Predicting Sitka Spruce Yields in the Buchan Area of North-East Scotland

R.B. HASSALL[1], D.C. MACMILLAN[2] and H.G. MILLER[3]

[1] Wester Gauldwell House, Craigellachie, Banffshire, AB38 9QX, Scotland.
[2] Land Use Division, The Macaulay Land Use Research Institute, Craigiebuckler, Aberdeen, AB9 2QJ, Scotland.
[3] Department of Forestry, Aberdeen University, St Machar Drive, Aberdeen, AB9 2UD, Scotland.

SUMMARY

Investigations were carried out into the effects of site characteristics on the growth rate of Sitka spruce (*Picea sitchensis* (Bong.) (Carr.), in the Buchan area of north-east Scotland, using General Yield Class (GYC) as a site index. The degree of correlation between GYC and Land Classification for Forestry (LCF) class was also investigated. Data collected from 90 temporary sample plots were analysed using Principal Components Analysis and stepwise multiple regression. A model was constructed which accounted for 44.9 per cent of variation in GYC, with an f statistic significant at the 1 per cent level. For a 95 per cent confidence interval, any single new prediction made by the model should be within ± 3.6 m^3 ha^{-1} yr^{-1} of the true value. Validation using independent data from a further 10 temporary sample plots gave a mean difference between observed and expected values of only 0.25 m^3 ha^{-1} yr^{-1}. No significant difference was found between the means of GYC recorded from plots on LCF classes 4, 5 and 6. The results of the study could be used to support the process of conversion of agricultural land to conifer plantation, and are pertinent to the development of more proactive policies by local authorities towards consultative rural development planning procedures.

INTRODUCTION

Assessment of future yields is an important part of decision making and strategic planning for conifer planting. It is useful to be able to predict how site factors, measurable before planting, will influence these yields. The development of Indicative Forestry Strategies within Structure Plans by Regional Councils in Scotland seeks to identify preferred areas for forestry development but has to rely on the quality and extent of available information on local environmental factors and growth expectation. It will however tend to predetermine their response to planting grant applications within existing procedures for public consultation, and the reliability of local data on expected growth rates of species will be very important. This paper

describes the development of a model for predicting yields of Sitka spruce (*Picea sitchensis* (Bong.) Carr.) in terms of General Yield Class (GYC; a site index that is expressed in terms of cubic metres per hectare per year at maximum mean annual increment) (Rollinson, 1986) for the Buchan area. Particular attention was given to determining whether yield could be predicted on the basis of the Land Classification for Forestry (Bibby *et al.*, 1988).

The Buchan area is situated in the north-east of Scotland roughly between latitudes 50°20' N and 57°40' N and longitudes 1°50' W and 2°20' W. It is bounded to the north and east by the North Sea (Figure 1) and so is highly exposed on the north, east, and south-east, and it is in the rain-shadow of the Grampian mountains which lie to the west and south-west. Roughly 4 per cent of Buchan is now under forest cover, the remainder being agricultural land. However recent changes to the Common Agricultural Policy, lower profit margins, and a need to diversify, may lead to an increase in interest in Buchan in the economics of forestry.

Climatic variables have been shown to be useful predictors of GYC for Sitka spruce on upland sites. Exposure is a measure of the adverse effects of
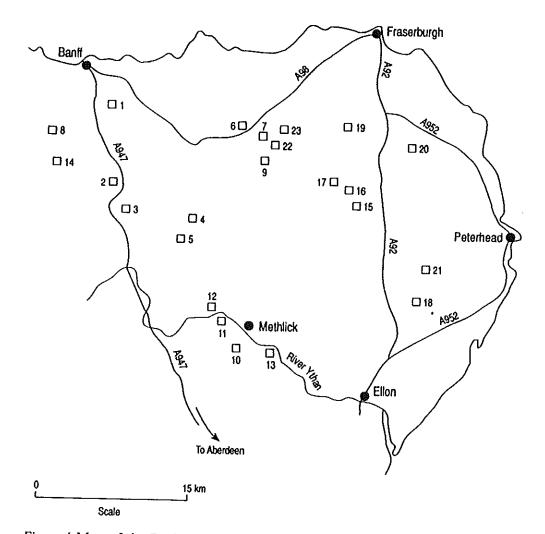

Figure 1 Map of the Buchan area showing approximate positions of the sites visited

wind on a growing crop. It increases with increasing elevation and with proximity to the coast (Worrell, 1987). It leads to lower plant tissue temperatures, localized water stress, and mechanical damage (Grace, 1977). A negative correlation has been found between GYC and elevation of specific sites, but higher GYC values have been recorded for inland than for coastal sites (Worrell, 1987). The regressions were displaced so that GYCs recorded at 350 m elevation varied from means of 16 m^3 ha^{-1} yr^{-1} on inland sites, down to only 10 m^3 ha^{-1} yr^{-1} on coastal sites (Worrell, 1987; Worrell and Malcolm 1990a). These displacements were plotted and found to resemble the geographical pattern of wind zones in Scotland (Miller, 1985; Miller *et al.*, 1987). It was concluded that they were, therefore a function of exposure (Worrell, 1987; Worrell and Malcolm, 1990a). The variation in GYC attributable to geographic location was established by Worrell (1987) and quantified using Yield Class Zones (YCZ). These were deduced from data on tatter flag attrition, which reflects mean wind speed (Lines and Howell, 1963; Reynard and Low, 1984), and published data for accumulated temperature (Birse and Dry, 1970). In producing YCZ maps Worrell (1987) suggested that yield on sites in the Buchan area may be depressed by 8–10 m^3 ha^{-1} yr^{-1} compared with comparable sites of similar elevation in more sheltered areas such as central Scotland. In the present study Yield Class Zone was used as a site variable as it represented the most accurate measure of the effect of geographical location available.

The degree of shelter provided by surrounding hills was also included as a variable, measured using the topex method, being the sum of the angles of elevation to the horizon at the eight cardinal compass points (Malcolm and Studholm, 1972; Pyatt, 1977). Higher topex scores, greater topographical shelter, have been shown to be associated with increased GYC (Worrell, 1987; MacMillan, 1991).

Aspect has also been shown to effect GYC. Worrell and Malcolm (1990a) identified an aspect of 11° south of west as one of maximum exposure, the influence then varying sinusoidally around the compass rose (Worrell and Malcolm, 1990a).

The same authors reported the effects of GYC on soil type, while significantly they only contributed 2–4 per cent towards r^2 in a regression of GYC on site factors. However an ordering of soil types was established as follows (from best to worst in terms of yield): brown earths, surface water gleys, podsols, iron pans and peaty gleys, and basin bogs. The application of Worrell's model to lower elevations was expected to result in overestimation of GYC due to effects of occasional moisture stress at such elevations (Jarvis and Mullins, 1987; Worrell, 1987; Worrell and Malcolm, 1990b).

On lowland sites soil and geomorphological characteristics could be expected to be more useful predictors of GYC than on upland sites, because elevation and exposure effects would be less limiting.

A yield model, developed from 121 temporary sample plots on better

quality lowland sites throughout the whole of Scotland described these effects in more detail (MacMillan, 1991). The likely effects of the movement of soil nutrients were estimated by a parameter called 'site drainage', this measures the slope curvature of the microtopography in the immediate vicinity of the plot. It might be expected that convex 'ridge' sites would disperse nutrients while concave 'valley' sites would collect them and increase yields (Blyth and MacLeod, 1981). Soil drainage effects were also investigated in order to discover the extent to which poorly drained soils might affect yields. Aspect was investigated by recording each plot in terms of, sine (east–west) and, cosine (north-south) components. The study showed that free draining soils, collecting sites, better soil types, southerly and easterly aspects all increased GYC. It was also suggested that predicted yields in north-east Scotland might be higher than those implied by YCZ. In both of the yield models (Worrell, 1987; MacMillan, 1991), sample sites in the Buchan area were inadequate and further research was required to improve predictions. The main object of this study, therefore, was to develop *de novo* a predictive model for Sitka spruce for the Buchan area based on site characteristics and then by way of validation, to compare it with the lowland model of MacMillan (1991).

A Land Classification map for Forestry at a scale of 1:250 000 (LCF) has been developed by Bibby *et al.* (1988) which divides Scotland into seven classes based on increasing limitation to species selection (in terms of plantation forestry). The criteria used for discriminating between the classes were based on the degree of limitation imposed by physical factors of soil, topography, and climate. The classes can also be considered to be a guide to comparative yield potential. MacMillan and Towers (1991) studied this relationship in Scotland and found a market increase in growth rate for Sitka spruce from class seven (considered unsuitable for forestry) to class four, but then found little additional increase in growth on moving to LCF classes 3 and 2. A secondary objective of this study was to test the potential of LCF for predicting yield class in the Buchan area.

METHOD

Sampling strategy

The approach adopted was to maximize the range of independent variables being tested; these being chosen for their relevance to yield, and the ease with which they could be measured. All the crops sampled were pure stands of Sitka spruce greater than 22 years of age and under Forestry Commission management. The age limit was set to minimize possible errors in transformation between Top heights and GYC.

One hundred 0.01 ha temporary sample plots were established in 26 sub-compartments. Each plot was selected at random, but points less than 10 m from the edge of the stand, or in areas of abnormal crop, were avoided.

Data collection and transformations

The following measurements were taken in each plot:

1. Top height. This was recorded by measuring the height of the tree of greatest diameter within a radius of 5.6 m from the centre of the plot (Edwards and Christie, 1981).

2. Slope was measured in degrees using a clinometer.

3. Site drainage; this was an observation of the immediate topography around the plot to assess water and nutrient movement through the plot (Blyth and MacLeod, 1981; MacMillan, 1991). The following system of transformation was used:

Slightly concave	+1
Even	0
Slightly convex	−1
Convex	−2
Strongly convex	−3

4. Major soil group (MSG) was assessed by digging a soil pit at each plot, using the Macaulay Institute Soil Classification as a guide (Glentworth *et al.* 1959), and the Forestry Commission Soil Classification (Pyatt, 1982). The following transformation was used for Major Soil Group (MSG):

MSG	*Score*[1]
Deep peats	5
Podsols & iron pans	4
Gleys	3
Brown earths	2

5. Soil drainage was assessed from an inspection of the physical properties of the soil, and the following transformations were used:

Freely drained	0
Imperfectly drained	−1
Poorly drained	−2
Very poorly drained	−3

6. & 7. Soil and peat depth were recorded in centimetres.

8. & 9. Aspect was recorded by taking the bearing of the downhill slope. This was transformed into sine aspect (east–west) and cosine aspect (north–south) (MacMillan, 1991).

10. Age was taken from compartment records both to obtain GYC, and for use as an independent variable.

11. Elevation was taken from 1:50 000 Ordnance Survey maps.

12. The Topex score was derived from Ordnance Survey maps using the procedure described by Wilson (1984).

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[1] Alluvial soils were scored 1 in the transformation, but were not encountered in the forests visited in sufficient quantity to be included in the model.

13. Yield Class Zone (YCZ) by interpolation from the map published by Worrell (1987).

14. Land Classification for Forestry (LCF). The position of each sample plot was located on the LCF map (Gauld *et al*, 1988) and the classification read off.

GYC, calculated from top height and age, was regressed on the 13 independent variables above.

ANALYSIS

Outline of mathematical technique

It was probable that there would be a high degree of intercorrelation between some of the site variables and that analysis by straightforward multiple regression could distort their relative influence on GYC. Following the technique used by MacMillan (1991) the data sets were analysed using Principal Components Analysis. This is a mathematical technique where a correlation matrix is formed from standardized values of the variables. It extracts the principal components (PCs) as functions of the original variables. Each PC is sequentially derived so that it accounts for the largest amount of remaining variation in GYC, but it is independent of (orthogonal to) the previously derived components. They are therefore uncorrelated with each other.

The PCs selected for inclusion in the regression equation are restricted to those which correlate with GYC with t values significant at the 5 per cent level. By excluding the others, this reduces the number of variables to be regressed. An equation is derived expressing GYC as a function of the PCs, and by taking account of their load values and regression coefficients, a second equation is derived expressing GYC as a function of the original site variables.

Provisions for validation

Out of the 100 data sets obtained from the plots, 1 in 10 were set aside systematically for use as an independent set for validation, leaving 90 for constructing the model.

RESULTS

Analysis of data

Table 1 summarizes the range of data recorded, and the degree of correlation between the standardized values of the variables and GYC from the

TABLE 1: *Range and means of site variables, and correlation* (r) *with General Yield Class*

Data item	Minimum	Maximum	Mean	r
GYC	13.0	26.0	17.7	
Age (years)	24	42	31.5	-0.432***
Slope (°)	0	15	4.3	0.311***
Elevation (m)	30	180	103	-0.372***
Topex	2	38	11	0.317***
Site drainage	-3	1	-0.4	0.287**
MSG	2	5	3.7	-0.400***
Soil drainage	-3	0	-0.6	0.021
Soil depth (cm)	25	130	56	-0.071
Peat depth (cm)	0	130	17	-0.166
Sin. aspect	-1	1	0.2	0.208*
Cos. aspect	-1	1	-0.1	0.052
YCZ	2.7	4.0	3.3	0.015
LCF	4	6	4.6	0.072

*10% significance, **5% significance, ***1% significance

correlation matrix. Selected PCs were regressed against GYC and gave the following predictive equation:

$$GYC = 17.7 + 0.688 \, PC2 - 0.669 \, PC3 - 0.413 \, PC5 + 0.888 \, PC6 \qquad [Eqn\ I]$$

The coefficients and t values for each of these principal components are listed in Table 2. The standard deviation of the dependant variable about the regression line was 1.831 giving a 95 per cent confidence interval of ±3.6 m^3 ha^{-1} yr^{-1} (20 per cent of the mean GYC) for any single new

TABLE 2: *Coefficient estimates,* t-*values, and* R^2 *of the four principal components selected in the model*

Predictor	Coefficient	s.d.	t-value	R^2
Constant	17.672	0.1931	91.54	
PC2	0.688	0.1186	5.80***	21.8
PC3	-0.669	0.1640	-4.08***	10.8
PC5	-0.413	0.1942	-2.13**	2.9
PC6	0.888	0.2332	3.81***	9.4

**5% significance, ***1% significance

TABLE 3: *Load values and sign of the principal components*

Variable	PC2 (+)	PC3 (-)	PC5 (-)	PC6 (+)
Age	-0.066	0.350	0.297	-0.525
Slope	0.497	0.176	0.233	-0.040
Elevation	-0.347	0.107	0.173	0.007
Topex	0.529	0.159	0.090	-0.033
Site drainage	0.208	-0.290	0.058	0.163
Soil drainage	0.111	0.204	0.323	0.390
Soil depth	0.173	0.141	0.230	-0.397
Peat depth	-0.090	0.284	-0.054	-0.231
MSG	-0.333	0.441	-0.014	0.162
Sin. aspect	0.284	-0.129	-0.431	-0.229
Cos. aspect	0.181	0.597	-0.420	0.276
YCZ	0.007	0.118	-0.467	-0.023
LCF	0.106	0.052	0.283	0.421

prediction. The degree of influence of each site variable on the four principal components is indicated by their load values listed in Table 3.

Interpretation of Principal Components (PCs)

Different site variables are more dominant in certain PCs (Table 3). These are indicated by the size of their load values, and although a number of them do not correlate with GYC significantly within the whole range of sites (see Table 1), it can be valuable to examine the contribution of their load values in specific PCs.

Figure 2 shows a plot of the load values of PC3 against PC2. The points representing site drainage and sine aspect, both in the upper right quadrant, indicate that collecting sites and easterly aspects are associated with higher levels of GYC in both PCs. Peat depth, elevation, MSG, and age, are in the lower left quadrant, indicating that GYC is lowered by poorer soils, increased elevation, peatiness and age. The load values of the other variables have opposite signs in each PC, and their points are in the upper left quadrant.

It is thought the influence of site variables on GYC may depend on how they interact on particular sites (MacMillan, 1991). This may explain why some variables have opposite signs in different PCs and it would tend to reduce their overall correlation with GYC.
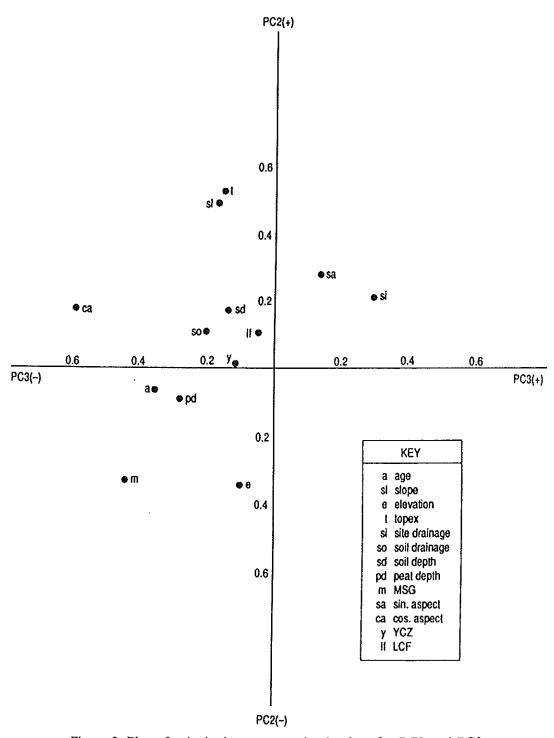
Figure 2: Plot of principal component load values for PC2 and PC3

Geomorphological effects

Table 3 shows that in PC2 slope, elevation, topex, and MSG, all have large load values. The first three are geomorphological characteristics in close association. The co-dominance of MSG may indicate how edaphic as well as climate conditions are associated with geomorphology, i.e. slopes with lateral influshing of nutrients, and elevation with progressively poorer soils.

Aspect effects

In PC3 southerly aspects and better soils are both associated with higher levels of GYC. It may indicate how on some sites the positive effects of increased insolation outweigh the negative effects of climatic exposure. In PC5 northerly and easterly aspects are associated with higher levels of GYC, and although Yield Class Zone (YCZ) did not correlate significantly with GYC over the full range of data (Table 1), it did have a large load value. This PC might suggest, therefore, that the geographical location, reflected in YCZ, is a determining factor regarding how aspect affects growth. For instance it may indicate that the further north-east one goes in Buchan (reducing YCZ) the more important aspect shelter becomes.

PC6 has large load values for soil drainage and soil depth as well as LCF class and age. This suggests that free draining soils are associated with higher levels of GYC. However deeper soils are associated with lower levels of GYC, this is probably because the latter were often peats, and where a large peat depth was recorded, the same figure was entered as the soil depth. Age and LCF are slightly correlated in Buchan because many peaty sites of higher LCF contain younger plantations.

Land Classification for Forestry (LCF)

Both PC5 and Equation II suggest that poorer LCF classes are associated with increased yield. However, a comparison of the means of GYC recorded on plots located on LCF classes 4, 5, and 6 indicated a trend line (Figure 3) where higher LCF classes were associated with slightly lower levels of GYC. The differences between the means were tested for their significance. Figure 3 and Table 4 illustrate these results.

A test for significant differences gave the following result:

Comparing LCF 4 with LCF 5 $t = 0.6276$ on 89 d.f.

Comparing LCF 4 with LCF 6 $t = 0.8725$ on 50 d.f.

Both of these tests indicate that there is not even weak evidence of any significant differences in the means of GYC. This suggests that LCF is not a good indicator of GYC in this area. The regression is probably picking up the effects of unmeasured variables, and attributing them to LCF.

The field model

For use in the field and for validation, Equation I was transformed into one expressing GYC in terms of the 13 site variables:

GYC = 23.3 + {–0.175 (Age) + 0.025 (Slope) – 0.010 (Elevation) + 0.046 (Topex) + 0.432 (Site drainage) + 0.166 (Soil drainage) – 0.018 (Soil depth) – 0.016 (Peat depth) – 0.376 (MSG) + 0.239 (YCZ) + 0.471 (LCF) + 0.387 (Sine aspect) + 0.204 (Cosine aspect)}   [Eqn II]
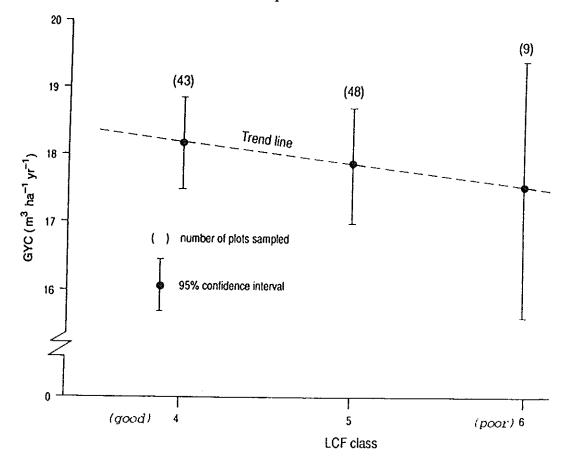
Figure 3: Values of General Yield Class (GYC) recorded on sample plots according to Land Classification for Forestry (LCF)

Each coefficient in the above equation is the sum of the products of the load value of that variable and the regression coefficient of each PC divided by the standard deviation for the variable in the input data. This removes the standardization used in the PC analysis and allows field data to be used directly for yield prediction.

Table 5 shows how GYC might be predicted from typical mid-range values of site factors.

TABLE 4: *The effect of Land Classification for Forestry (LCF) on mean General Yield Class (GYC)*

LCF class	Mean GYC	Variance s^2	No. of plots
4	18.16	4.83	43
5	17.82	8.29	48
6	17.44	5.97	9

TABLE 5: *Calculation of GYC from typical site values*

Site variable (description)	Data	GYC
Constant	–	23.30
Age (years)	32	–5.60
Slope (°)	5	+0.13
Elevation (m)	100	–1.00
Topex (°)	12	+0.55
Site drainage (shedding)	–1	–0.43
Soil drainage (imperfect)	–1	–0.17
MSG. (Gley)	3	–1.13
Soil depth (cm)	50	–0.90
Peat depth (cm)	0	0.00
Sin. aspect (NNE)	+0.5	+0.19
Cos. aspect	+0.87	+0.18
YCZ	2.7	+0.65
LCF	5	+2.36
Predicted GYC		18.13

Validation tests

The 10 data sets which were set aside for validation were tested using Equation II. The differences between observed and predicted yields for these 10 plots gave a mean under-prediction of 0.25 m^3 ha^{-1} yr^{-1}. Analysis of the mean differences ('d' values) using a paired t test showed that there was no significant difference between the mean 'd' value and zero. ($t = -0.746$ on 9 d.f.).

The same data sets were then applied (after making appropriate transformations) to the lowland model of MacMillan (1991), and the same analysis technique was used. This also showed no significant difference between observed and predicted values (see Figure 4).

DISCUSSION

Yield models on upland sites have found that climatic variables alone can account for over 78 per cent of variation in yield (Tranquillini, 1979; Worrell and Malcolm, 1990b). Variation in climatic factors, in lowland areas, is much less, so their dominance is decreased, and high r^2 values are much more difficult to obtain. To achieve satisfactory predicting ability lowland models have to take account of a wide range of factors, some of which may have subtle effects. Also, because no single dominant factor limits yield, unmeasured variables also may have a greater influence. This study was carried out
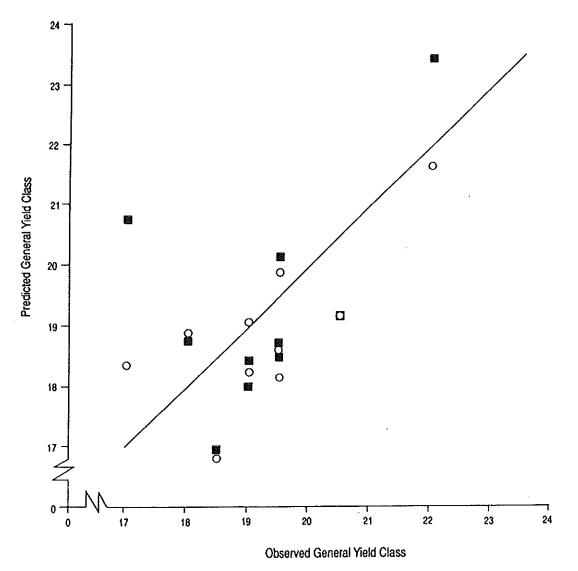
Figure 4: Plot of predicted against observed General Yield Class using an independent data set to validate this model (o) and MacMillan's model (■).

over a relatively small geographical area and so the density of sample plots per 100 km² was relatively high. That tends to minimize the range of some geographically related unmeasured variables such as: mean water vapour pressure deficit, and the parent rock types from which the major soil groups are derived. It should therefore be possible to obtain better correlations between site factors and GYC within smaller localities.

Age

Age was negatively correlated with GYC in this study. This concurs with the results of other studies (Worrell, 1987; MacMillan, 1991). Various reasons have been suggested for this, for example improved silvicultural practice and genetic stock (MacMillan, 1991). Increased levels of atmospheric CO_2 could be giving rise to increased rates of photosynthesis in

younger crops (Cannell *et al.* 1989). Alternatively since it is found so consistently, it might also be considered to be partly an 'artefact' of the Yield Class (site index) curves. If so, the Yield Class curves may need to be revised. However uncertainty over the cause of this very high correlation (see Table 1) means that the validity of the application of this model for future prediction must be open to question. If the age correlation is indeed produced by changes in management or environmental factors then it is clear that such effects could not be extrapolated in an linear manner into the future without serious error. For these reasons it is important that the cause of this correlation is established.

Soil and geomorphological effects

Previous studies have shown soil depth to have little effect on GYC (Worrell and Malcolm, 1990b). However small differences in depth at the lower end of the range may well be far more significant in their effect than those at the top end. This could be studied using a transformation such as: $(1 - 60/d)$ where d = depth in cms.

Soil drainage effects are poorly correlated overall (see Table 1), and show opposing effects in the PCs. This may be because some poorly drained sites are offsetting the expected effects of moisture stress on lowland sites (Jarvis and Mullins, 1987).

Steeper slopes may enhance aspect effects. In some cases this could be the result of ground warming by isolation before canopy closure. It was observed, that certain steep sites gave unexpectedly high values for GYC, compared with others with similar characteristics. This was particularly noticeable regarding two sites on the slopes of the Ythan valley.

The coefficient for elevation in Equation II is 0.01 compared with 0.04 found by Worrell and Malcolm (1990a). This may confirm their prediction of a curvilinear effect at lower elevations.

Land classification for forestry

Statistical analysis of the relationship between LCF class and GYC for the whole of Scotland involving over 300 plots (MacMillan and Towers, 1991), also found no significant differences between LCF classes 4, 5 and 6. In both that study and the one described here, this result can be partly attributed to the considerable variation in recorded GYC within each LCF class. Further the LCF classification is very broad and seeks to describe site suitability for a range of tree species under a number of limiting factors, some of which are unrelated to potential tree growth rates (MacMillan and Towers, 1991). Although the actual average GYC values recorded in LCF classes 4 and 5 in Buchan fall within the 95 per cent confidence interval of the national study, values for LCF class 6 (17.4) in Buchan are very high

compared with the national average of 13.9. This result may be related to the difficulties in extrapolating the available climatic data used in the LCF classification to the Buchan area (there is only one meteorological station within Buchan and none to the north-east). This could result in the effects of exposure, particularly in relation to the growth of Sitka spruce, being over stated (Lilley, MLURI, personal communication).

Aspect effects

More specific research would be needed to investigate the effect of geographical location on how aspect affects GYC, but the contradictory effects, in different PCs, described in this study might explain why the previous studies gave contradictory results. Worrell (1987), showed the benefit of shelter provided by north-easterly aspects on upland sites, while the results of the study of better quality lowland sites showed the benefit of southerly aspects (MacMillan 1991). The mean value for YCZ was 5.1 in the lowland study of MacMillan as opposed to 3.3 in the current study, so exposure may have been generally less limiting. In other words, as YCZ increases, or elevation decreases, so the effect on GYC of southerly aspects may reverse from negative to positive in a country dominated by south westerly winds.

Table 1 indicates that easterly aspects are associated with increasing GYC within the full range of data, but the overall effect of the north–south component was not significant. In view of the observations made by Worrell and Malcolm (1990a) concerning the direction of maximum exposure, the effect of a given wind speed of direction 259° would have a greater westerly than a southerly component vector and therefore exposure effects are likely to be more easily detected on analysis of data from east–west (sine) than on north–south (cosine) aspects.

Other site factors

The inherent fertility of plots in relation to soil nutrient status, and the rate of weathering of parent material, were not assessed. These might be considerations for future studies aimed at refining predictive models. The course of the podsolization process might have to be investigated further to enable models to be used for prediction from data on field sites.

Differences between GYC recorded at sample plots, and those implied by records of sale of timber from the sub-compartments where the plots were sited, can be expected. Crop irregularities, and wastage due to poor form, are possible reasons. It would be useful if a comparison could be made between GYCs recorded in this study and yields actually achieved according to Forestry Commission records. It might be possible to correlate such differences with specific site characteristics, and refine the model. For example, deep peats might be found to be associated with irregular crops.

CONCLUSION

This study demonstrates that data on site variables from only 90 temporary sample plots in a small geographical area can provide sufficient information for the construction of a useful model for yield prediction which is relevant to that specific locality. The validation test suggests that, in the area of the study, this model has a similar predictive ability to the lowland model of MacMillan (1991). The implication appears to be that Buchan may be regarded as lowland for these purposes, consequently former fears about the depressing effect of exposure on GYC in the area may not be entirely justified. It also suggests that within Buchan the Land Classification for Forestry should not be taken as a guide to comparative yields of Sitka spruce between sites, and that Local Authorities would be wise to seek professional advice where the interpretation of LCF maps is a critical factor concerning decisions on proposals for new planting.

These findings should however be an encouraging pointer towards future commercial afforestation and an increased role for tree planting generally as a component in agricultural diversification in Buchan.

ACKNOWLEDGEMENTS

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