FORESTRY COMMISSION
OCCASIONAL PAPER 46

# Forestry Expansion –
## a study of technical, economic and ecological factors
### New Planting Methods, Costs and Returns

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## INTRODUCTION

Other papers in this set discuss the wide variety of different benefits which forests can provide including timber, recreation and wildlife habitat. But these benefits and the cost of creating new forests will vary substantially depending on the type of forests that are created e.g. predominantly coniferous, broadleaved or mixed, the extent to which native or exotic species are used, the relative importance placed on different benefits in managing the forests and the location of these forests. Although there is a wide variety of alternatives, past experience serves as a guide to what is likely to be most feasible and beneficial. Therefore in describing methods and evaluating costs and returns only a limited number of options will be considered.

## AFFORESTATION METHODS

Forests will become established naturally in most parts of Britain in the absence of grazing animals and cropping or cultivation by man but the time required to achieve this would be unacceptably long and the type of forest created would not necessarily best meet future needs. In meeting these needs foresters must ensure that the tree species used are well adapted to the site, climate and other aspects of the environment including actual and potential pests and diseases. The species used should also be those most likely to satisfy future demands whether for raw material or for visual amenity and other environmental benefits. The main broadleaves available are native species such as ash, oak, birch and, in the south of England, beech; or naturalised trees such as sycamore and sweet chestnut. In addition introduced species such as *Nothofagus* and various clones of poplar grow well on selected sites in lowland Britain.

The number of native species of conifers is few being confined to Scots pine, yew and juniper. A large number of introduced conifer species are well adapted to British conditions including Norway spruce, European larch and Corsican pine from continental Europe; Sitka spruce, Douglas fir and lodgepole pine from North America; and Japanese larch.

Rapid and cost-effective establishment of new forests requires the use of good quality plants carefully planted in a site that allows good root and shoot growth. Young trees must be free from other vegetation which will inhibit growth by competing for nutrients and moisture, and by shading or smothering them. Removal of invasive species may be required if these are causing serious damage to the preferred trees. Where mixtures are used, selective removal of one species may be required in order to prevent the preferred species being suppressed. Fertilisers may be applied, either at time of planting in order to ensure rapid establishment, or later in the crop's life in order to increase volume production. Trees must also be protected from damage by domestic stock, deer, rabbits, hares, small mammals and insects. Domestic stock can usually be excluded by fencing, but additional control measures may be required for wild animals. Once the trees have reached 3-4 metres in height, little further work is required to ensure their survival.

Subsequent management of the forest will depend on the objectives of management which may well change with the passage of time. Except on sites where there is a high risk windthrow, thinning will usually be possible and desirable both for early revenue and to concentrate growth on the remaining trees. Even where timber production is not a prime objective, thinning will normally be a desirable operation in the interests of wildlife management and recreation.

Once the trees reach economic maturity they are usually felled followed by replanting of the site for the next rotation. Felling of mature trees can be managed in selection systems to produce natural regeneration of young trees; however, due to the irregularity of seed production this has seldom been successfully practised in Britain. As it is unlikely that decisions on where and how to create new forests will be strongly influenced by the choice of restocking techniques for the following rotation, it will be assumed that clearfelling will be the normal practice. An exception to this is coppicing where cutting takes place at a comparatively young age (5-15 years). Shoots develop from the tree stump and further cutting takes place on a regular cycle. Coppicing is only practised with broadleaved species.

Trees can also be planted at wide spacing to allow intercropping or grazing, a practise known as agroforestry. Normally land is used for whichever purpose, agriculture or forestry, gives the best returns. An intimate mixture of the two will imply some reduction in the value of the output compared with concentrating on the most profitable activity, unless one activity provides benefits to the other e.g. trees giving shade or shelter to stock, or the two activities make fuller use of the site than a single one would. These benefits need to be sufficient to compensate for the potentially lower output and the higher costs arising from the greater complexity of the system.

# FUTURE DEVELOPMENTS AFFECTING METHODS, COSTS AND RETURNS

The long time scale of forestry requires a consideration of future developments which might affect the growth of trees and future costs and returns. Because this study is also considering possible afforestation programmes over the next 10-15 years there also needs to be a consideration of possible developments in afforestation techniques in that time scale.

Increasing concentrations of greenhouse gasses in the atmosphere are expected to lead to a rise in average temperatures (see Cannell and Cape, 1991). This would extend the growing season for trees with beneficial effects on timber production, however a reduction in rainfall, especially if combined with higher temperatures, could lead to moisture stress being more significant especially in the eastern half of the country. It has also been suggested that higher temperatures could lead to stormier conditions increasing the risk of windthrow. It would therefore be prudent to avoid tree planting on the most exposed areas where the risk of windthrow is greatest, but a modest improvement in growth rate is possible due to the combined effects of higher temperatures and greater availability of $C0_2$. A warmer climate will also create opportunities for extending the range of some species, particularly broadleaves but this is not likely to happen before there is clear evidence of a change in climate.

Over the last 70 years most new planting has been on land previously used for rough grazing, and afforestation methods have mainly been developed for such sites. Little new planting has taken place on former arable land. If such land is used in the future, it is likely that there will be scope for new methods, including the use of tractor mounted machinery in planting and tending young trees. The use of better sites will also allow faster growth and a wider choice of tree species.

Developments in tree breeding are resulting in the production of planting stock that has been selected for vigour as well as other desirable traits such as straightness or fine branching, but it takes time to produce improved planting stock in quantity. To date these developments are largely confined to Sitka spruce because of its economic importance, Scots pine because of its ability to produce seed at a young age, and poplar because it can be easily propagated vegetatively. Scots pine planting stock is now available which would allow an increase in volume production of around 8%. Increasing quantities of Sitka spruce are available with increases of around 15% and poplar clones are available with gains of up to 100%. These higher growth rates are reflected in the yield class assumptions for these species used in subsequent calculations. It is unlikely that improved planting stock for other species will be available in sufficient quantity for planting over the next 10-15 years.

The main uncertainty in the appraisal of forestry is the likely level of prices for timber when the trees are felled. This question is addressed in more detail in **Arnold, 1991** where it was concluded that there is unlikely to be appreciable long term increases in the price of timber in real terms.

The net effect of developments in technology and changes in climate are unlikely to be sufficient to revolutionise the practice and economics of forestry. Therefore in appraising the options the following assumptions have been adopted:

1. where timber production is a significant objective, average growth rates will be at the top end of the range currently being achieved on any particular site;

2. unit costs will remain constant in real terms despite a probable rise in the cost of employing labour, i.e. labour productivity will increase in forestry at approximately the same rate as in the rest of the economy; and

3. with the possible exception of high quality hardwoods, timber values will remain constant in real terms.

All costs and prices quoted are financial year 1989/90 values.

## OPTIONS

The rest of this chapter considers ways of creating different types of forests and the likely costs and marketable returns from the timber. The options considered are:

1. Spruce in the uplands

2. Semi-natural pinewoods in the uplands

3. Spruce/Douglas fir plantations on better land in the lowlands

4. Pine in the lowlands

5. Native broadleaves on better land managed mainly for timber production

6. Semi-natural broadleaves in the lowlands managed for non-market benefits

7. Semi-natural broadleaves in the uplands managed for non-market benefits

8. Non-native broadleaves on better land managed for timber production

9. Mixed woodlands in the lowlands

10. Agroforestry

11. Coppice

Because of the long time-scale for both the costs and the revenues these have to be discounted to a common date which has been taken as the year of planting. Rates of 3% and 6% have been used to demonstrate the sensitivity of the results to the choice of rates. To remove the effect of different rotation lengths the net present values have been

expressed as annual equivalents. Internal rates of return have also been calculated. At this stage the value of land has been excluded. Allowance will be made for different opportunity costs of land in subsequent calculations (see Pearce, 1991).

For simplicity it is convenient to group operations and their associated costs into the establishment and the maintenance phases. The first lasts until the trees are about 5 years of age and includes the operations of fencing, site preparation, planting and weeding. The second lasts throughout the rotation and does not vary greatly with the age of the trees, although some may occur as lump sum payments in a single year, eg the cost of replacing a fence. Establishment costs will be assumed to occur on average at year 1. In addition there are the costs of roading, either at time of planting or before harvesting, and the overhead costs which will be partly a function of the amount of activity taking place and partly a function of the area being managed, its complexity and the duration of management. Overhead costs have therefore been expressed partly as a proportion of direct expenditure and partly as a unit cost per hectare per annum for the duration of the rotation. Overhead costs associated with harvesting and marketing have been deducted from the harvesting revenue before discounting.

*Option 1 – Spruce in the uplands*

In much of Britain the fastest growing conifer species is Sitka spruce and it is invariably the preferred species for timber production in most of the uplands. Sitka spruce thrives in the oceanic climate of Britain particularly where rainfall is over 800 mm annum. Its timber is well suited for pulping, chipping and a wide range of uses as sawn wood. It reaches economic maturity at around 50 years of age by which time the total volume production will typically have reached 6-800 $m^3$ per net hectare giving a maximum mean annual volume production (also known as yield class) of 12-16 $m^3$ per hectare per annum although significantly higher growth rates can be achieved. In this example it is assumed that sites are in the uplands but not exceeding 1000 feet in elevation. On such sites establishment is comparatively simple following ploughing and planting with little weeding being required. Fertilising, particularly with phosphate is often beneficial on the poorer mineral soils and both phosphate and potash may be required on the poorer peats. Except on the heather dominated heaths it is seldom necessary to plant spruce in mixture with other species but even on the sites suitable for pure Sitka spruce it is unlikely that this species will occupy more than 70% of the gross area planted. A yield class of 16 has been assumed in the calculations. Larch, pines and broadleaf species would be used to give variety and for their visual and conservation benefits. For purposes of the appraisal 15% of the area is assumed to be planted with larch with a yield class of 12. Five per cent broadleaves has been assumed and no timber revenue has been assigned to this. Ten per cent of the area is left unplanted for purposes of wildlife management, conservation and access.

The direct cost of establishment is estimated at around £800 per hectare with subsequent maintenance cost of £7 per hectare, per annum. A low density road system will be required at time of establishment with upgrading of the network to full specification being made at time of harvesting. The overall cost of this is assumed to be £300 per hectare.

For extensive spruce forests in the upland margin, management costs are modest by comparison with more complex forestry in lowland areas. Twenty per cent has been added to all direct expenditure to cover the cost of overheads and a further £10 per

hectare per annum has been included to cover inspections, planning functions and liaison with other parties such as neighbours and local authorities. This figure also includes an allowance for insurance.

Typical sites will be former rough grazing land but with sufficient rooting depth and shelter to allow thinning of the crop. The current Scottish price level has been assumed in calculating income with an allowance of £3/$m^3$ for overhead costs associated with harvesting and marketing.

The assumptions and results of the economic appraisals are set out in Table 1.

**Table 1** Spruce in the uplands.

| Assumptions | | | | |
|---|---|---|---|---|
| Species | Sitka spruce | Larch | Broadleaved | Unstocked |
| Proportion of gross area | 70% | 15% | 5% | 10% |
| Yield class | 16 | 12 | – | |
| Rotation length | 50 | 50 | | |
| Establishment costs year 1 | £800/ha | £800/ha | £700/ha | |
| Roading costs year 20 | | £300/ha | | |
| Forest maintenance costs years 1-50 | | £ 7/ha/annum | | |
| Road Maintenance costs years 21-50 | | £ 3/ha/annum | | |
| Overheads | £10/ha/annum + 20% of direct expenditure | | | |
| Land price | Nil | | | |
| Timber price | Scottish conifer | | | |

| Results | | |
|---|---|---|
| Discount rate | 3% | % |
| Discounted expenditure | £1629/ha | £1337/ha |
| Discounted revenue | £3505/ha | £ 939/ha |
| Net present value | £1876/ha | £ 398/ha |
| Annualised NPV | £ 73/ha/annum | £ 26/ha/annum |
| Internal rate of return | 5.0% | |

*Option 2 – Semi-natural pinewoods in the uplands*

The natural tree cover of much of the Scottish highlands is Scots pine in mixture with a variety of native broadleaved species including birch, rowan, willow, aspen, alder and sessile oak. Despite the fact that only remnants of these pinewoods remain they are the natural habitat of native plants and animals and have great aesthetic and conservation value.

Extension and conservation of these woodlands can be carried out by natural regeneration or by planting of trees of local origin. The first method is preferred, because uniformity is not thereby imposed on the site and there is no risk of trees being derived from other than local seed sources. The area over which this can successfully be carried

out is limited by the amount of seed produced and the distance of natural spread. This is likely to be only 200-300 m from existing native pinewoods and therefore the total area which could be afforested by natural seeding over the next 10-15 years would be only a few thousand hectares.

Scarification or controlled burning can be carried out to encourage the growth of young seedlings and in most areas it will be essential to fence against sheep and deer. Where very dense natural regeneration occurs respacing may be carried out to reduce the number of stems to around 2500/ha. An average overall cost of establishment of £400/ha has been assumed for both the Scots pine and broadleaved components of these woods. Because growth will be comparatively slow a harvesting road network will not be required until about age 30 and then only at a modest density.

Planting of Scots pine derived from locally collected seed would allow a much larger area to be afforested. The establishment methods are similar to those for establishing Sitka spruce except that a wider spacing would be acceptable and there would be less necessity to replace losses, as gaps and open areas are an accepted feature of native pinewoods. Although many sites would be poor heathlands, fertilising would not normally be necessary to ensure establishment and therefore the overall cost of establishment would be significantly less than that for Sitka spruce. A figure of £700/ha has been assumed for both the conifer and broadleaved components with a subsequent maintenance cost of £7/ha/annum. Roading costs would be delayed until about age 30 and the intensity of roading would be less than that for a more productive crop.

All other assumptions are the same as in Option 1 and these and the rates of return are set out in Tables 2a and 2b.

**Table 2a** Semi-natural pinewoods in the uplands – extension of existing pinewoods by natural regeneration.

Assumptions

| Species | Scots pine | Native broadleaves | Unstocked |
|---|---|---|---|
| Proportion of gross area | 65% | 15% | 20% |
| Yield class | 8 | – | |
| Rotation length | 75 | | |
| Establishment costs year 1 | £400/ha | £400/ha | |
| Roading costs year 30 | | £200/ha | |
| Forest maintenance costs years 1-75 | | £ 7/ha/annum | |
| Road Maintenance costs years 31-75 | | £ 2/ha/annum | |
| Overheads | £10/ha/annum + 20% of direct expenditure | | |
| Land price | Nil | | |
| Timber price | Scottish conifer | | |

Results

| Discount rate | 3% | 6% |
|---|---|---|
| Discounted expenditure | £1132/ha | £812/ha |
| Discounted revenue | £ 973/ha | £133/ha |
| Net present value | - £ 159/ha | - £679/ha |
| Annualised NPV | - £ 5/ha/annum | - £ 41/ha/annum |
| Internal rate of return | 2.7% | |

Table 2b Semi-natural pinewoods in the uplands – afforestation by planting.

Assumptions

| Species | Scots pine | Native broadleaves | Unstocked |
|---|---|---|---|
| Proportion of gross area | 65% | 15% | 20% |
| Yield class | 8 | – | |
| Rotation length | 75 | | |
| Establishment costs year 1 | £700/ha | £400/ha | |
| Roading costs year 30 | | £200/ha | |
| Forest maintenance costs years 1-75 | | £ 7/ha/annum | |
| Road Maintenance costs years 31-75 | | £ 2/ha/annum | |
| Overheads | £10/ha/annum + 20% of direct expenditure | | |
| Land price | | Nil | |
| Timber price | | Scottish conifer | |

Results

| | 3% | 6% |
|---|---|---|
| Discount rate | | |
| Discounted expenditure | £1482/ha | £1151/ha |
| Discounted revenue | £ 973/ha | £ 133/ha |
| Net present value | - £ 509/ha | - £1018/ha |
| Annualised NPV | - £ 17/ha/annum | - £ 62/ha/annum |
| Internal rate of return | 2.2% | |

*Option 3 – Spruce/ Douglas fir on better land in the lowlands*

On lowland sites the better climate and richer soils give the opportunity for growing high yielding plantations of spruce and Douglas fir. 10% of the site is assumed to be planted with broadleaves, 10% with larch or pine and 10% left unplanted leaving 70% planted with Sitka spruce and Douglas fir in equal quantities with a yield class of 20. No revenue is assumed for the broadleaves. Establishment costs are similar to Option 1 with savings in fertilising costs offset by higher weeding costs. Roading costs are reduced because of the higher density public road network. All other assumptions are the same as Option 1 apart from an increase in overheads to £12/ha/annum, a reduction in rotation length to 45 years and the use of England and Wales price levels which tend to be a little higher than in Scotland.

The assumptions and results are set out in Table 3.

*Option 4 – Pine in the lowlands*

This option assumes the use of Corsican pine with a yield class of 14. No other conifer species is used in any quantity but 10% of the area is planted with broadleaves and 10% left unplanted. In all other respects the cost assumptions are the same as Option 3. Roading takes place at age 20 and clearfelling at age 55.

The assumptions and results are set out in Table 4.

**Table 3** Spruce/Douglas fir on better land in the lowlands.

Assumptions

| Species | Sitka spruce | Douglas fir | Larch | Broadleaves | Unstocked |
|---|---|---|---|---|---|
| Proportion of gross area | 35% | 35% | 10% | 10% | 10% |
| Yield class | 20 | 20 | 12 | – | – |
| Rotation length | 45 | 45 | 45 | | |
| Establishment costs year 1 | £800/ha | £800/ha | £800/ha | £700/ha | £700/ha |
| Roading costs year 18 | | | £200/ha | | |
| Forest maintenance costs years 1-45 | | | £ 7/ha/annum | | |
| Road Maintenance costs years 19-45 | | | £ 2/ha/annum | | |
| Overheads | | £12/ha/annum + 20% of direct expenditure | | | |
| Land price | | | Nil | | |
| Timber price | | | England and Wales conifer | | |

Results

| | | |
|---|---|---|
| Discount rate | 3% | 6% |
| Discounted expenditure | £1567/ha | £1308/ha |
| Discounted revenue | £5157/ha | £1610/ha |
| Net present value | £3590/ha | £ 302/ha |
| Annualised NPV | £ 146/ha/annum | - £ 19/ha/annum |
| Internal rate of return | 6.6% | |

**Table 4** Pine in the lowlands.

Assumptions

| Species | Corsican pine | Broadleaves | Unstocked |
|---|---|---|---|
| Proportion of gross area | 80% | 10% | 10% |
| Yield class | 14 | – | |
| Rotation length | 55 | | |
| Establishment costs year 1 | £800/ha | £700/ha | |
| Roading costs year 20 | | £200/ha | |
| Forest maintenance costs years 1-55 | | £ 7/ha/annum | |
| Road Maintenance costs years 21-55 | | £ 2/ha/annum | |
| Overheads | £12/ha/annum + 20% of direct expenditure | | |
| Land price | | Nil | |
| Timber price | | England and Wales conifer | |

Results

| | | |
|---|---|---|
| Discount rate | 3% | 6% |
| Discounted expenditure | £1616/ha | £1313/ha |
| Discounted revenue | £3455/ha | £ 855/ha |
| Net present value | £1839/ha | - £ 458/ha |
| Annualised NPV | £ 69/ha/annum | - £ 29/ha/annum |
| Internal rate of return | 4.9% | |

*Option 5 - Native broadleaves on better land managed for timber production*

Oak can be established on fertile lowland sites with a growth rate of yield class 6. In order to produce good quality timber it is necessary to plant at close spacing and this leads to the high establishment costs of £1500/ha. Eighty per cent of the site is assumed to be occupied by this species, 10% planted with other native species but generating negligible revenue, and 10% left unplanted. Roading costs can be deferred until age 40. Overhead costs are assumed to be the same as in Option 3. Prices are assumed to be twice the current level for hardwood timber although this has only a modest effect on NPV at a 3% discount rate and a negligible effect at 6%.

The assumptions and results are set out in Table 5.

**Table 5** Native broadleaves on better land managed for timber production.

Assumptions

| Species | Oak | Other native broadleaves | Unstocked |
|---|---|---|---|
| Proportion of gross area | 80% | 10% | 10% |
| Yield class | 6 | – | |
| Rotation length | 120 | | |
| Establishment costs year 1 | £1500/ha | £700/ha | |
| Roading costs year 40 | | £150/ha | |
| Forest maintenance costs years 1-120 | | £ 7/ha/annum | |
| Road Maintenance costs years 41-120 | | £ 15/ha/annum | |
| Overheads | £12/ha/annum + 20% of direct expenditure | | |
| Land price | Nil | | |
| Timber price | England and Wales conifer broadleaves x 2 | | |

Results

| Discount rate | 3% | 6% |
|---|---|---|
| Discounted expenditure | £2396/ha | £1979/ha |
| Discounted revenue | £ 541/ha | £ 56/ha |
| Net present value | - £1855/ha | - £1923/ha |
| Annualised NPV | - £ 57/ha/annum | - £ 115 ha/annum |
| Internal rate of return | 1.1% | |

*Option 6 – Semi-natural broadleaves in the lowlands managed for non-market benefits*

As timber production is not the objective for this option, a greater variety of native species can be used and there is no necessity to plant at close spacing in order to ensure straight stems and light branching. As for the native pinewoods it is possible to extend existing native broadleaved woodlands by natural regeneration. However, for species with heavier seed such as oak and beech the spread of seed in sufficient quantity is unlikely to be more more than 50 m from the parent trees. Some woodland could be created by extension from existing hedgerow trees, but this is not generally a practical option. Smaller seeded species such as birch and ash would regenerate over more extensive areas, however, this would lack the diversity which is an objective of creating semi-natural broadleaved woodlands for non-market benefits.

Fencing against grazing animals will be essential. As such woodlands will be largely confined to the fringes of existing woodlands, fencing costs per hectare as well as maintenance and management costs will be high. There will be off-setting savings in planting costs and therefore an overall establishment cost of £1000/ha has been assumed for the natural regeneration option.

Native broadleaved woodlands can also be created by planting. Assuming this is done in plantations of at least 20 ha in size, establishment costs can be assumed to be similar to that for conifer woodland. With no significant revenue assumed from the timber there need not be a high input in roading. Management and maintenance can also be assumed to be carried out at a lower intensity than for conifer plantations managed for timber production.

The assumptions and results are given in Tables 6a and 6b.

**Table 6a** Semi-natural broadleaves in the lowlands managed for non-market benefits. Created by natural regeneration.

| Assumptions | |
|---|---|
| Species | Native broadleaves |
| Proportion of gross area | 100% |
| Yield class | – |
| Rotation length | – |
| Establishment costs year 1 | £1000/ha |
| Roading costs year 30 | £ 100/ha |
| Forest maintenance costs years 1-200 | £ 12/ha/annum |
| Road Maintenance costs years 31-200 | £ 1/ha/annum |
| Overheads | £20/ha/annum + 20% of direct expenditure |
| Land price | Nil |

| Results | | |
|---|---|---|
| Discount rate | 3% | 6% |
| Discounted expenditure | £1690/ha | £1300/ha |
| Discounted revenue | – | – |
| Net present value | - £1690/ha | - £1300/ha |
| Annualised NPV | - £ 156/ha/annum | - £ 52/ha/annum |
| Internal rate of return | | <0% |

**Table 6b** Semi-natural broadleaves in the lowlands managed for non-market benefit. Created by planting.

Assumptions

| | | |
|---|---|---|
| Species | Native broadleaves | Unstocked |
| Proportion of gross area | 90% | 10% |
| Yield class | – | |
| Rotation length | – | |
| Establishment costs year 1 | £800/ha | |
| Roading costs year 30 | £100/ha | |
| Forest maintenance costs years 1-200 | £ 7/ha/annum | |
| Road Maintenance costs years 31-200 | £ 1/ha/annum | |
| Overheads | £20/ha/annum + 20% of direct expenditure | |
| Land price | Nil | |

Results

| | | |
|---|---|---|
| Discount rate | 3% | 6% |
| Discounted expenditure | £1884/ha | £1442/ha |
| Discounted revenue | – | – |
| Net present value | - £1884/ha | - £1442/ha |
| Annualised NPV | - £ 59/ha/annum | - £ 87/ha/annum |
| Internal rate of return | <0% | |

*Option 7 – Semi-natural broadleaves in the uplands managed for non-market benefits*

This option is similar to Option 6a but lower costs are assumed as more extensive areas are capable of being regenerated naturally if stock are excluded by fencing. (Table 7).

**Table 7** Semi-natural broadleaves in the uplands managed for non-market benefits. Created by natural regeneration.

Assumptions

| | |
|---|---|
| Species | Native broadleaves |
| Proportion of gross area | 100% |
| Yield class | – |
| Rotation length | – |
| Establishment costs year 1 | £450/ha |
| Forest maintenance costs years 1-60 | £ 5/ha/annum |
| Overheads | £10/ha/annum + 20% of direct expenditure |
| Land price | Nil |

Results

| | | |
|---|---|---|
| Discount rate | 3% | 6% |
| Discounted expenditure | £985/ha | £799/ha |
| Discounted revenue | – | – |
| Net present value | - £985/ha | - £799/ha |
| Annualised NPV | - £ 35/ha/annum | - £ 49/ha/annum |
| Internal rate of return | <0% | |

*Option 8 – Non-native broadleaves managed for timber production*

Several introduced species, e.g. sycamore and *Nothofagus* grow much more rapidly than oak or beech in lowland Britain. The highest yielding species currently available is poplar if certain disease-resistant clones are used. The most productive clones can give yields of at least 20 $m^3$/ha/annum and reach maturity in as little as 25 years. Planting is normally at wide spacing (8 m x 8 m) using cuttings. Establishment is rapid and maintenance is confined to a year or two of weeding immediately around the young trees with mowing of grass between the rows for the first 5-6 years. Pruning is carried out at 2-yearly intervals from age 3 to age 11. Because of the need to be selective in the choice of sites the average size of each woodland area is low adding to the cost of fencing, maintenance, roading and management. These costs have therefore been increased by 50% compared with Option 1. Overall establishment costs are estimated at £1000/ha.

The assumptions and results are set out in Table 8.

**Table 8** Non-native broadleaves managed for timber production.

Assumptions

| | | |
|---|---|---|
| Species | Poplar | Unstocked |
| Proportion of gross area | 90% | 10% |
| Yield class | 20 | |
| Rotation length | 25 | |
| Establishment costs year 1 | £1000/ha | |
| Roading costs year 25 | £ 450/ha | |
| Forest maintenance costs years 1-25 | £ 10/ha/annum | |
| Road Maintenance costs | – | |
| Overheads | £18/ha/annum + 20% of direct expenditure | |
| Land price | Nil | |
| Timber price | England and Wales conifer | |

Results

| | | |
|---|---|---|
| Discount rate | 3% | 6% |
| Discounted expenditure | £ 1834/ha | £1597/ha |
| Discounted revenue | £13637/ha | £6659/ha |
| Net present value | £11803/ha | £5062/ha |
| Annualised NPV | £ 678/ha/annum | £ 396/ha/annum |
| Internal rate of return | 13% | |

*Option 9 – Mixed woodlands in the lowlands*

This woodland type combines the environmental benefits of growing native broadleaves with the timber producing advantages of growing conifers. As practised on many traditional estates in lowland Britain it has created landscapes which are much appreciated for their beauty while allowing the landowner to derive significant revenue from the timber. The costs assume that 60% of the area is planted with conifers, 25% with broadleaves and 15% left unplanted although careful siting of the broadleaved element can give an appearance of a higher proportion of broadleaves.

Because the woodlands are intimately mixed with farmland, fencing, roading, management and maintenance costs have been increased by 50% over Option 1. Otherwise the costs are assumed to be the same as Option 3 for the conifers and Option 5 for the broadleaves. Yield classes of 18 have been assumed for Sitka spruce and Douglas fir, 12 for larch and 6 for oak.

The assumptions and results are set out in Table 9.

**Table 9** Mixed woodlands in the lowlands.

Assumptions

| Species | Douglas fir | Sitka spruce | Larch | Oak | Unstocked |
|---|---|---|---|---|---|
| Proportion of gross area | 20% | 20% | 20% | 25% | 15% |
| Yield class | 20 | 18 | 12 | 6 | |
| Rotation length | 50 | 50 | 50 | 120 | |
| Establishment costs year 1 | £900/ha | £900/ha | £900/ha | £1600/ha | |
| Roading costs year 20 | | | £450/ha | | |
| Forest maintenance costs years 1-50 or 120 | | | £ 10/ha/annum | | |
| Road Maintenance costs years 20-50 or 120 | | | £ 4.5/ha/annum | | |
| Overheads | | £18/ha/annum + 20% of direct expenditure | | | |
| Land price | | | Nil | | |
| Timber price | | England and Wales conifer and broadleaves | | | |

Results

| | | |
|---|---|---|
| Discount rate | 3% | 6% |
| Discounted expenditure | £2454/ha | £1930/ha |
| Discounted revenue | £3396/ha | £ 920/ha |
| Net present value | £ 942/ha | - £1010/ha |
| Annualised NPV | £ 36/ha/annum | - £ 64/ha/annum |
| Internal rate of return | 3.5% | |

*Option 10 – Agroforestry*

Agroforestry is an intimate mixture of trees and farm crops on the same land. In British conditions it is likely that the farm crop will be grass for grazing. Although conifers have been grown by this method in New Zealand it is largely untested in this country and therefore a broadleaved species (sycamore) has been assumed. Planting is at wide spacing (10 m x 10 m) with the aim of producing a saleable log in 50 years. Fencing costs are assumed to be less than the poplar option as there is less need to be selective in choice of site. An overall establishment cost of £700/ha has been assumed.

Although sycamore will achieve growth rates of yield class 10, total timber yield in agroforestry is reduced because of the wide spacing. It is estimated that the trees will on average produce 2.5 $m^3$ of timber or 250 $m^3$/ha over 50 years. No allowance has been made for agricultural income but land price has been set at nil on the assumption that the capitalised value of the agricultural output over 20 years is no greater than the land value. If it was then there would be a case for keeping the land in agriculture. The annual maintenance and management costs have been reduced to £3 and £6/ha/annum for the

first 20 years and increased to £6 and £12/ha/annum thereafter on the basis that the agricultural use of the site after that time is negligible. Roading costs are assumed to occur at age 50 at a cost of £200/ha.

The assumptions and results are set out in Table 10.

Table 10 Agroforestry.

| Assumptions | | |
|---|---|---|
| Species | Sycamore | |
| Proportion of gross area | 100% at wide spacing | |
| Yield class | 250 $m^3$ at age 50 | |
| Rotation length | 50 | |
| Establishment costs year 1 | £700/ha | |
| Roading costs year 50 | £200/ha | |
| Forest maintenance costs years 1-20 | £ 3/ha/annum | |
| 21-50 | £ 6/ha/annum | |
| Road Maintenance costs | - | |
| Overheads | £6/ha/annum 1-20 | |
| | £20/ha/annum + 20% of direct expenditure | |
| Land price | Nil | |
| Timber price | England and Wales broadleaves | |
| **Results** | | |
| Discount rate | 3% | 6% |
| Discounted expenditure | £1194/ha | £992/ha |
| Discounted revenue | £ 737/ha | £203/ha |
| Net present value | - £ 457/ha | - £789/ha |
| Annualised NPV | - £ 17/ha/annum | - £ 47/ha/annum |
| Internal rate of return | 1.6% | |

*Option 11 – Coppice*

The growth of a coppice crop is quite different from plantation forestry with different costs and returns. The markets are often specialised with sweet chestnut being used for split fencing, hazel for thatching and hurdles, ash and sycamore for turnery and oak for charcoal. All of these markets would become flooded if extensive areas were grown specifically for these purposes. But coppice material can also be used for fuelwood and pulpwood and it is the latter market which is assumed in this option. The greatest volume production will be achieved with poplar planted at 2 m x 2 m spacing with cutting taking place every 10 years. The cost of establishment is estimated at £1400/ha with maintenance costs of £10/ha/annum. Roading is assumed to take place at year 10 at a cost of £200/ha. The volume at each cut is estimated at 200 $m^3$/ha generating an income of £1500/ha net of overhead costs and costs of replacing gaps.

The assumptions and results are set out in Table 11.

**Table 11** Coppice.

Assumptions

| | | |
|---|---|---|
| Species | Poplar | Unstocked |
| Proportion of gross area | 90% | 10% |
| Yield class | | |
| Cutting cycle | 10 years | |
| Establishment costs year 1 | £1400/ha | |
| Roading costs year 10 | £ 200/ha | |
| Forest maintenance costs years 1-50 | £ 10/ha/annum | |
| Road Maintenance costs 11-50 | £ 2/ha/annum | |
| Overheads | £18ha/annum + 20% of direct expenditure | |
| Land price | Nil | |
| Timber income | £1500/ha/cut | |

Results

| | | |
|---|---|---|
| Discount rate | 3% | 6% |
| Discounted expenditure | £2641/ha | £2230/ha |
| Discounted revenue | £3367/ha | £1794/ha |
| Net present value | £ 726/ha | -£ 436/ha |
| Annualised NPV | £ 28/ha/annum | -£ 28/ha/annum |
| Internal rate of return | approx 5% | |

## SUMMARY OF RESULTS

The returns from each option are summarised in Table 12. Table 13 ranks the options by annualised NPV at 6% and Table 14 by IRR. While this shows some change in the order it is apparent that with the exception of poplar (Options 7 and 11) conifers generally give higher returns than broadleaves. However, these figures make no allowance for the opportunity cost of land or for non-market benefits. These are considered in **Pearce, 1991.**

**Table 12** Summary of results.

| *Options* | (£s/ha) *NPV* | | *Annualised NPV* (£s/ha/annum) | | *IRR* |
|---|---|---|---|---|---|
| | *3%* | *6%* | *3%* | *6%* | |
| 1 Spruce in the uplands | 1826 | - 398 | 73 | - 26 | 5.0% |
| 2a Semi-natural pinewoods – NR | - 159 | - 679 | - 5 | - 41 | 2.7% |
| 2b Semi-natural pinewoods planting | - 509 | - 1018 | - 17 | - 62 | 2.2% |
| 3 Spruce/DF in lowlands | 3590 | 302 | 146 | 19 | 6.6% |
| 4 Pine in lowlands | 1839 | - 458 | 69 | - 29 | 4.9% |
| 5 Native broadleaves for timber | - 1855 | - 1923 | - 57 | - 115 | 1.1% |
| 6a Semi-natural broadleaves in lowlands – NR | - 1690 | - 1300 | - 156 | - 52 | 0% |
| 6b Semi-natural broadleaves in lowlands – planting | - 1884 | - 1442 | - 59 | - 87 | 0% |
| 7 Semi-natural broadleaves in uplands – NR | - 985 | - 799 | - 35 | - 49 | 0% |
| 8 Non-native broadleaves for timber | 11803 | 5062 | 678 | 396 | 13% |
| 9 Mixed woodlands | 942 | - 1010 | 36 | - 64 | 3.5% |
| 10 Agroforestry | - 457 | - 739 | - 17 | - 47 | 1.6% |
| 11 Coppice | 726 | - 436 | 28 | - 28 | 5.0% |

**Table 13** Options ranked by annualised NPV at 6%.

| *Options* | *Annualised NPV at 6%* (£/ha) |
|---|---|
| 8 Non-native broadleaves (poplar) for timber | 396 |
| 3 Spruce/DF in lowlands | 19 |
| 1 Spruce in the uplands | - 26 |
| 11 Coppice | - 28 |
| 4 Pine in lowlands | - 29 |
| 2a Semi-natural pinewoods – NR | - 41 |
| 10 Agroforestry | - 47 |
| 7 Semi-natural broadleaves in uplands – NR | - 49 |
| 6a Semi-natural broadleaves in lowlands – NR | - 52 |
| 2b Semi-natural pinewoods – planting | - 62 |
| 9 Mixed woodlands | - 64 |
| 6b Semi-natural broadleaves in lowlands – planting | - 87 |
| 5 Native broadleaves for timber | - 115 |

**Table 14** Options ranked by IRR.

| *Options* | *IRR* |
|---|---|
| 8 Non-native broadleaves (poplar) for timber | 13% |
| 3 Spruce/DF in lowlands | 6.6% |
| 11 Coppice | 5.0% |
| 1 Spruce in uplands | 5.0% |
| 4 Pine in lowlands | 4.9% |
| 9 Mixed woodlands | 3.5% |
| 2a Semi-natural pinewoods – NR | 2.7% |
| 2b Semi-natural pinewoods – planting | 2.2% |
| 10 Agroforestry | 1.6% |
| 5 Native broadleaves for timber | 1.1% |
| 6a Semi-natural broadleaves in lowlands – NR | <0% |
| 6b Semi-natural broadleaves in lowlands – planting | <0% |
| 7 Semi-natural broadleaves in uplands | <0% |

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# 'FORESTRY EXPANSION: A STUDY OF TECHNICAL, ECONOMIC AND ECOLOGICAL FACTORS'

This is one of a series of papers which form part of a study to consider the scale, location and nature of forestry expansion in Britain.

The Forestry Commission invited fourteen specialist authors, including economists, foresters, ecologists and biological scientists to write about current knowledge and to assess the main factors bearing on decisions about the future direction of forestry expansion. It is intended that the papers will form the basis for future discussions of the location and type of forestry that will best meet the demands of society for wood products, jobs, recreation, amenity, wildlife conservation, carbon storage and the other uses and public benefits supplied by the country's forests.

Published by the Forestry Commission on 19th July, 1991.

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| Occasional Paper No | Title | Author |
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| 34 | British Forestry in 1990 | Hugh Miller, University of Aberdeen |
| 35 | International Environmental Impacts: Acid Rain and the Greenhouse Effect | Melvyn Cannell and John Cape, Institute of Terrestrial Ecology |
| 36 | The Long Term Global Demand for and Supply of Wood | Mike Arnold, Oxford Forestry Institute |
| 37 | UK Demand for and Supply of Wood and Wood Products | Adrian Whiteman, Forestry Commission |
| 38 | Development of the British Wood Processing Industries | Iain McNicoll and Peter McGregor, University of Strathclyde and Bill Mutch, Consultant |
| 39 | The Demand for Forests for Recreation | John Benson and Ken Willis, University of Newcastle |
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| 46 | New Planting Methods, Costs and Returns | Jim Dewar, Forestry Commission |
| 47 | Assessing the Returns to the Economy and to Society from Investments in Forestry | David Pearce, University College London |

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