

As usual with An Foras Forbatha booklets, the cover on this inventory is a delight depicting a romanticised Killarney scene.

P. Mac OSCAIR

FORESTRY PRACTICE. O. M. Blatchford, Editor.
Forestry Commission Bulletin No. 14 Ninth Edition. Price £3.50.

The dangers associated with monoculture have been dramatically empasised by the devasting attacks of the Pine Beauty moth, *Panolis flammea* on the lodgepole pine stands of North Scotland over the past three years. Obviously, this book was well in preparation before the scale of this infestation became apparent. Nevertheless, a word of caution is included, pointing out the vulnerability of a rapidly expanding forest estate, based on exotic species, to disease and insect attack. It might be expected that this word of caution should be associated with a plea for more imagination in species selection, calling perhaps for greater diversification both in species and in provenance within species. Unfortunately, this is not the case. In the table of plant indicators, eight plant associations are common to both this and the last edition of the bulletin, published in 1964. Although the wording is practically identical in both editions, Sitka spruce now appears as an indicated species in seven of the eight associations compared with three in the earlier edition.

This is not to take from the merits of this excellent publication. To those in forestry who do not have ready access to "Forestry Practice", this edition is strongly recommended. And to the great number of Irish foresters who already have a well thumbed copy of an older edition on their shelves, it should be said, that this, the ninth edition, contains new material sufficient for it to be an original publication. New chapters have been added on roads, safety, management and administration, recreation, radio communications and careers in forestry. The bulletin is well produced with 27 line drawings and 17 well chosen and informative photographs.

The most serious criticism I would have is that the treatment of different topics is rather uneven. Site preparation and drainage are approached as if the reader is quite ignorant of the topic, yet the description of techniques is inadequate for the uninitiated. The discussion of the theoretical basis of drainage is quite confused and can hardly be of much assistance to the reader. Similarly, we are told that only 1% of the area fertilized by the Forestry Commission in recent years has received nitrogen. We are not told that nitrogen fertilizers applied to very young or phosphate deficient crops may be positively harmful, leading to high mortality. This would seem to be a serious omission for the reader approaching the subject from a background in modern agricultural practice. Contrast this lack of detail with the table of "Recreation Use Requirements" which, for 19 different activities lists the space requirements, the ground surface texture, climatic constraints and many other details. Did you know for example that for pheasant shooting soil pH should be greater than 7 and fog is a climatic constraint? Again, minute detail is provided on the features of a good chainsaw although much of the considerable detail in the chapter on harvesting would seem to be of value to those involved in this area.

E. P. FARRELL

OTHER PUBLICATIONS RECEIVED

Forestry Commission. Report on Forest Research, 1978. £2.25.

Forest Record 117. *Gilpinia hercyniae,* A Pest of Spruce. 50p.

Forest Record 119. Pine Looper moth. 50p.

Leaflet 70. Forest ploughs. 60p.

Society Activities

Society Annual Study Tour, 1978: Donegal/Tyrone

TUESDAY, SEPTEMBER 19, MORNING

Our first stop was at Raphoe Forest, where we were met by the tour leader, Mr. Ernest Johnston. The President of the Society, Mr. Fergal Mulloy, formally opened the proceedings and Mr. Johnson introduced the local Forester-in-charge, Mr. S. O Domhnaill who, having welcomed us in Irish, gave details of the Mongorry Property, where our first stop was located. This was a Sitka spruce stand, P1954 (YC24, stems/ha 1150, vol. $300m^3$, mean volume tree $0.26m^3$). The stand was due a third thinning in 1979, but there was no problem in selling thinnings which were, for the most part, exported across the border to be used as fencing posts. This land was good agricultural land and was ploughed with an agricultural plough before planting. Dr. Dick McCarthy described an exposed soil profile. The soil was a gley derived from glacial drift, similar to the Leitrim gleys, but not as sticky and very fertile. He was of the opinion that the minimum of soil disturbance was desirable here. Mr. Dillon, remarking that root penetration seemed shallow, advocated shallow ploughing only, if ploughing must be done. Good management, especially in relation to thinning was important on this site.

The next stop was a P1958 stand of lodgepole pine (coastal) (YC18, stems/ha 3700, vol. $150m^3$, mean tree volume $0.041m^3$). Mr. Noel Foley explained that a line thinning of 1 in 7, with a selective thinning in between had been carried out on this crop. He was of the opinion that this was preferable to a 1 line in 3 thinning. Dr. P. M. Joyce asked why LP was planted on this site since SS was growing so well nearby. Mr. John Haughy explained that when the LP was planted 29 years ago the site was growing a heather/grass mixture and that LP represented a conventional species selection at that time. The wisdom of this selection was vindicated by the stand in question, in the view of Mr. Mulloy. In the course of a discussion on the relative merits of the two species, Mr. Tom Purcell pointed out that the coastal provenance growing here was atypical and was a much superior strain of coastal. Mr. Tony Mannion likened it to the Mt. Ranier strain found in Kilworth Forest and Mr. Joe Freeman suggested that this strain deserved further investigation.

At the next stop. Woodquarter Property of Mulroy Forest, Mr. Johnston introduced the local Forester-in-charge, Mr. D. O'Sullivan, who explained that the site had previously grown oak, Scots pine and European larch. There are now 18 species in this property. Mr. Johnston mentioned that eel grass (*Zostena* spp) was growing beneath the nearby seawater. Eel grass is not common in Ireland and is a source of food for geeses, many of whom, together with duck and several species of wader, overwinter here.

LIAM QUINN

WEDNESDAY, SEPTEMBER 20, MORNING

Day two of our tour and we left Donegal behind as we headed for Killeter Forest in west Tyrone. A light drizzle hardly dampened the enthusiasm of those in a profession where a wet sock in a wet boot is not exceptional. Mr. Dick O'Donovan, chairman for the morning session introduced the staff of the Forest Service of the Ministry of Agriculture for Northern Ireland, who were our hosts for the day. Mr. Cecil Kilpatrick, Chief Forest Officer; Mr. John Philips, tour leader for the day: Mr. William Bryan, District Officer for west Tyrone and Mr. James Mackin, Head

Forester at Killeter Forest. Mr. Kilpatrick welcomed the Society to Killeter Forest and congratulated it on the choice of the Donegal/Tyrone venue. Both he and Mr. Bryan went on to outline the main features of Killeter Forest.

Killeter is one of the largest forests in Northern Ireland comprising some 4500ha of which about 3000ha are planted. With the adjoining properties of Bournesmore, Killygordan, Lettercran and Lough Eske of the Forest and Wildlife Service, these areas total about 9200ha of which 6500ha are planted. This area is one of the largest blocks of continuous forest in the country and its extent is increasing annually. At Killeter 150ha are being planted each year. The rainfall here is very high and over 2500mm have been recorded, indeed in the week preceding our visit over 100mm fell. Most of the forest lies between 150 metres and 300 metres elevation. Sitka spruce has been used extensively, comprising over 90% of the planted area. In recent years, however, there has been a swing towards lodgepole pine (of Cloosh Valley origin) and in 1977 it accounted for 40% of the planting programme, a dramatic increase from 2% in 1972. Yield classes for Sitka spruce range from YC8 to YC24 (average YC16) and for lodgepole pine from YC8 to YC14 (average 11). These figures are all based on estimates from very young crops. Most of the area is covered with oligotrophic blanket peat with areas of mesotrophic peat where some flushing occurs, with occasional hollows of euthrophic peat. Part of the higher elevation peats are dystrophic.

Mr. Mackin outlined the fertilizer regime thusfar for Sitka spruce at Killeter. We were surprised to learn that no nitrogen has yet been applied as top dressing but it is still early days from a nitrogen deficiency standpoint as most of the plantations are less than fifteen years old. The Sitka spruce we were standing near still looked quite vigorous and showed no signs of nitrogen deficiency. It was planted in 1964 and before planting the area received a broadcast application of CRP fertilizer at 500kg/ha. In 1972 it was refertilized with 630kg/ha CRP. Current practice is a preplanting broadcast application of 750kg/ha of CRP. This compares with the 500kg/ha broadcast application of CRP used on similar sites by the Forest and Wildlife Service.

The biggest difference, perhaps, in management between the two Services is the adoption of a no thinning policy by Northern Ireland. This was sure to stimulate discussion so it was adjourned until the afternoon session. Another conspicuous difference is that at Killeter extraction racks are left every 24 metres or so, about 4 metres wide.

Mr. Stan Milner, Research Officer, Forest Service took over and led us to a provenance experiment on eroded peat. It is not possible to plough eroded peats so the plants were planted on turves where they were available, or directly into the mineral soil on bare areas. Seven provenances of lodgepole pine and two of Sitka spruce are included in the experiment. No growth differences have been found between provenances but it was clear that the Long Beach, Washington and Newport, Oregon provenances of lodgepole pine were showing the greatest vigour but also had poor form. Terrace, B.C. provenance of lodgepole shows promise in that it has reasonable vigour and good form. Apart from the provenance experiment itself, it was interesting to note the success of this crop on eroded peat, 500kg/ha CRP were applied at planting in 1967 followed by 500kg/ha CRP and 250kg/ha muriate of potash in 1975. A disscussion on the merits and demerits of lodgepole pine provenances followed. The alternatives seem to be low production and good form or high production and bad form. This may be an oversimplification, however, and provenances such as Mount Rainier may be a suitable compromise on some sites. It was generally agreed that if it were decided what was to be the end use of the crop it would make choice of provenance far easier. Nobody was willing to recommend one provenance to the exclusion of all others and it is clear that this particular discussion will continue for some time.

After enjoying the view of the surrounding countryside from Cross Hill we made our way to Sheskinawaddy where Mr. Mackin and Dr. Tom Hassard of Queens

University took us over the area which had examples of the vegetation types and microtopographies which were used in preparing site maps of the forest. Mr. Mackin outlined the basis of the mapping. It started in 1961 when it was felt that some form of vegetation mapping might be useful in the future for manurial treatment recommendations. Seven vegetation classes were used to map most of the forest area prior to planting.

Dr. Hassard dealt with his work on the relationships between the different vegetation types and various measurements of fertility, peat moisture content, measures of exposure and topography. When the vegetation types were examined in terms of the differences between them in terms of various fertility, site and growth criteria, major differences could be explained on the basis of two nutrient-enrichment phenomena: flushing and the influence of the material (mica-schist). It was concluded therefore that the vegetation pattern at Killeter can be explained in terms of "topographically controlled nutrient enrichment".

Further details of Dr. Hassard's work can be found in: Hasaard, T. H. (1978). The application of some methods of multivariate statistical analysis to the study of the growth-environment relationships of Sitka spruce in Northern Ireland. (Ph.D. Thesis, The Queen's University, Belfast).

After some discussion of the potential value of site mapping for afforestation the party made its way back to the car-park where tea was kindly provided by the forest staff. Full credit to Mr. Mackin and company for slaking our thirsts and providing seating in one of the buildings at Sheskinawaddy.

EUGENE HENDRICK

WEDNESDAY, SEPTEMBER 20, AFTERNOON

On two of the four stops, wildlife reared its head, albeit imaginary. Unfortunately, we did not see a real head of either of the two animals discussed, the deer and the Greenland white-fronted goose.

Stop 3 Whilst we did not see any of the 20-30 deer thought to be present at Killeter Forest, one had the impression that some of them were up there on the hillsides laughing and leering at us from behind the safety of cover, mostly hardwood. They might have known that the experts below in the valley were confused as to what to do about them. Anxiety was expressed that the damage to hardwoods, caused by deer, whilst not serious now, might in time, become so if deer control measures were not enforced. One opinion, expressed by several participants, was that it was much too early to make decisions regarding control, since the population was too small. Another opinion was that Red deer do more damage than Sika deer in large populations and that control of the Red-dominated population in Killeter Forest should be done now before it is too late. A method of reducing damage by deer was suggested (C. Crowley), whereby zones within grazing areas chosen by the deer themselves, are fenced in, where shelter and food are then propogated and maintained. The discussion ended with no one disagreeing that there was still a lot to learn about deer control.

Stop 4 We departed the deer haven and sought the higher reaches to what was referred to as a goose lawn. Mr. J. Philips told us that Ireland was the main wintering place of the Greenland white-fronted goose, staying about eight months in this country. Mr. J. Mackin estimated that 130-140 geese frequent the area in flocks of about 30 and he referred to speculation by a Walter Davis from Wales to account for why they came to this area at all. According to this speculation, the geese are attracted to areas featuring *Rhyncospora alba,* which harbour nutrient-rich capsules. The geese prefer remote areas, preferably elevated, where they can see people approaching. Cultural practices, such as ploughing, drainage and fertilization would lead to the disappearance of those plants favoured by the geese. Some hard questions on forest policy will have to be answered if further conservation of the species is to be pursued.

Stop 5 Mr. W. Bryan then brought us to see a tunnel plough and a ditcher in action. The plough, which operates only on peat, creates a tunnel about 1m below the surface. It does not restrict rooting as do conventional furrows. Results after 15 years of experimentation with the plough showed no increase in height growth as a result of using it, but rooting at depth was greatly improved. Mr. E. Hendrick listed the three main requirements for use of the tunnel plough: (1) peat should not be less than 1.3m deep; (2) the peat should be fibrous; and (3) the topography should be generally flat. The enthusiasm of Messrs Dillon and Hendrick for the machine was not shared by their counterparts in the North. Mr. Bryan claimed the plough had severe limitations which had forced them, in his district, to revert to the DMB on occasions. While this discussion was in progress, the tunnel plough worked merrily away, disgorging impressive long slivers of Killeter peat at our feet. Mr. Bryan seemed to summarise for all when he said "She's a damn good machine if you have a suitable site".

Stop 6 From the Marvellous Mayo Machine, Mr. Bryan took us to see another metal model. the Merry Ditcher, which came, not too seductively from Sweden at a cost of £15,000 in 1976 (£28,000 in 1978). The main function of the machine is to clean and maintain drains, but new drains can be made simply by making two runs. Two men are required to operate the machine which was pulled by a Ford County 764 tractor in this demonstration. The main part of the machine consists of heavy discs which are set at approximately 45° and these spit off chunks of peat which make onlookers keep their distance. It is suitable for operation on peat soils only and on such sites the output is 200-300m per machine hour which is up to ten times more efficient than manual cleaning of drains. The chairman of the afternoon session, Dr. P. M. Joyce, was determined not to let our northern friends go without justifying their no-thinning policy and so an unpremeditated(?) discussion commenced. The result of this after-hours session could be termed a high scoring draw. The northerners confine this policy to surface-water gleys and blanket peats in recognition of the high wind risks on these soils in the province; the Republic's foresters appear willing to accept wind casualities in the expectation of gaining more saw-log material through thinning.

Finally, the chairman and president of the society thanked all those present or absent from the Northern Ireland Forest Service for making our day in Killeter such an enjoyable one. Mr. Cecil Kilpatrick replied, emphasising that we are all one family and that we were to come back again soon.

DICK McCARTHY

THURSDAY, SEPTEMBER 21, MORNING

Meenglas Property — Barnesmore Forest

At Meenglass Property, our first stop, the President, Mr. Molloy introduced Mr. Arthur Simpson as Chairman for the morning session. Mr. P. Hand, District Inspector, explained that the South Donegal District, comprising some 18000ha, extended from Ballybofey, in the north to Bundoran in the south, and from Killeter in the east to Glencolmkill in the west.

Forester-in-charge, Mr. McBride, outlined the history of Meenglass. The property comprises 900ha. First planting took place in 1947, Sitka spruce is the main species and is of good performance. All harvesting was done by forest staff, which practice afforded greater control of thinning operations. Mr. Hand pointed out that the absence of a harvesting tradition in the area contributed to a policy of direct harvesting. Mr. T. Mannion, stressed the importance of staff training with particular emphasis on safety precautions, so that harvesting would be both safe and economical. The skill of the chain-saw operative, and the intellegent presentaion of the log in the extraction-rack were of extreme importance to the efficiency of the operation.

Extraction here was via a Ford County 754, 4 equal-wheel drive tractor, mounted with an Igland double-drum winch, capable of carrying an average load of .7m^3 to

$1.6m^3$. Outlining some harvesting costs, based on an average haul distance of 200m, Mr. Mannion said that felling and extraction of first thinnings cost £7.75 per m^3. For second thinnings the figure was £5.75; for third thinnings £4.75; and for clearfell, £2 to £3.50 per m^3.

In response to Mr. Gerhardt Gallagher's query on the method of first thinning, Mr. Mannion stated that 1 line in 3 — one third of the crop — was removed. Extraction racks, so created, were critical to the low costs. The President, Mr. Molloy, enquired as to the level of damage during extraction. Replying, Mr. Mannion said that by reducing the load during extraction, damage could be minimised. Dr. J. Gardiner enquired as to the ability of the tractor to deal with difficult ground conditions and was assured that its versatility enabled it to deal with most situations.

In reply to a question from Dr. Joyce, Mr. Mannion stated that 25% of first thinnings were suitable for pallet-board. This fact increased substantially, the profitability of first thinnings.

Mr. M. Peoples, a chain-saw instructor, gave a practical demonstration of correct tree-felling and snedding operations. Efficiency of movement, effort and energy expended were clearly evident. Mr. E. Martin demonstrated correct extraction procedure.

Our next stop was at Croaghonagh property where, on deep peat, a fertilizer experiment on lodgepole pine (coastal) prompted lively discussion. The area was planted in 1953. Mr. J. Freeman outlined that the experiment trial was laid down in 1973. While the provenance was not known, the characteristics of the south coastal provenance were very evident.

Mr. E. Hendrick stated that the object here was to determine the profitability of fertilizing pole-stage LP(C) on deep peat to obtain reasonable volume production. Results were not conclusive, but responses in height-growth warranted further investigation.

Dealing with soil fertility in the area, Dr. McCarthy indicated that in two pits P and K levels were very low. The deficiency in K was surprising as the area had a high rainfall. The President, Mr. Molloy felt that some leaching of K had taken place, creating a deficiency. Dr. McCarthy concurred and added that in his view, K from rainwater was available only during the growing season. Mr. Hand raised the question of K requirements in Donegal. Dr. McCarthy commented that in general, good leader-growth and sufficient rainfall indicated the presence of healthy levels.

The basal sweep characteristics of LP(C) came in for some discussion. Mr. Hendrick posed two theories, (a) that it was a genetic trait; (b) that it was cultural. However, a reference to Forest Commission experiments indicate a genetic origin.

It was also observed that here that root systems of LP(C) reached down to a ½m in depth. Mr. Mannion, referring to other experiments, said that with lowering of water-table through drainage, rooting depths followed up to 1m.

Moving to a stand of LP(C), aged 25 years YC10, Mr. Hand invited comments on management options, with a crop of this nature. A number of suggestions followed. Mr. Johnson suggested complete tree utilisation as a longterm policy. Mr. M. O'Brien offered the possibility of selecting and pruning of 400 stems per ha for commercial purposes. This was in keeping with practices of stem selection of *Pinus radiata* in New Zealand. Supporting this view, Dr. Gallagher said that stress-grading studies on LP were very encouraging, eliminating fears as to its suitability for joinery work. Dr. Gardiner commented that LP was a very versatile timber which found more outlets as a general purpose timber in the U.S. and Canada than Sitka spruce.

Lough Eske Demesne

Lough Eske Forest (F/C Mr. A. Connolly; A/F Mr. D. Gallagher) provided a picturesque setting for lunch. Mr. Connolly, in welcoming members, commented that the amenity development at Lough Eske was to some extent attributable to the Society's "Guided Forest Walks".

Mr. E. Johnston referred to a stand of Redwoods (Sequoia sempervirens). He pointed out that it was management policy to retain this stand.

Afternoon chairman Mr. P. Crowe, on behalf of members extended his appreciation to all concerned.

DENIS GALLAGHER

THURSDAY, SEPTEMBER 21, AFTERNOON

The first stop of the afternoon was at Monellan property, Killygordon Forest, where Mr. Peter Crowe, Chairman, introduced the local forest staff, Forester-in-charge, Mr. C. J. Jeffers, Deputy P. Dalton, Assistant M. Regan. After Mr. C. J. Jeffers welcomed the party to Killygordon Forest and gave a brief history of Monellan property we moved on to our next stop where Dr. R. McCarthy described the soil of the property as a Brown Podsolic with a tendency to gleying and as good if not better than a Brown Earth. The pH at 4.1 was low and there was little Fomes annosus. At stop three, Mr. E. Johnson posed the question of the day "when do we fell this excellent crop?" He described how the SS stand, 13.4ha planted in 1939/40 (Yield Class 20) was fully mature for the best prices available and was approaching critical height. It would take three years to clear-fell the SS crop. The very much larger area of NS (37.5ha) planted 1939/40 YC 18 would not be fully mature for another 10 years, but removing the SS crop now could put the adjoining NS at risk of windblow, worth as it stands today over £250,000. The entire clear-fell operation would take approximately seven years to complete. The mean diameter of the NS was currently only 27cms and this is well below the top price range category.

Dr. Padric Joyce thought we should not be stampeded into felling the NS and suggested the rotation of maximum MAI for this species, and commence felling the SS now. Mr. O'Brien felt a 30% reduction in the age of maximum MAI of the NS could be made without loss. The crop at that stage would have a mean diameter of about 33cms. Mr. O'Donovan supported Dr. Joyce's view.

In answer to a question from Mr. F. Mulloy concerning the most utilisable size for NS, Mr. T. Purcell stated this would be about a mean diameter of 34cm dbh and would be reached about age 50 years. Mr. Johnston pointed out a mean dbh of 34cm will give diameter sizes ranging from 26cm to 46cm and once the mean of 34cm is past the price per cubic metre may start to drop. Dr. Joyce then modified his view and he said he favoured removing the larger diameter trees in the Norway crop as a control of mean diameter size. Dr. G. Gallagher stated "Price size curves" used to determine time of felling indicated that when trees reached sawlog category it becomes uneconomical to hold the crop on financial grounds. Mr. J. Gillespie stated that the age of maximum financial return for the SS was 40 years. Mr. R. Tottenham asked could the NS have been more heavily thinned giving larger diameters, to which Mr. Donovan pointed out the crop was in fact thinned close to the line suggested in the BFC Management tables as present stocking and volume confirmed. In answer to a question from Mr. van der Wel on direction of felling coupe Mr. N. Foley suggested felling the NE side of the crop first. Mr. T. Mannion pointed out that a serious climatic factor in the area is the velocity and frequency of winds. The prevailing winds are from the South and West, especially in the period October to March. Records show that in this period winds of force 8 or more can be expected on at least 34 days, but very severe storms can also blow from North to West and this is the gamble that has to be taken. In answer to Dr. Joyce's question why rotation of maximum MAI was not the most profitable Dr. G. Gallagher replied the chief reasons were interest rates and the return on capital.Mr. D. Mangan thought the position where a lesser price was paid for a greater size category of timber might not always prevail and he favoured "felling before the wind fells for you". Mr. A. Mannion thought the NS might suffer from die-back if the SS were removed from it. At this point the Chairman called the discussion to a halt summarising it was difficult to come to a decision and thought the problem might best be left to local management.

Our final stop was the Farm Training Centre at Ballyfofey, owed by the County Committee of Agriculture. Before introducing the local staff here the Chairman thanked Killygordon Forester-in-charge, Mr. C. J. Jeffers and his staff for their co-operation. We were welcomed to the Farm Training Centre by Messrs John O'Sullivan, Pat Mulloy and A. Gallinagh. The centre, which was acquired in 1964, totals an area of 10 acres, 6 acres of which are used as a nursery to supply trees and hedge plants for the shelter belt scheme in the County. Approximately 150,000 plants are supplied annually from the nursery to an average of 500 applicants. 100 trees is the minimum number supplied to any applicant and 2000 the maximum. The grant for the scheme is comparable to the Forest and Wildlife's grant scheme for private planting. The County Committee employs an instructor in forestry and he inspects each site before plants are sent out. Demonstrations are given in planting methods etc. and night-classes are held in nine centres throughout the county which encourages the 'green belt parish'. The buildings at the centre consist of an office block, lecture hall, and farm kitchen and courses are provided here for farmers and housewives. After the introductions by Mr. Mulloy and Mr. Gallinagh the party was then led through the garden plots by Mr. J. O'Sullivan.

Long flowering shrubs like *Cydonia Japonica, Spirea Anthony Waterer,* the comparatively rare plant *Berberis condula* and many others made an interesting change from the usual forest trees. The most common species in the nursery section were SS, NS and Lawson's Cypress, with some LP; and *Pinus radiata.* The latter species, Mr. O'Sullivan stated, they found difficult to establish in Co. Donegal. Frost was a serious problem here particularly with such species as *Oleria traversii, Escallonia* and *Griselinia.*

The President, Mr. F. Mulloy, thanking the staff, stated that Donegal County Committee of Agriculture had done a lot of tree planting over the years and helped bring about, as it were, a marriage between forestry and agriculture. In concluding, he thanked all present.

Another successful tour was ended.

PAT DOOLIN

STUDY TOUR PARTICIPANTS 1978

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