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Whither forestry? The scene in AD 2025

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1 Introduction

When thinking about the future of forestry, it is necessary to recognize that the form of the landscape in the year 2025, or at least the significant forestry element, has already been largely determined. Even though trees tend to grow faster in the UK than in most countries of the European Communities, those planted between now and 2025 will have less impact on the landscape than those already planted. Further, it should be appreciated that the use of land is strongly influenced by political decisions which are inevitably determined by events, both national and international. Thus, although the UK economy is freer than many, it is not a free economy; land use reflects, in large measure, the availability of grants, concessions, tax exemptions and intervention payments. Without the annual support given to the agricultural industry by the British government, which amounted to £970M in 1981–82 (Ministry of Agriculture, Fisheries and Food 1983), much of the British agriculture would be unprofitable compared to energy farming and forestry (Mitchell *et al.* 1983). Britain, as a member of the Commission of the European Communities (CEC), is obliged to take cognizance of the needs and views of the other members of the Commission and, predictably, these are likely to have an increasing impact, particularly in relation to land use.

1.1 The wilderness concept

When debating the future of the Scottish Highlands, it is essential to consider the mosaic of uplands and lowlands, the use of the one impinging on that of the other. Further, it is necessary to recognize that the use of both the uplands and lowlands influences, and is influenced by, the distribution of the resident population and the movements of visitors which, in turn, reflect regional infrastructures. Thus, it is worthless to consider the well-being of forests and wildlife without being mindful of the requirements of the human population.

Two years ago, at a conference concerned with 'Wilderness – the way ahead', many speakers strongly argued the merits of the 'wilderness concept'. In doing so, they referred to the Wilderness Act, passed in the USA in 1964, which aims 'to assure that increasing population, accompanied by expanding settlement and growing mechanisation, does not occupy and modify all areas within the U.S.' (Block 1984). As defined by Zunino (1984), the philosophy of the wilderness concept accepts 'the balanced use of natural resources based on the idea of creating an environmental heritage for posterity; it entails imposing limits on human developments in order to preserve an everlasting space for nature and its wild creatures'. While being firmly embedded in the virtues of resource conservation, the concept encompasses a sociological or spiritual desire, namely the need to have wild and free space so as to commune with nature. To some, this desire may seem to be an unnecessary affectation, but to an increasing number of others it is an absolute necessity.

Although it could legitimately be argued that the Highlands, like the rest of Britain, have already been comprehensively altered by the activities of man, anyone ignoring 'wilderness' as a legitimate land use when considering the future of the Highlands will do so at his peril. How will the owners of designated wilderness areas be compensated for the loss of 'improvement'? If we are willing to pay for unwanted agricultural excesses, there is doubtless a way to facilitate the maintenance of wilderness, always presupposing that the proponents of wilderness have sufficient political backing to present widely acceptable arguments.

1.2 Agriculture

Until the Mansholt plan was unveiled about 17 years ago, it was tacitly assumed that most agricultural land within the European Communities would continue to be used for agriculture in perpetuity (MacKerron & Rush 1976). Now, however, our judgements are being challenged. The forecasts suggested that the UK would be self-sufficient in 1984 in wheat (producing 104% of its requirements), barley (143%), oilseed rape (112%), beef and veal (101%), skimmed milk powder (224%), and full-cream milk powder (667%). In many instances, the forecast for the European Communities suggested even larger surpluses. Of the major agricultural crops, UK growers under-supply only potatoes and sugar, but, within the Communities, the outputs of these crops were expected to reach 99% and 123% respectively of anticipated requirements (Melchett 1985).

When contemplating the significance of these data, other considerations should be taken into account. As noted at the 1985 Oxford Farming Conference by Mr Fawcett, the Managing Director of Dalgety Agriculture, food production in the developed world is increasing rapidly, often as a result of 'improved efficiency', while consumption (in the developed world) is lagging behind. Within the UK, total cereal production has doubled in the last 15 years; yields of barley increased from 8.5 Mtonnes to about 11 Mtonnes despite a decrease of 10% in the area planted, while milk output has increased by more than 30% (mainly as a result of enhanced yields per cow). On the other hand, consumption, except of vegetables and fruits, has been either static or declining, eg decreases of 40% in the domestic consumption of sugar (which has not been offset by a matching increase in the use of sugar in manufactured foods), 30% in the consumption of butter between 1960 and 1981, and 21% in the consumption of UK beef, veal and lamb. Taken together, these trends of increasing 'efficiency' and over-production and of decreasing consumption inevitably lead to the conclusion that changes are needed in the ways in which we steward our land resources.

A range of estimates has been made of the areas of the European Communities that need to be removed from existing agricultural usages, if surpluses are to be minimized. Giraud (1985) suggested 9 Mha by 1990, Strehler (1985) proposed 8 Mha, while Buckwell, of Wye College, London, in addition to estimating 5.25 Mha for the Communities, detailed losses within the UK of 0.5 Mha of wheat, 0.4 Mha of barley and 0.03 Mha of sugar beet.

Should the Commission of European Communities continue to spend 40% of its agricultural budget disposing of food surpluses (Dalsager 1983)? If not, would the probable decrease in cattle and sheep enable the present artificially depressed tree-line in the Cairngorms to rise, eg from 600 m to 700 m (Pears 1967)? However, before turning our attention from an agricultural land use, is it conceivable that 'new' plant and animal crops may be found, possibly for industrial uses, eg the supply of starch, biofuels, fibres, natural dyes and a range of feedstocks for chemical industries? If they were found, would any of them be suitable for the lowlands and uplands of the Scottish Highlands?

1.3 Forestry

Following discussion of the Mansholt plan, the Commission of the European Communities published its *Forestry policy in the European Community* (CEC 1979). It was suggested that 5 Mha of land, submarginal for agriculture, should be transferred to forestry, recognizing that the change could be reversible. But why to forestry? When discussing the UK timber industry, Bradley (1985) indicated that imports in 1983 of round- and sawnwood, wood manufactures and reconstituted wood, wood pulp and waste paper, and paper and board amounted to £937M, £569M, £420M and £1,906M, giving a total of £3,832M. This amount in 1983 was equivalent in value to about 90% of the timber and timber-based products used in Britain: the European Communities (including the figures for Britain) import 60% of their timber needs (Centre for Agricultural Strategy 1980). In short, the Communities have a very large timber deficit which, even accepting the need for goods to sustain trade, is probably putting an excessive long-term pressure on the timber resources of those countries that export.

In considering a strategy for the UK forest industry, the contributors to the report prepared by the Centre for Agricultural Strategy (CAS), Reading, bluntly stated that timber production should be increased (CAS 1980). They suggested that the increase should be achieved by (i) the selection of genetically superior planting stock and more productive silvicultural and harvesting procedures, (ii) the conversion of unproductive woodland, and (iii) the addition of sizeable areas to the UK forest estate. They recognized that an annual increase of 60 000 ha yr^{-1} was likely to lead to 26% self-sufficiency in timber by AD 2025, when 16% of Britain would be afforested, compared with 8% at present.

The report suggested that hardwoods should not be entirely ignored in the uplands, where production cannot be expected to be high but where conservation and landscape interests are important. It also assumed that the bulk of the broadleaved planting would take place in the lowlands, where it would form only a small part of the total. The aim should be to increase the ratio of areas planted with broadleaved trees to those planted with conifers from 1:30 at the present to 1:20 by 2025.

The balance of the 'new' areas, ie the vast majority, would be afforested with conifers, it being tacitly assumed that Sitka spruce (*Picea sitchensis*) would be the favoured species. When the report was published in 1980, it was also assumed that only the poorer land would be afforested, ie those areas graded 'V' in England and Wales (Agricultural Development and Advisory Service 1974) and 'D' in Scotland (Scottish Development Department 1981), and considered to be 'marginal for agriculture', which are not constrained by rocky outcrops, by uneconomically slow growth rates attributable to high altitudes, or by the danger of adversely affecting water yields, and so on. As a result, it was suggested that the tree cover in the former East, West and North Conservancies of the Forestry Commission might increase from 13%, 16% and 8% to 26%, 40% and 20% by the year 2030. All 30 of these Conservancies include areas of what is collectively known as the Highlands (Figure 1).

In the CAS report, it is clear that the authors did not wish to be straightjacketed by 'either/or' statements; instead, they attempted to develop a range of options or scenarios but, in doing so, they did not provide a framework on which to insert and judge the merits of changed uses of land.

2 Framework for assessing land use options

To consider and assess the comparative merits of a range of options, it is desirable to have a system in which the different uses, such as forestry, agriculture,

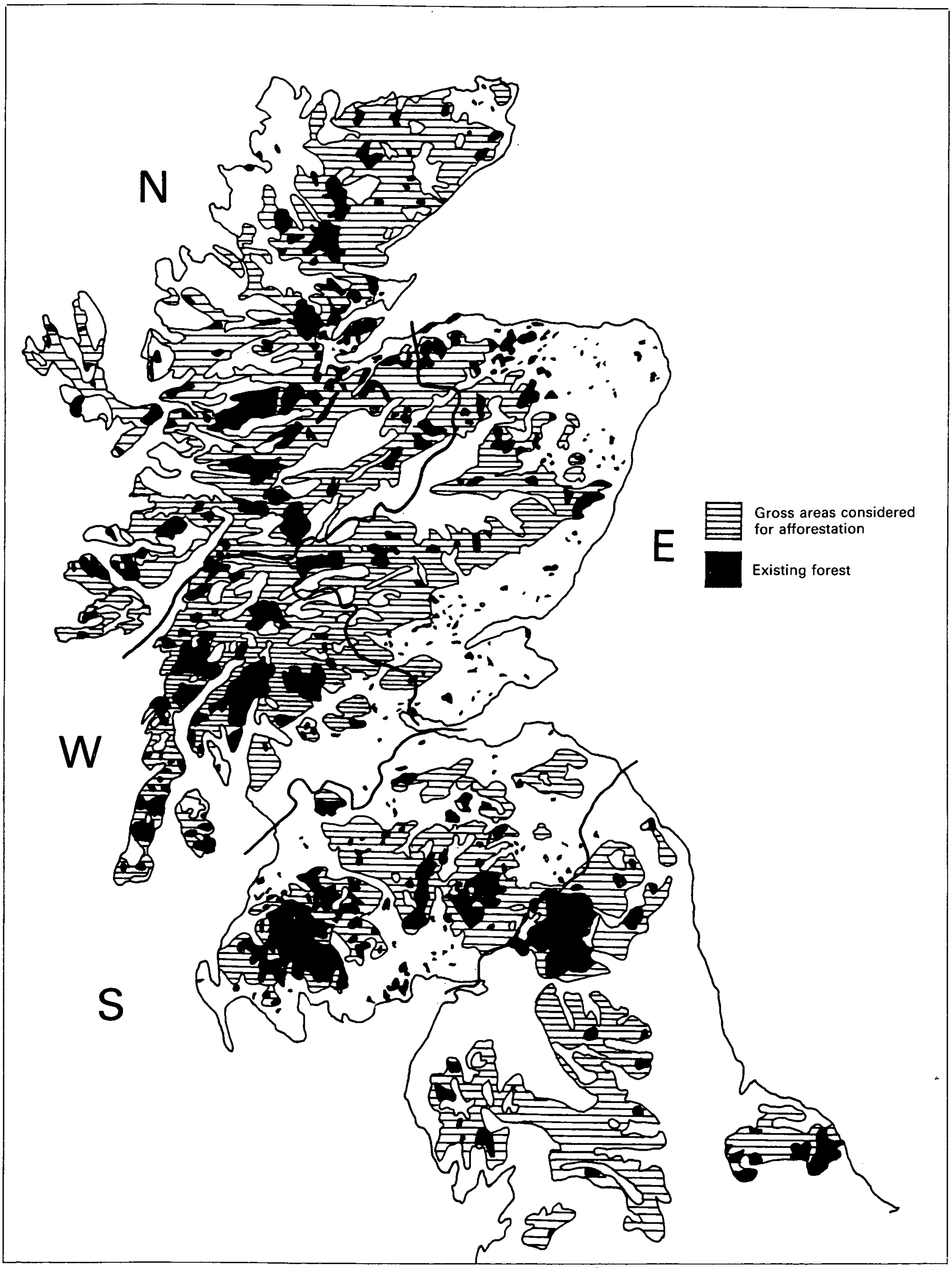


Figure 1. Gross areas in northern Britain considered for afforestation in relation to existing forests, scenic areas and water constraints (source: CAS 1980). Boundaries refer to former Forestry Commission Conservancies in Scotland

the conservation of water and/or wildlife, can be inter-related. For, whatever we may think, these options are still over-ridingly influenced, except for political considerations, by environmental factors. Anderson and Fairbairn (1955) recognized that different types of silvicultural practices were developed in response to the influences of sunshine, wind, rain . . . but, with the data handling techniques available to them, they found it 'extremely difficult, if not impossible, to combine more than 2 factors'. Times have changed. With a variety of more recently evolved statistical procedures, including cluster analysis (Howard & Howard 1980), it is now possible to derive land classifications using complexes of extant map-readable information related to geological, topographical and climatological features.

Using data derived from the central one kilometre square of each of the 1228 squares (15 km x 15 km) into which Great Britain can be divided, Bunce and his colleagues have, with the application of Indicator Species Analysis (Hill *et al.* 1975), evolved 32 land classes (Plate 9). The data employed included:

— mean numbers of days with snow falling
— mean daily minimum temperature in January
— mean daily duration of bright sunshine
— maximum elevation
— distance to west coast – a measure of longitude and oceanicity
— distance to south coast – a measure of latitude and associated changes, eg daylength
— details of solid, and drift, geology

Some of the land classes are mainly located in England and Wales, eg classes 1–8, whereas Scotland is dominated by land classes 17–32 (Bunce *et al.* 1981; Bunce & Last 1981). As the descriptions of land classes 21, 24, 28 and 29 indicate, it is possible to provide a detailed assessment of the environments which plants and animals would experience in the different land classes (Table 1). By consulting the appropriate records and/or exercising judgement, it is then possible to attach 'performance functions' to each of a wide range of plants for the differing conditions of each land class. Additionally, it is possible to attach costs of inputs, including interest on capital expenditure, and value of outputs for each crop in each land class, so enabling judgements to be made of likely net costs.

In recent years, this system of land classification has been developed and exploited by the Planning Department of the Highland Regional Council (HRC), Scotland, whose data-bases are attuned to 1 km squares (HRC 1985a). Broadly speaking, the Region can be divided into 2 parts: a coastal array of lowland land classes 25–32 which are characteristic of the northern half of Britain, and an inland zone of land classes 17–24, sorted primarily by altitude. Some of the latter land classes are shared with upland areas wherever

Table 1. Characteristics of the more abundant land classes in the Highland Region, Scotland (source: Bunce *et al.* 1981)

LAND CLASS 21 (23% of the area of the Region)	
Central and northern Scotland	
Steep hillsides predominate, but there are some moderate slopes	
Bleak upland landscapes, sometimes enclosed and afforested	
Open-range grazing or forest, moorland and peatland vegetation	
85% at altitudes of 199–488 m, 2% over 488 m, slope 8°	
Mean minimum January temperature	0.0°C
Mean number of days on which snow falls	54.3
Mean daily duration of bright sunshine	4.1 h
LAND CLASS 24 (12.5% of the area of the Region)	
Central and western Scotland	
Precipitous and extremely steep slopes with land at high altitude	
Rugged mountain scenery, often rocky, with fast-flowing streams	
Limited open-range grazing, mainly peatland with some moorland vegetation	
56% at altitudes of 199–488 m, 31% over 488 m, slope 18°	
Mean minimum January temperature	0.1°C
Mean number of days on which snow falls	51.4
Mean daily duration of bright sunshine	4.1 h
LAND CLASS 28 (12.9% of the area of the Region)	
South and north-east Scotland	
Mostly flat land but with some gentle gradients at medium to low altitudes	
Heterogeneous landscape, from enclosed farmland to open moors	
Pasture and rough grazing but with some good grassland, also peatland	
89% at altitudes of less than 199 m, 11% at 199–488 m, slope 4°	
Mean minimum January temperature	0.2°C
Mean number of days on which snow falls	45.3
Mean daily duration of bright sunshine	4.3 h
LAND CLASS 29 (9.6% of the area of the Region)	
West Scotland	
Indented coastlines, uneven topography, with some steep slopes	
Complex scenery with many contrasting elements	
Mainly open-range grazing, some crofting, peatland and moorland, also some bracken	
95% at altitudes below 199 m, 5% at 199–488 m, slope 13°	
Mean minimum January temperature	1.7°C
Mean number of days on which snow falls	31.5
Mean daily duration of bright sunshine	4.6 h

they occur in Britain. The Highland Region has comprehensive collections of data concerned with the environment, land uses, infrastructure, the human population and artefacts for its 27 915 squares.

Importantly, the system of land classification is arranged so that policy options can be considered and, to an extent, tested. For this strategic purpose, it is not necessary to have a complete enumeration of every square within a Region. Instead, experience has shown that adequate approximations are obtained using data from 8 randomly selected squares of each land class.

At present, the Highland Region is dominated by moorland. This habitat occupies 63% of the land area; grassland/pasture accounts for 17%, arable 3%, commercial woodland 13% and amenity woodland 4% (Figure 2) (HRC 1985c). Setting aside, for the time being, political aspects of the question 'Should a greater area be afforested?', is it possible to decide if there *could* be larger areas of productive forests in the Highland Region?

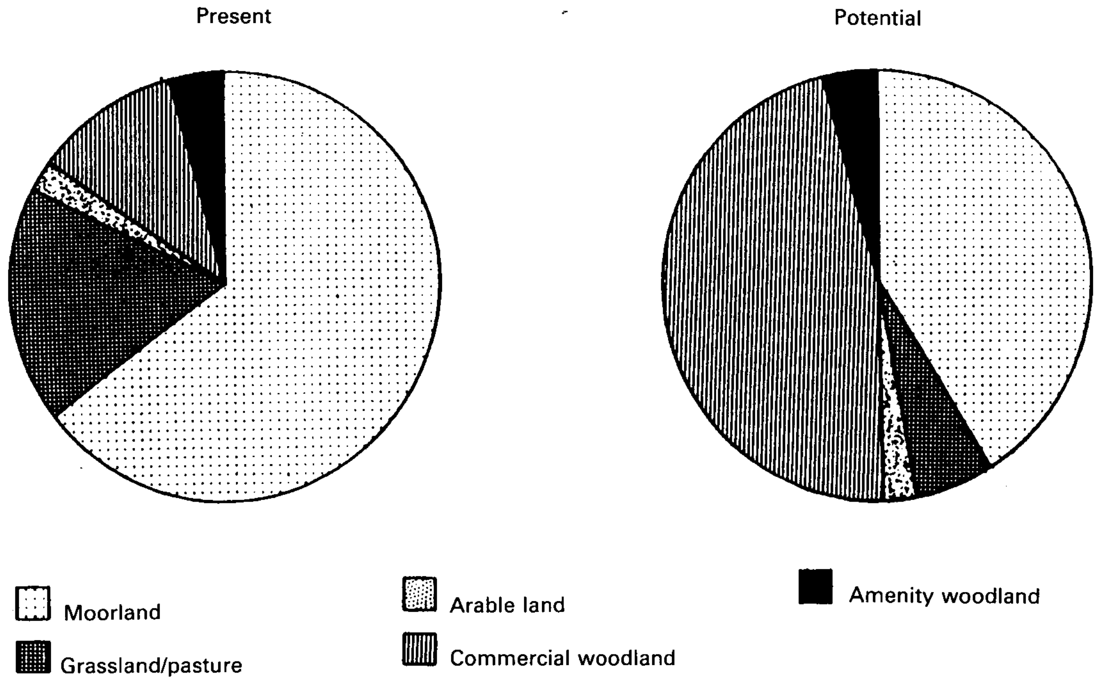


Figure 2. Present and potential land uses in the Highland Region, Scotland, judged on present-day yield expectations and costs, and assuming a discount rate of 3% (source: HRC 1985c)

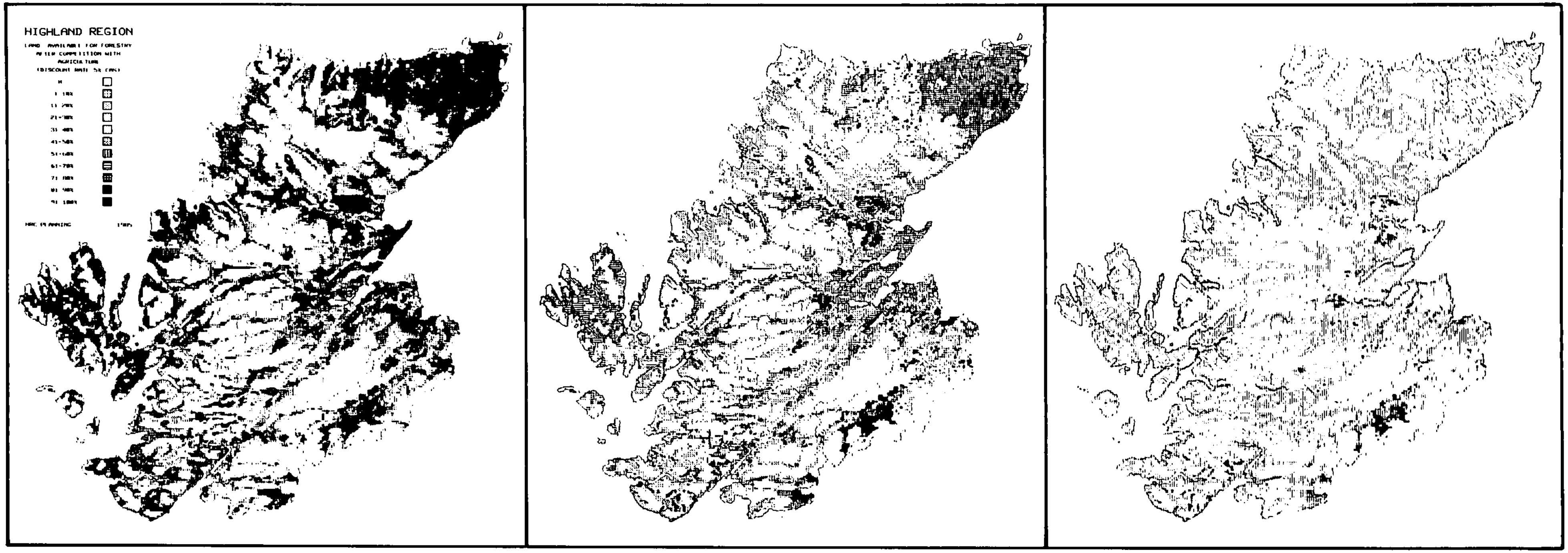
This question can be answered in a number of ways, but first it is necessary to identify the land which is theoretically suitable for afforestation, by excluding those areas of the different squares judged to be physically unplantable because they are sea, intertidal, loch/lochan, sea cliff, urbanized, already afforested (Figure 3) or above the tree-line (an altitudinal arbiter which varies in different parts of the Region, ranging from 200–250 m in the north and west to 600 m in the south-east). It is then possible to proceed by deleting areas designated by the Nature Conservancy Council as (i) Sites of Special Scientific Interest (SSSIs) and (ii) National Nature Reserves (NNRs), and by assuming that the present uses of commercial peat deposits and land in Macaulay Land Capability Classes 1–5 (Bibby *et al.* 1982) and crofting tenure will not be altered. However, is this a prudent way to proceed when the values of different land uses are likely to change relative to each other?

It is widely accepted that forestry prices will increase against those of agriculture. The preferred approach is to minimize the number of assumptions and instead attempt to obtain an objective estimate by examining the net costs of different options. For each land class in the Highland Region, 14 possible forest enterprises, including the planting of Sitka spruce, lodgepole pine (*Pinus contorta*), Japanese larch (*Larix kaempferi*), Douglas fir (*Pseudotsuga menziesii*) and Corsican pine (*Pinus nigra* var. *maritima*), were compared with a range of existing land uses, including the cultivation of barley, oats, wheat, potatoes, turnips, swedes, rough grass, short-term grass and permanent grass. It was found that significant areas of present-day grassland/pasture and moorland could be converted remuneratively, at present-day prices, to commercial afforestation, so as to increase the existing commercially afforested areas within the Region from 13% to about 40% assuming a discount rate of 3%, or to 24% with a discount rate of 5%.

With the land class system it is possible, as the maps show (Figure 3), to pinpoint with a degree of certainty those areas in which land uses might change. But, for the future, should we concern ourselves solely with the maximization of monetary return? Ever since the oil crisis, greater concern has been expressed for the proper stewardship of our non-renewable resources, with a movement towards optimization instead of maximization.

3 Forestry scenarios

Changes in the use of land must be considered against a range of possible scenarios, partly because we cannot be certain that any one scenario is likely to be correct, but also to enable us to test the sensitivity of the factors influencing our decisions against the different possibilities. Most of the factors needing to be considered have already been mentioned, and they include the increased importance of timber production relative to the production of food. There is already a world shortage of many kinds of timber, and the rate at which mature timber is being felled will almost certainly trigger a sharp rise in timber prices. Faced with both increased prices and real shortages of the kinds of timber which we have traditionally imported, it will be necessary to reconsider our established dependence on imported supplies. Similarly, changes in the availability of timber will themselves have an effect on the practical uses that we make of wood. Bulk use



Area suitable: 1 110 kha (44%)	*Area suitable: 700 kha (28%)*	*Area suitable: 279 kha (11%)*
Excludes areas judged to be physically unplantable (sea, intertidal, loch, land cliff, seacliff, urban land or existing woodland and that above stipulated altitudinal limits)	Judged against agricultural options, assuming a discount rate of 3%	Judged against agricultural options, assuming a discount rate of 5%

Figure 3. Areas of the Highland Region which are not afforested but could be profitably, compared with existing land uses, at discount rates of 3% and 5% (source: HRC 1985c)

of inferior timber may well be replaced by more specialized and craft uses of higher quality timbers, leading to a new balance being struck between the demands for softwoods and hardwoods. The rapid development of electronic communications also seems likely to reduce greatly our demand for pulpwood, at least for the making of paper.

By far the most influential factor will be the future cost of energy. Almost all current operations in forestry and agriculture have been made possible by the availability of energy, as fossil fuels, at ridiculously low prices, bearing in mind the fact that these fuels are not renewable in a timescale which bears any relationship to the rate at which they have been used. There are only limited reserves of fossil fuels, and the creation of energy by alternative methods is never likely to provide energy at prices lower than those of today, especially for the transport of people and materials.

Figure 4 illustrates 4 scenarios used recently by the Forestry Research Co-ordinating Committee as a basis for planning forestry research. The first of the scenarios, that of least change, assumes the continuation of the existing forest poly in Britain, with no very marked increase in the area of forest, and an unchanged balance between the areas devoted to growing hardwoods and softwoods. This scenario assumes no marked increase in the proportional cost of energy, and that recreation, amenity and wildlife conservation will be given equal value to the production of timber.

There are 2 forest production scenarios, differing only in the extent to which there is a marked increase in the proportional cost of energy. In both of these scenarios, increased importance is given to forest production, with the area of forest being increased to at least 10% of the total land surface. The production of wood is assumed to be given higher value than recreation, amenity and wildlife conservation. Possibly greater emphasis will be given to hardwoods, and to the closer integration of forestry with agriculture.

The final scenario is one of world shortages of timber, leading to an increase of the forest area to 15% or more of the total land surface of the UK. With the value of wood higher than that of most foods, hardwoods and softwoods are assumed to be of about equal importance. Energy costs are assumed to be high, especially for motive energy, and the emphasis will be on resource conservation rather than on wildlife conservation.

It is, of course, impossible to predict which, if any, of these scenarios is likely to be closest to the truth, but the most unlikely scenario is that of least change. Whatever choice of total forest area results from the combination of pressures that create our countryside, forest policy will itself have to adapt to the needs of

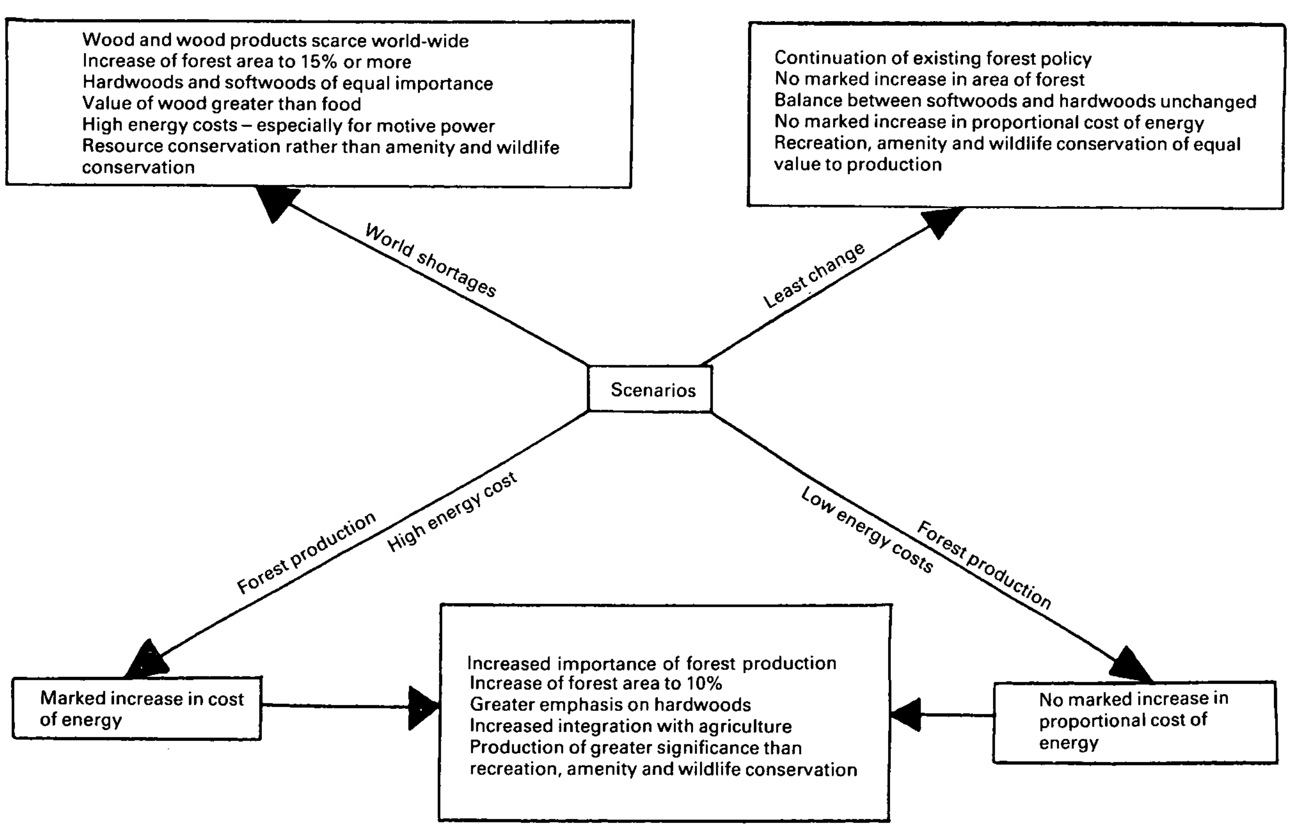


Figure 4. Four scenarios used recently by the Forestry Research Co-ordinating Committee as a basis for planning UK forestry research

British society. Four possible forest policy scenarios are given in Table 2. Again, the first of these scenarios assumes the continuation of the *status quo*, with the social and economic pressures for and against forestry continuing more or less as at present, and with the principal emphasis on softwood production and only a very marginal interest in hardwoods, mainly expressed as a continuing demand for broadleaved woodland devoted to amenity, wildlife conservation and sport.

Table 2. Four possible forest policy scenarios based on the assumption that the afforested area of the UK will be increased

Scenario 1.	*Status quo*, assumes that social and economic pressures for and against forestry will continue more or less as at present, with the principal emphasis on softwoods and only very marginal interests in hardwoods, but a continuing demand for broadleaved woodland for amenity and sporting interests.
Scenario 2.	*High-yield policy*, concentrating on a narrow range of conifer species grown so as to produce the highest possible yield. Hardwoods mainly of interest as energy and fuelwood crops, apart from a limited area kept for amenity or sport. Many broadleaved woodlands replanted as conifers.
Scenario 3.	*High-quality policy*, switching attention from yield *per se* to timber of high quality, whether softwood or hardwood, but particular emphasis on hardwood because of reduced supplies of tropical hardwoods. Timber properties emphasized rather than yield.
Scenario 4.	*Agro-forestry policy*, supplementing conventional forestry, mainly in the uplands, by a new style of lowland, mixed or broadleaved, forestry combined with agriculture, sport and energy farming.

An alternative high-yield policy would concentrate attention on a narrow range of conifer species, grown to produce the highest possible yield. Apart from limited areas of hardwoods for amenity and sport, broadleaved species would mainly be grown as energy and fuelwood crops. Many existing areas of broadleaved woodland would probably be replanted with conifers. A high-quality timber policy would switch attention from yield *per se* to the production of timber with the highest possible quality. Both hardwoods and softwoods would be produced, with a strong emphasis on hardwoods because of the scarcity of tropical hardwoods. Finally, but not necessarily exclusively, forest policy might embrace a strong agroforestry element, where conventional upland forestry would be supplemented by a new style of lowland mixed or broadleaved forestry combined with agriculture, amenity, sport and energy farming.

Whatever the scenario for the future may be, there is certain to be change, and the change may be both extensive and rapid. As pointed out by Seligman (1985) at the 3rd Energy from Biomass Conference of the European Communities, the world is becoming more conscious of its environment every day. In the UK, we have relied far too long on being able to obtain our essential timber supplies from overseas, and principally from the developing countries. Wood is an essential commodity in the Third World, and there is certain to be a strong demand from developing countries for us to grow a bigger proportion of the wood we need, rather than to continue exploiting their reserves. We should recognize that we have a responsibility to increase our self-sufficiency in timber and wood products so as to relieve the pressure on forests in developing countries (Campbell 1984).

4 Some factors constraining the forestry options

In using the land classification system, it has been shown that future forestry developments are, to a very considerable extent, determined by habitat features, but there are other constraints which should be considered and which are equally identifiable in advance. These constraints include the need to avoid (i) NNRs and SSSIs which may have been designated to conserve assemblages of plants and animals or specific species, and (ii) areas where forest canopy interception losses may deleteriously affect the yields of water from catchments or mini-catchments (Calder 1985). It is also desirable to obviate conflicts with deer and grouse and to minimize risks of increasing the acidification of fresh waters.

4.1 Silvicultural factors

In considering the impact of optimizing the utilization of resources, we have questioned some aspects of the future development of commercial forestry, but the advisability of concentrating on the use of Sitka spruce can be challenged from considerations of wildlife and landscape; it also requires continual reassessment when considering the threat of potential pests and pathogens. Unlike most agricultural crops, forest trees are outbreeding and, as a result, there are continuing opportunities for maintaining populations which are heterogeneous except for the attributes upon which selection is based.

Nonetheless, forestry is tending to follow agriculture, but on a greatly extended timescale. Inevitably, forest crops are likely to become less variable, a trend that might be hastened by the desire for quick genetic gains using vegetatively propagated clones. This process might be facilitated by micro-propagation. While we sometimes tend to forget that commercial forestry is, in reality, an extended form of agricultural cropping, there is no doubt of the advisability of seeking alternative tree crops and, in doing so, it would be foolish to disregard the increasing environmental interest in broadleaved trees.

Can we really say that we have exactingly examined the potential of our native species, notably birch (*Betula* spp.)? Brown (1984) suggested that 'sophisticated silviculture allied to breeding superior cultivars of birch could quite readily produce home grown veneer quality trees'. He also believes that the multiple-use management of birch woodlands would benefit forester, farmer, sportsman and tourist. Is it conceivable that exotic broadleaved species with sufficient frost and cold tolerance can be selected for conditions in the Highlands (Murray *et al.* 1986)?

4.2 Water conservation

The quality of water in headwater streams of the River Forth in central Scotland is greatly affected by afforestation where these streams drain mini-catchments overlying slowly weathering bedrock (Harriman & Morrison 1982). Streams draining 'basins' whose catchments were more than 50% covered by Sitka spruce more than 15 years old were significantly and continuously more acidic than those draining unafforested moorland basins or where the trees were less than 15 years old. This variation in the effect of trees of different ages suggests that the increased acidity is not attributable to soil disturbance during and following site preparation and planting. Instead, the effect has been attributed, to different extents, to the greater dry deposition of gaseous and particulate atmospheric pollutants on trees than on moorland rough grazings, and to alterations in the amounts of evapotranspiration and base cation uptake. However, the impact of these influences will be predictably greater where ground and surface waters lack alkalinity (Henriksen *et al.* 1984), the 'cut-off' separating sensitivity from tolerance being greater (100 mg $CaCO_3\ l^{-1}$) for ground waters (Edmunds & Kinniburgh 1986) than for surface waters (Stoner *et al.* 1984). Acidic waters occur where (i) soils are acid, or glacial drift is thin or absent, (ii) carbonate minerals are absent, and (iii) the residence time of water is short.

Edmunds and Kinniburgh (1986) have been able to

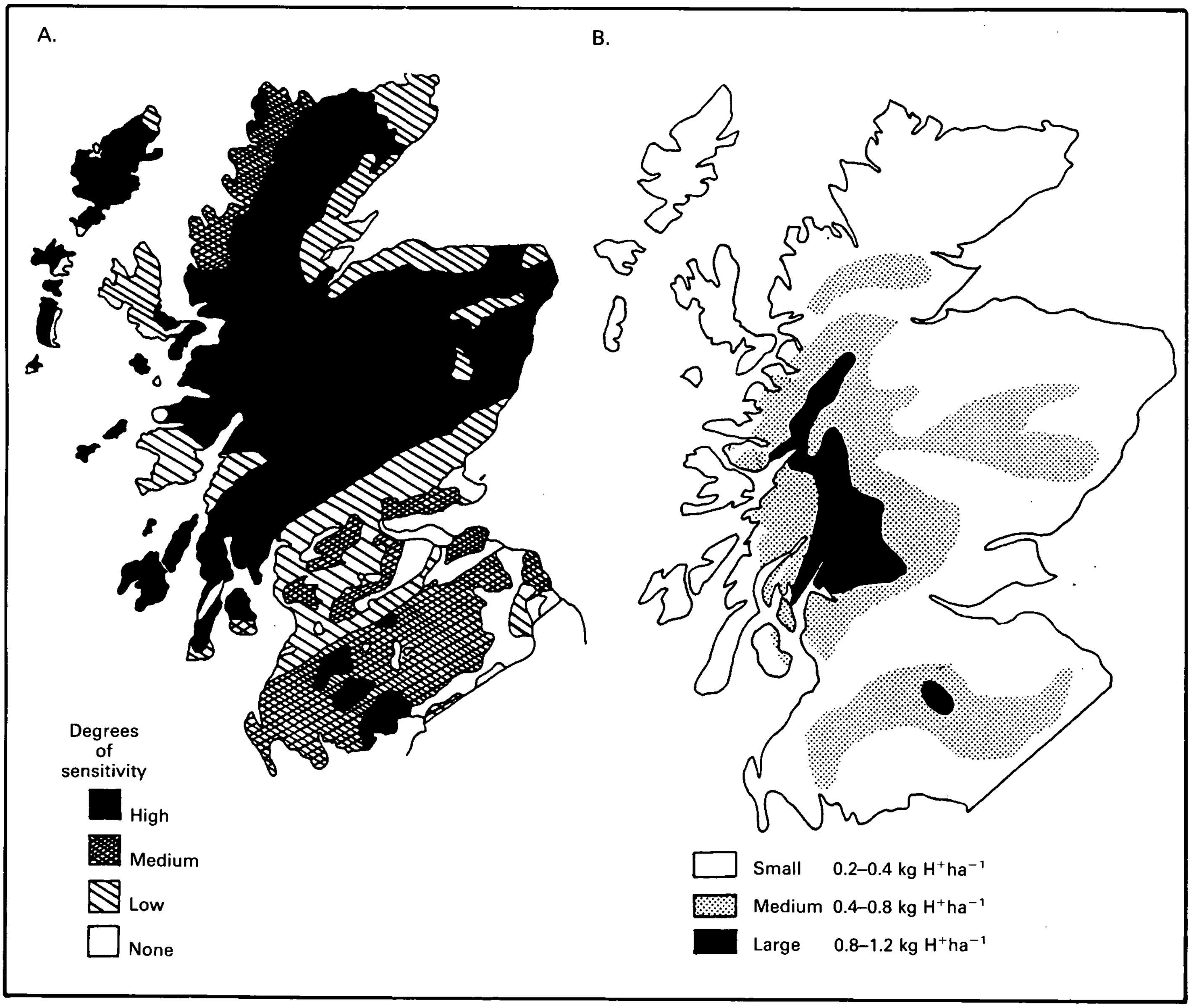


Figure 5. Occurrence, and possible areas of influence, of acid rain sensu stricto, *in northern Britain. A. Ground waters in Scotland with different sensitivities to acidic deposition (source: Edmunds & Kinniburgh 1986). B. Mean hydrogen ion inputs in wet precipitation, 1978–80 (source: Last* et al. *1984)*

produce a map of the likely distribution of sensitive and tolerant ground waters. If this is overlain by maps showing the predictable occurrence of wet and dry acidic deposition, it is possible to identify areas where afforestation may exacerbate the degree of acidity, with concomitant changes in freshwater biota, including the loss of salmonids. The areas affected include parts of south-west Scotland and, more importantly for this symposium, the west central Highlands (Figure 5). Should these locations be afforested? If they were to be afforested, can the risks of intensified acidification be minimized?

4.3 Wildlife

Because systems of forestry and woodland management in the Highlands are greatly concerned with the damage caused by deer, notably red deer (*Cervus elaphus*), it is worth considering if some areas of future afforestation, which will inevitably encroach on deer forest, may be at greater risk from their attack than others. The term 'deer forest' was first applied to areas of land that were used exclusively for deer stalking. Originally, they were devoid of agricultural interest but, in order to gain from agricultural subsidies, landowners introduced sheep, a trend which is now being reversed.

In 1957, there were 183 deer forests in Scotland, mostly in the Highlands, occupying 1.13 Mha (DAFS 1959): in 1982, the gross incomes from stags (trophy and carcase) and hinds (carcase) were £200–£240 and £45–£55 respectively, compared with £25–£40 for a brace of grouse (Jenkins & Matthew 1984). Although the winter distribution of red deer may, in future, be altered by the increasing areas of maturing plantation forests, repeat surveys made in 1972–73 and 1984–85 of the South Ross and West Inverness Districts of the Highland Region show that the winter distribution of red deer can be described in terms of land class. Thus, a much larger proportion of the 1 km squares of land classes 18, 19 and 24 were 'occupied' by red deer than of land classes 20, 25, 27 and 28. On the other hand, a greater proportion of the squares of land classes 26, 27 and 28 were estimated to be capable of profitable afforestation than those of land classes 18, 23 and 24 (Figure 6). By combining the 2 sets of data, it is apparent that relatively large proportions of land classes 25, 26, 27 and 28 are potentially afforestable with possibly minimal initial interference from red deer, but nonetheless it would be necessary to institute control measures to prevent their later multiplication.

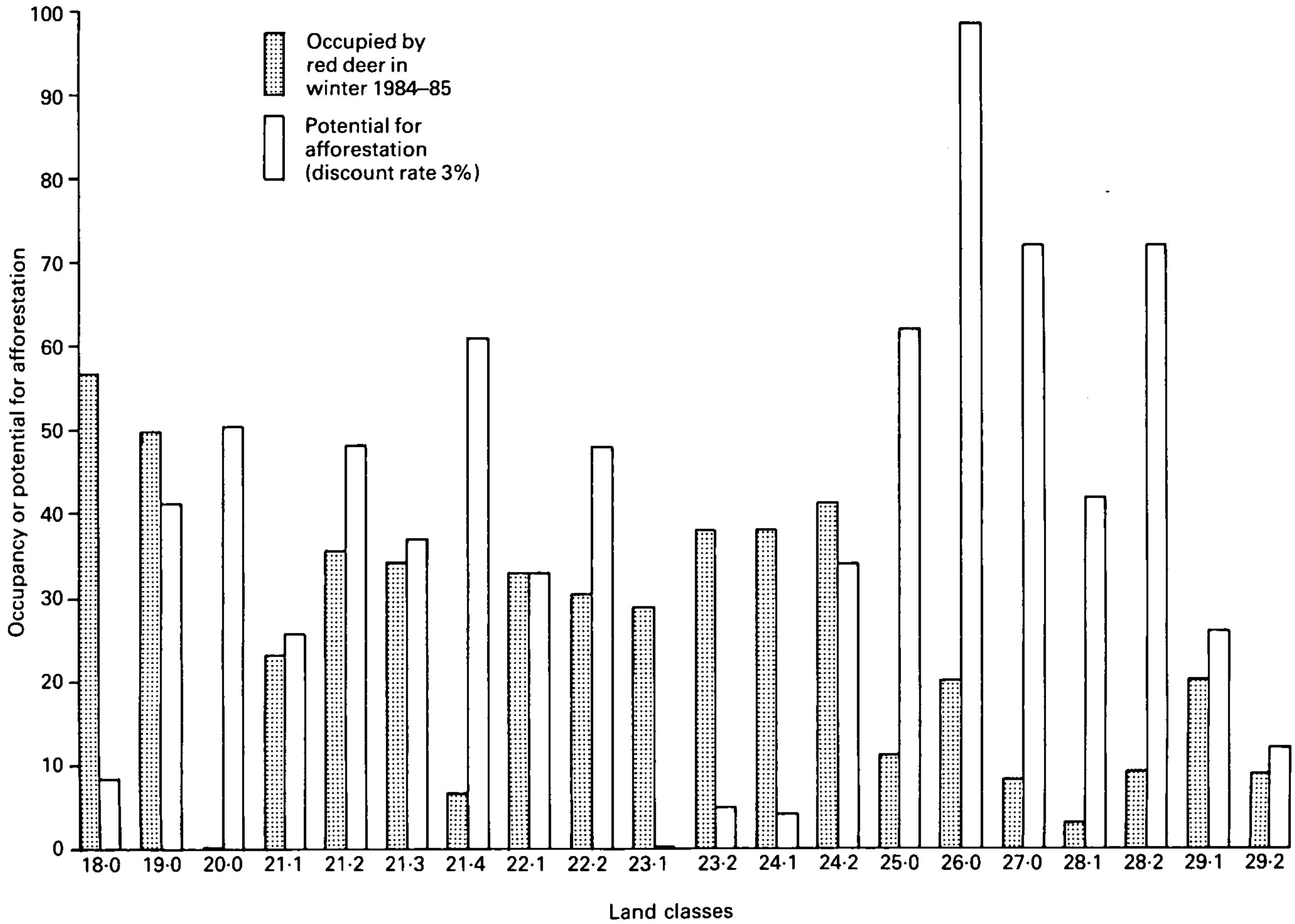


Figure 6. Proportions of different land classes in the Highland Region, Scotland, that (i) were occupied by red deer in winter 1984–85 and (ii) might be afforested profitably, assuming a discount rate of 3% (source: data held by the Red Deer Commission and Highland Regional Council, both at Inverness)

5 Commentary

There is no doubt that the future of forestry will be decided politically, whether regionally, nationally, within the European Communities, or by other 'external' forces. We envisage that there will be a diversion of funds from the maintenance of agricultural excesses to the enhanced production of wood, whether for structural timber, furniture, pulp or fuelwood. While pursuing these objectives, foresters should not underestimate the importance of 'amenity' trees. During 1984, surveyors in the Highland Regional Council categorized 19 different types of 'woodlands', ranging from roadside trees to major commercial plantings (Table 3). The list of 'woodlands' gives some idea of the niches occupied by trees, and, at the same time, indicates the relevance of amenity and landscape, in addition to single-minded production.

As would be expected, the dominant trees in the different types of woodland differ, eg hawthorn (*Crataegus monogyna*) and beech (*Fagus sylvatica*) in hedgerows, compared with birch and alder (*Alnus* spp.) alongside rivers and streams, and lodgepole pine and Sitka spruce in man-made forests. While some of the more 'worthy' assemblages of these trees are found in SSSIs and NNRs, and therefore subject to continuing management, the majority, which have a disproportionately large and beneficial visual impact, remain largely untended.

In thinking about the 'commonplace', most people would not wish to see the present-day list of trees altered by the intrusion of non-native incomers. Instead, the mix should remain much as it is today, perhaps with the more frequent planting of our native cherries, gean (*Prunus avium*) and bird cherry (*P. padus*), species which are greatly under-rated. Foresters would be ill advised not to accept responsibility for sustaining and augmenting the commonplace, sometimes irreverently regarded as unproductive. These species are productive but their productivity is measured in terms of visual impact; they enhance diversity and, very importantly, by allowing the growth of understorey vegetation, they provide a foliage height diversity which seems to favour a wide range of bird species (Newton & Moss 1981) (Figure 7).

Production forestry, in essence long-term agriculture, possibly involving a mixture of trees, and of trees with shorter-term vegetation, may spread to a greater variety of more fertile sites than heretofore and, in doing so, may replace traditional agriculture. Will it be recognized that forest plantations ('agricultural forests') and semi-natural stands are equally productive, the one in terms of timber and energy, and the other in relation to conservation and amenity. But, what proportion of each use is ideal, and in what kind of mosaic? The answer has still to be given, but at least it is possible to show in a predictable manner, using the system of land classification, what would, or would not, be sustainable in the physical environments of the different land classes of the Scottish Highlands. Additionally, the system of land classification provides a useful framework for judging economic implications, while facilitating the examination of many predictable constraints related to conservation (wildlife and water), 'acid rain' and amenity. For such analyses, it is becoming increasingly urgent to establish a comprehensive multi-land use advisory service, covering the management of conservation, forestry, agriculture, recreation, wildlife and water (see Campbell 1984).

Landscapes are dynamic. They have been continually evolving over the centuries. Are our 'institutions'

Table 3. Distribution, within urban and rural areas of the Highland Region, Scotland, of (i) different types of 'woodland' and (ii) the most numerous tree species (source: HRC 1985b)

Types of 'woodland'	Average area (ha km^{-2}) of each woodland within the different types	Area occupied by each type of woodland as % of: total woodland within Highland Region	total area of Highland Region	Most numerous tree species
Coniferous plantations	11.6	72.4	10.6	Lodgepole pine, Sitka spruce, Scots pine
Semi-natural coniferous woodlands	6.3	0.8	<0.1	Scots pine, birch, goat willow
Semi-natural broadleaved woodlands	3.9	11.8	1.7	Birch, goat willow, oak
Semi-natural mixed woodlands	4.3	2.5	0.4	Birch, Scots pine, juniper
Broadleaved woodlands underplanted with conifers	3.5	1.7	0.2	Birch, Scots pine, European larch
Mixed plantings	2.0	0.6	<0.1	Beech, Scots pine, birch
Multi-stemmed stands	2.8	0.4	<0.1	Hazel, birch, wych elm
Policy woodlands	0.9	0.4	<0.1	Lime, Scots pine, birch
Semi-natural copses	—	0.2	<0.1	Birch, goat willow, Scots pine
Semi-natural clumps	—	0.1	<0.1	Birch, goat willow, Scots pine
Shelterbelts	0.6	0.3	<0.1	Scots pine, European larch, Douglas fir
Hedgerows	0.8	0.3	<0.1	Hawthorn, beech
Roadside trees	0.6	0.6	<0.1	Birch, beech, wych elm
Riverside trees	1.4	2.0	0.3	Birch, alder, rowan
Railway-side trees	1.9	0.2	<0.1	Birch, ash, beech
Others	—	2.6	0.4	Scots pine, birch, rowan

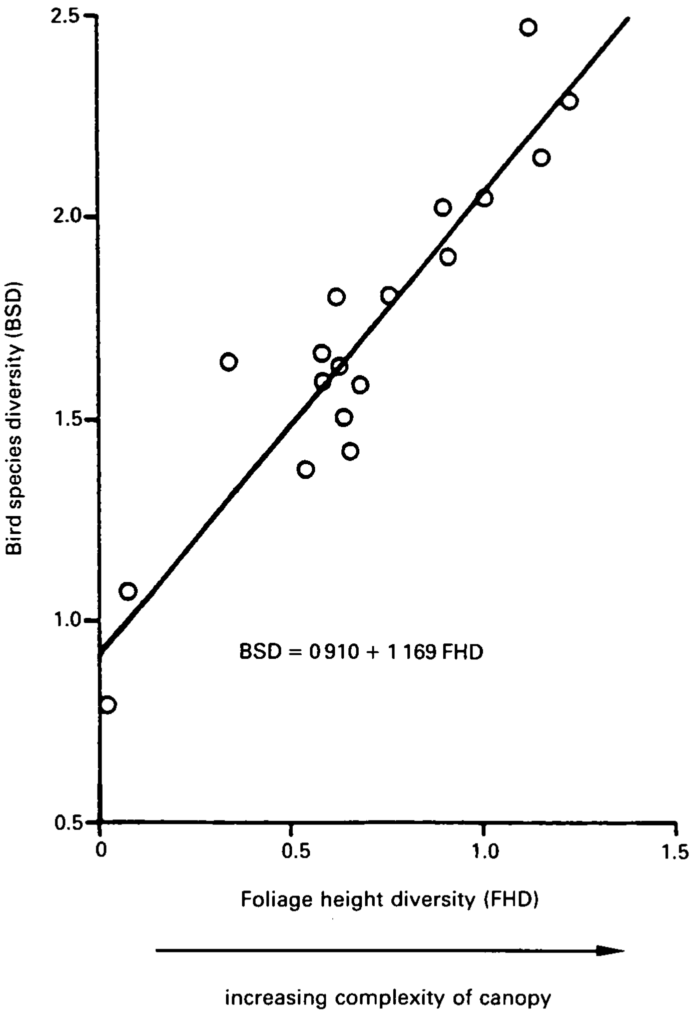


Figure 7. Relationship between bird species diversity and foliage height diversity when examining a variety of mature woods with broadleaved or coniferous species or mixtures (source: Newton & Moss 1981)

sufficiently imaginative to ensure that they collaborate to guide and prevent the abuse of the Highlands? Are they, and those responsible for political decisions, adequately briefed and sympathetic? Do they realize that the results of many of their decisions can be predicted? If not, there is a need for ecologists to assume a greater educative role.

6 Summary

By analysing 'plant performance functions' and 'assessments of net management costs' for a range of intensive and extensive agricultural crops and a variety of managed forests/woodlands, it is suggested that a greater monetary return would be obtained if large areas of the uplands were to be afforested. Within the Highlands Region, it is suggested that 700 kha could be converted remuneratively at a net discount rate of 3%; at a discount rate of 5%, the area would be 279 kha.

There is, therefore, a very considerable potential for afforestation, but will this potential, or should it, become a reality, remembering that land use is influenced greatly by political factors? On the one hand, the overwhelming dependence of the UK on outside sources of timber, and the over-production of many agricultural products (for which demand is steadily decreasing) suggest that land should be converted to production forestry. On the other hand, it is essential to recognize the importance of conservation (wildlife and water) and amenity, and the desire to maintain landscape linked with the 'wilderness concept'.

Assuming that these political considerations, linked to the availability of grants, concessions and tax exemptions, can be resolved to permit further afforestation, it is suggested that the type of afforestation needs to be attuned to changing conditions, in which the cost of energy may be over-riding and in which the balance of softwoods to hardwoods may change in favour of the latter.

The outcome of political issues cannot be predicted. However, it is possible to predict the location of some ecological factors likely to constrain future afforestation, eg those areas where (i) afforestation may unduly exacerbate the risk of freshwater acidification, or (ii) young plantings may be subject to possibly severe damage by red deer.

Irrespective of what happens between now and then, the forestry element which will have a major impact on the landscape in the year 2025 has already been planted. However, the role of 'non-productive' woodlands and amenity trees in relation to (i) landscape and (ii) the provision of niches for wildlife must be acknowledged more widely, as well as the need to take more positive steps to enhance these resources of trees, preferably of native species.

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