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Ecological Site Classification – supporting decisions from the stand to the landscape scale

In the decade since the first Earth Summit in Rio de Janeiro (Anon., 1992) and the Helsinki ministerial conference to discuss the protection of forests in Europe (Anon., 1993), a number of measures have been introduced to improve sustainable forestry and conserve and enhance forest biodiversity. The measures include the *UK Forestry Standard* (Anon., 1998), the *UK Woodland Assurance Scheme* (Anon., 2000), *Native Woodland Habitat Action Plans* (Department of the Environment, 1996) and national forestry strategy documents (Anon., 1999a, 1999b, 2001).

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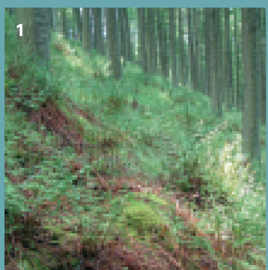

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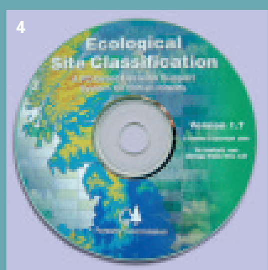


1. Stand of mature Japanese larch with a broad buckler-fern-dominated field layer in Glentress Forest, Scottish Borders.
2. Investigating a surface-water gley soil profile.
3. Yellow pimpernel indicates a Soil Nutrient Regime of Rich.
4. ESC decision support system version 1.7 on CD.

INTRODUCTION

The first step towards sustainable forest management, on which all other decisions depend, is to ensure that the tree species are suited to the site conditions, whether the aim is a timber plantation or a native woodland community. The professional ability of the forester to 'read' the site conditions and select well-suited tree species is of fundamental importance. Commercial considerations dominated forestry practice in the UK in the middle to latter part of the 20th century. Forest managers tended to select from a short list of species and adjust the site conditions (ground preparation and fertilisation) to ensure optimal growth, so that the skill of matching species to site type declined.

Ecological Site Classification (ESC) has been developed to rekindle these skills and to draw together the accumulated knowledge of site suitability, for a range of species. ESC is a decision support system that brings together site-related information, presenting it in a format for the forest manager to use and decide on species choice, and assist the development of a woodland management plan that stems from species selection. The ESC classification has been designed in a similar way to forest classification systems used in other countries, for example Biogeoclimatic Ecosystem Classification (BEC) in British Columbia (Pojar *et al.*, 1987). However, since Britain has no natural forest, the methodology predicts suitable National Vegetation Classification (NVC) woodland communities and a range of native and exotic timber species for any site.

METHOD

The method uses six factors (Pyatt *et al.*, 2001) as criteria for testing site suitability:

- four climatic factors: accumulated temperature, moisture deficit, windiness and continentality;
- two soil quality factors: soil moisture regime (SMR) and soil nutrient regime (SNR).

ESC–DSS (Ray, 2001) calculates the climatic indices from the grid reference and elevation of the site. Soil quality is estimated from a combination of soil type and associated measurements, and an analysis of the field layer plant indicator species occurring. The ESC suitability models assess which factor is likely to limit suitability and growth on any particular site. The method assumes that any number of suitable or very suitable factors cannot compensate for an unsuitable factor. The approach also offers a sensitivity analysis to assess the effect of varying one or more factors on the results.

USING ESC AT DIFFERENT SCALES

ESC was designed to be used at the stand scale. ESC–DSS (Ray, 2001) allows the user to input basic site information and obtain results for a single location; more detailed information can refine the predictions. However, over the last 5 years there has been a rapid increase in the use of Geographical Information System (GIS) technology for forest and woodland management. This GIS revolution has enabled the development of ESC as an extension to ArcView GIS (ESRI, Redlands, California) in which the suitability of tree species (timber) and NVC woodland communities are analysed spatially using the same six factors (Clare and Ray, 2001; Ray *et al.*, in press). The ESC–GIS model derives climate factors from a digital elevation model, and calculates default values of soil quality (SMR and SNR) from digital soil maps, or vegetation community maps that have been validated by field survey. Ideally, a soil map surveyed at a scale of 1:10 000 should be used to provide soil quality for an ESC analysis at the forest landscape scale. However, soil or vegetation information surveyed at a scale of 1:25 000 would provide reasonable soil quality information for a regional ESC analysis (Ray *et al.*, in press).

It is therefore possible to use ESC analyses at three different scales: stand, forest landscape and regional.

At the stand scale the forester would check species or woodland community suitability from surveyed information prior to management operations within a coupe. Forest landscape scale analyses would be useful for more general forest planning, such as the production of design plan scenarios and site yield assessments. At the regional scale of forest planning, the Indicative Forestry Strategy scenarios (Quine *et al.*, 2002) or the effects of climate change on tree species suitability can be explored. In the three sections that follow ESC case studies are presented to illustrate these uses.

ESC FOR STAND ANALYSIS

In this example ESC has been used to answer the question: which native woodland NVC community is suitable for the site type? Table 1 shows site details for an ESC demonstration site, a 10 ha sub-compartment on an elevated ridge of the Pennant sandstone within the Forest of Dean. In the summer of 2000, the sub-compartment contained Scots pine, Corsican pine, European larch and birch.

Table 1

Forest of Dean site details.

Site name	Barnhill Plantation
Grid reference	SO 597106
Elevation	190 m
Geology	Pennant sandstone
Soil type (FC classification)	1z - Podzolic brown earth
Slope	10 degrees – east aspect
Rooting depth	80 cm
Stoniness	1%
Soil texture	Sandy loam
Humus form	Moder like mull

The site location and elevation were entered into ESC–DSS, and climate models calculated AT, MD, windiness and continentality (see Table 2). These data show that the area is relatively warm and quite dry for an elevation of nearly 200 m in western England. In addition the windiness score shows the east facing site is quite sheltered, and has an average continentality score between the lower (Conrad) scores of coastal sites (milder winters and cooler summers) and the higher scores of central England (colder winters and warmer summers).

Table 2

Climatic and soil quality data calculated in ESC for the Forest of Dean site.

ESC climate factor	
Accumulated Temperature (day-degrees above 5˚C)	1579
Moisture Deficit (mm)	139
Windiness (DAMS)	10
Continentality (Conrad Index)	8
Soil Moisture Regime	Slightly Dry
Soil Nutrient Regime	Poor

The soil type, texture, stoniness and rooting depth were entered into ESC–DSS which calculated the SMR as Slightly Dry. The recorded field layer (Table 3) comprised plants indicating a range of conditions, for example, Very Poor SNR (e.g. *Vaccinium myrtillus, Calluna vulgaris*), Poor SNR (e.g. *Blechnum spicant, Deschampsia flexuosa, Agrostis capillaris*) and Medium SNR (*Holcus mollis, Rubus fruticosus*). ESC–DSS weights the contribution of individual species to the SNR calculation by the proportion in which they occur on the site, resulting in a site classification of Poor SNR.

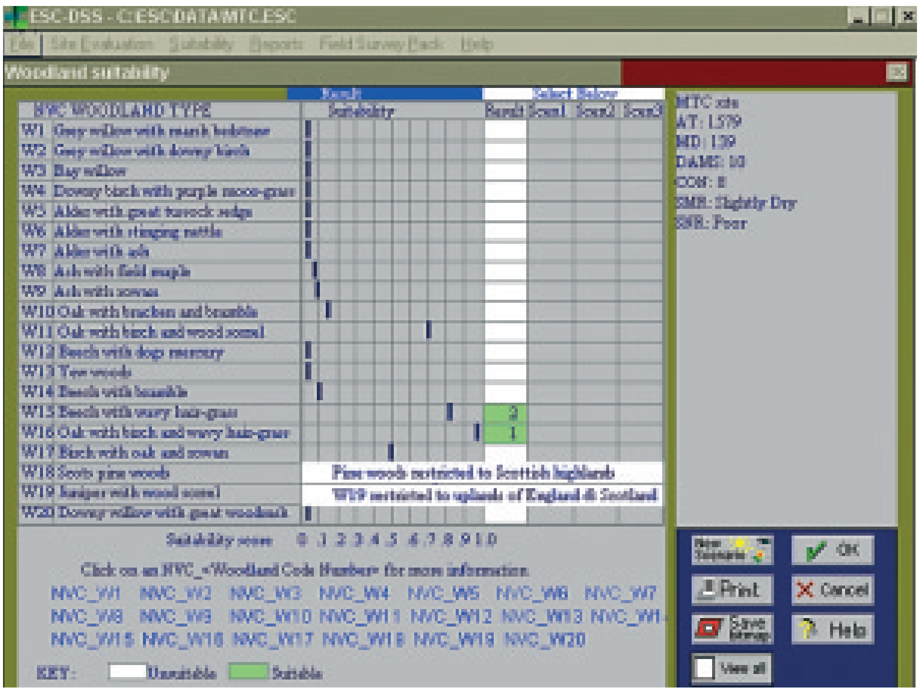
Table 3

Plant indicator species at the Forest of Dean site.

Indicator species	Quadrat – % cover									
	1	2	3	4	5	6	7	8	9	10
Deschampsia flexuosa	65	5	30		30		60	70		40
Agrostis capillaris	15						5	10		
Vaccinium myrtillus	5					65		30	2	
Rubus fruticosus	10	20	60	50	20	20	15	15	60	30
Pteridium aquilinum	5	25	25	50	80	1	10	25		20
Dryopteris dilitata			5			5			10	2
Blechnum spicant			1					2		
Calluna vulgaris							2			
Holcus mollis									10	

ESC–DSS identified that a *Quercus* sp.–*Betula* sp.–*Deschampsia flexuosa* woodland (W16 oak–birch with wavy hair-grass) community was best suited to the site (Figure 1) with the *Fagus sylvatica*–*Deschampsia flexuosa* woodland community (W15 beech with wavy hair-grass) less well suited. But both NVC woodland communities are suited to the site conditions, providing some flexibility in the management options. The analysis methodology is transparent, the rules contained in the model for species or woodland suitability can be examined, and further details on soil type and indicator plant identification keys are contained within the help system of ESC–DSS.

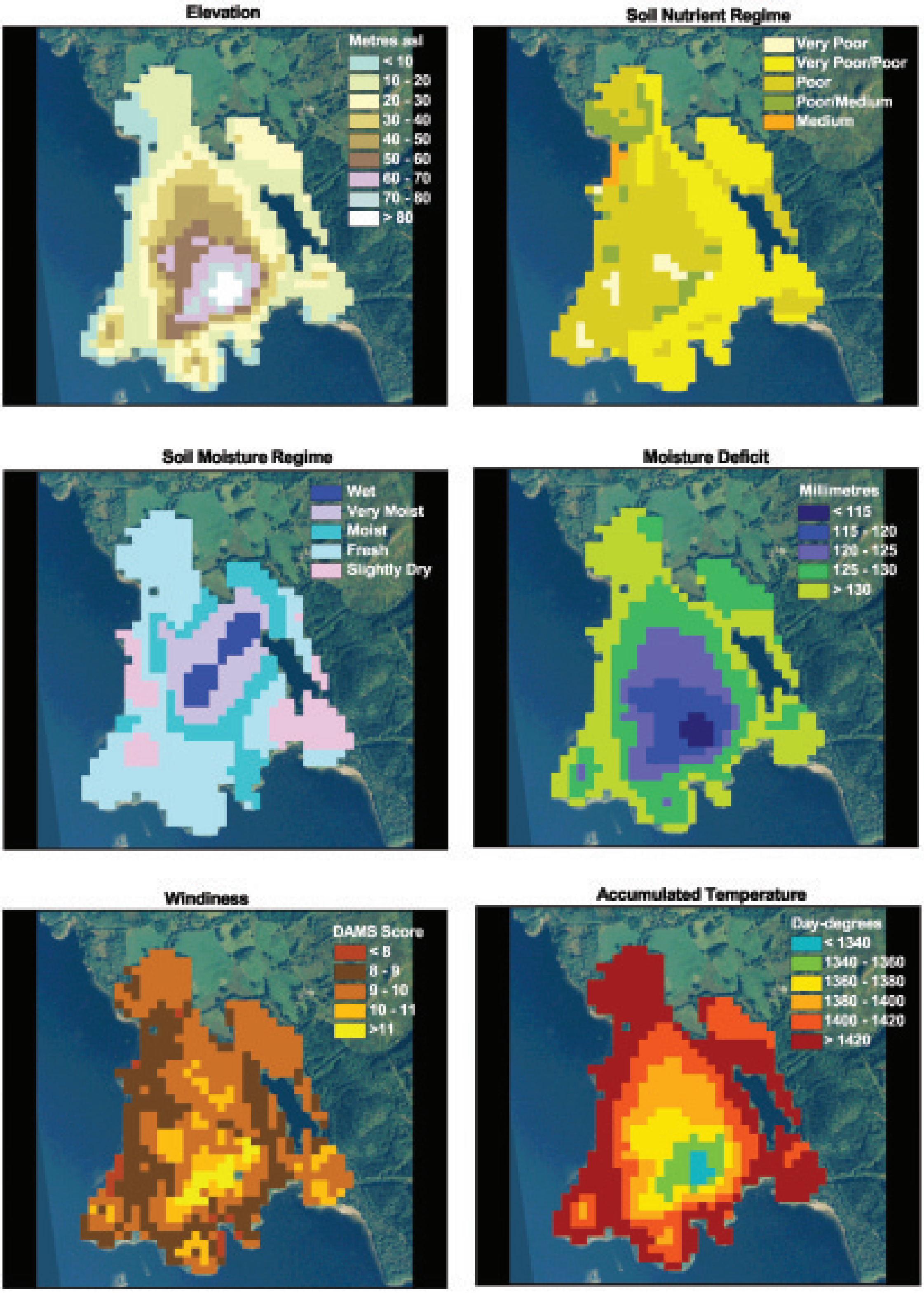
Figure 1



Output analysis of NVC woodland community suitability from ESC–DSS for a site in the Forest of Dean.

Figure 2

ESC factors at Ross Wood on the eastern shore of Loch Lomond overlaid on orthorectified aerial photographs.



ESC FOR FOREST LANDSCAPE ANALYSIS

In this example the ESC–GIS analysis is used to assess the options of restoration to native woodland at the forest landscape scale. Ross Wood on the eastern shore of Loch Lomond was assessed as part of the EU Natura Life Project on Atlantic Oakwoods. ESC–GIS was used to answer the question: are upland oak woodlands (NVC woodland communities 11 and 17) suited to the site types currently planted with exotic conifer stands within the north-western part of Ross Wood? The vegetation communities and soil types were surveyed, recorded and mapped, providing information for detailed soil quality maps of the SMR and SNR. The climate data were calculated using the ESC–GIS climate models and data were provided by a 50 m resolution digital elevation model (DEM) as shown in Figure 2.

The ESC–GIS analysis shows that Ross Wood is suitable for three NVC woodland communities (Rodwell, 1991) as shown in Figure 3, and the distribution is defined by the soil quality. The native woodland types predicted are: downy birch wet woodland NVC type W4, upland oak/birch woodland NVC type W11 and birch woodland NVC type W17.

ESC FOR STRATEGIC REGIONAL ANALYSIS

In this example, ESC is used to consider the impact of climate change scenarios on ESC climate factors and the consequent tree species suitability. The UKCIP98 medium-high climate scenario predictions (Hulme and Jenkins, 1998) for the 30-year periods 2010–2039, 2040–2069 and 2070–2099 have been used to calculate new ESC AT (Figure 4) and MD (Figure 5) (Ray *et al.*, 2002).

Figure 3

Suitable NVC woodland communities in Ross Wood, overlaid on an orthorectified aerial photograph (resolution is 50 m).

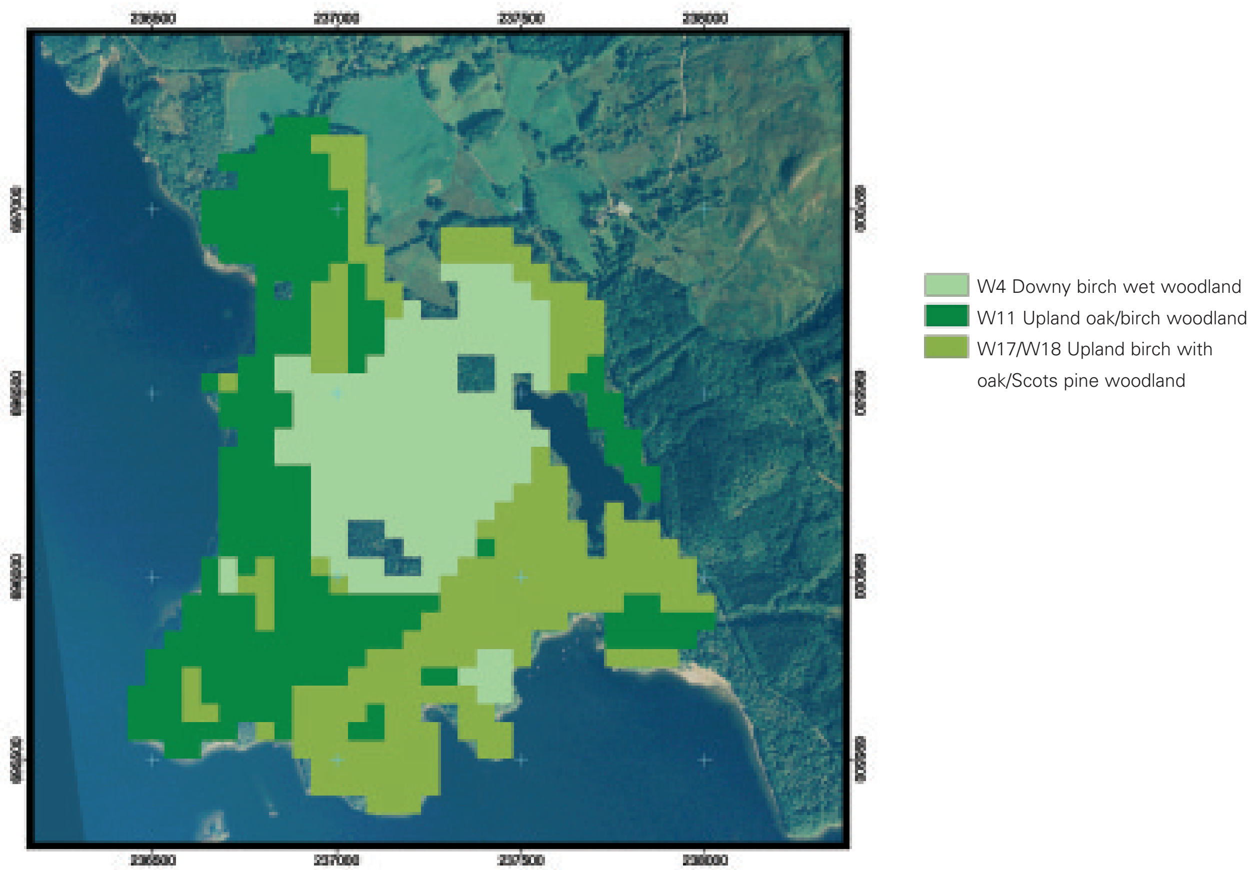


Figure 4

Accumulated Temperature (day-degrees above 5°C) for the baseline (1961–90; current) and predicted climates of the 21st century.

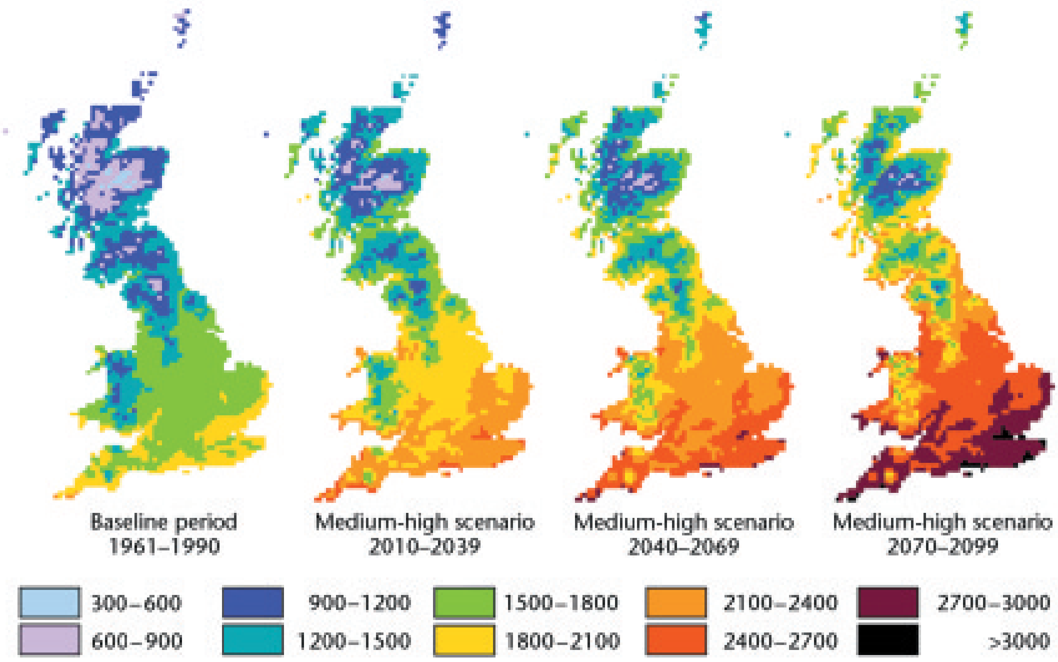
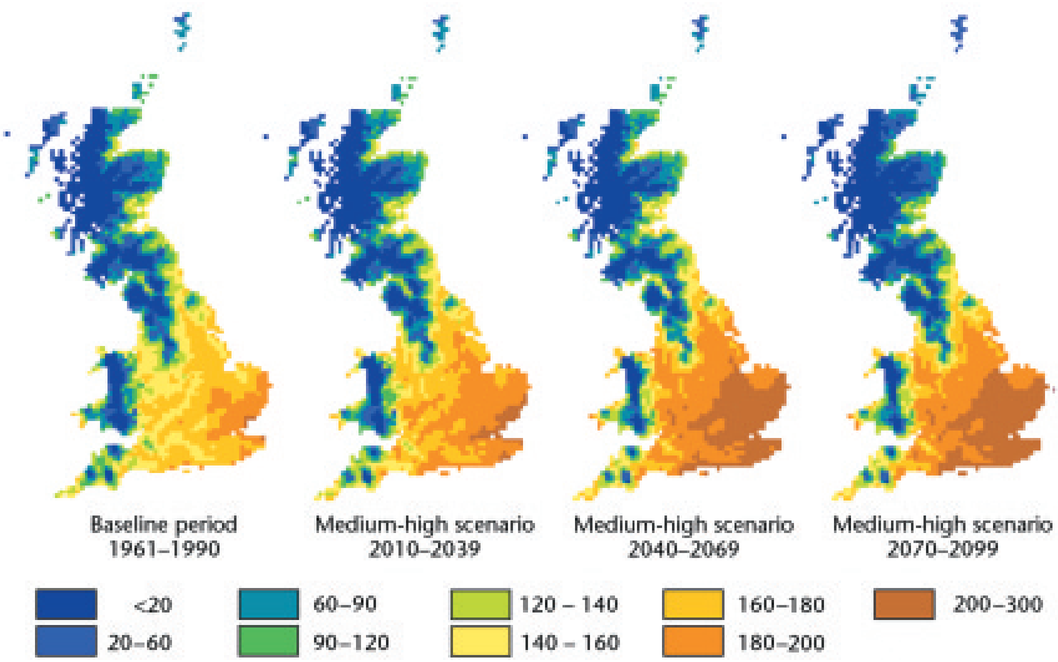


Figure 5

Moisture Deficit (mm) for the baseline (1961–90; current) and predicted climates of the 21st century.



The sequence of maps in Figure 4, from the baseline to the 2070–2099 period, show the ESC climate factor AT increasing throughout the century across Britain. The increased AT reflects the warmer summers but also longer growing seasons. The extent of cool montane climates, with an AT less than about 600 day-degrees, is reduced to a few 10 km squares covering the central Grampian Mountains. Eastern and central Scotland, northern England and central Wales are likely to experience increased warmth of 600 day-degrees over the next century, whereas in central and southern England and south-west Wales an AT of over 3000 day-degrees is predicted, representing a 50% increase on the baseline value.

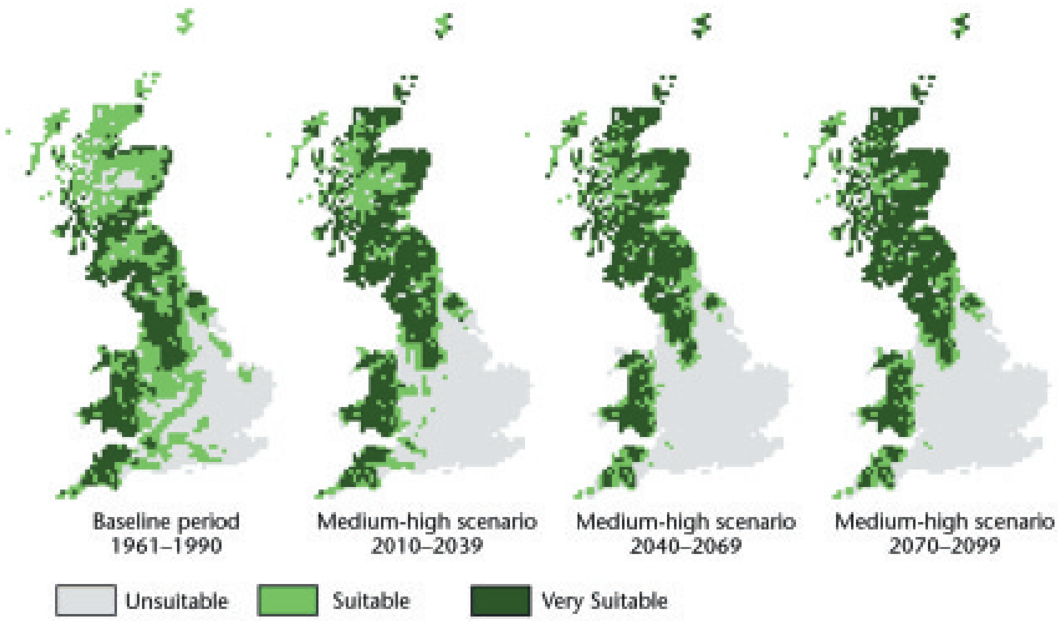
Figure 5 shows the predicted ESC climate factor MD from the baseline to the 2070–2099 period. In the north and east of Scotland a reduction in the MD reflects the prediction for slightly wetter summers, whereas in southern Scotland and northern England there is very little change in MD. In central and southern England, in west Wales and the western peninsula, where summers are predicted to be drier, MD will increase substantially.

The ESC model has been used with these revised climate layers to predict the broad suitability of tree species. Note that in this form of ESC climate suitability analysis, the assumption is that the soil quality is very suitable for growing any particular species, and that climatic factors impose the only restrictions on the species distribution. The ESC definitions of species suitability (Pyatt *et al.*, 2001) suggest that, in approximate terms, where one of the ESC climate factors is unsuitable for a species, it will have a yield class of half, or less than half, the maximum yield class for that species in Britain. Very suitable climates enable the species to achieve a yield class in the upper quartile of its yield range. This type of analysis must be treated with caution. Aside from the uncertainties in the climate predictions and the lack of soil information, the ESC MD factor has been predicted on the basis of assumptions linking the relative rates of potential and actual evaporation, and no adjustment has been made for increased CO_2 levels.

With this cautionary note in mind, Figure 6 shows the predicted change in the climatic suitability of Sitka spruce in Britain. The species is a native of the Pacific Northwest, where it grows well along a narrow coastal strip, featuring a humid oceanic climate. The two main provenances of Sitka spruce widely planted in Britain (Queen Charlotte Islands and Washington) are regarded as unsuitable wherever MD exceeds about 180 mm. In the baseline climate, Sitka spruce is unsuitable in the relatively dry central and southern parts of England. By 2080, this area is predicted to expand northwards and westwards across much of England south of the Humber and Mersey Rivers. In the southwest peninsula and in southwest Wales where a substantial increase in AT, but only a small increase in MD, is predicted, Sitka spruce should remain at least suitable. Throughout Scotland and northern England the climatic suitability should improve, with warmer and wetter climates, and in particular, increased summer precipitation leading to a reduced MD by 2080. The recently published UKCIP02 climate scenario predictions (Hulme *et al.*, 2002), provide an opportunity to modify the ESC climate factors and further develop tree species suitability scenarios.

Figure 6

Climatic suitability for Sitka spruce.



CONCLUSIONS AND FUTURE DEVELOPMENTS

ESC can provide decision support for forest planning at a range of scales using ESC–DSS or ESC–GIS. The examples have illustrated the application of the ESC methodology, to species or native woodland suitability at the stand scale (ESC–DSS), the development of forest design plans (ESC–GIS), and the assessment of the strategic futures of forestry at a national or regional scale in a changed climate. At each level of use, and despite the different types of data being used, ESC uses a common terminology that is consistent between the users. This brings transparency to the forest planning process, also enabling users to assess and make sense of the variation that occurs when moving from one scale of application to another.

The ESC–GIS decision support system is at an advanced stage of development, and following testing by FE Forest Districts and others will be released in 2003. A major constraint in the use of ESC–GIS is access to digital soil or vegetation community data at a resolution consistent with the use of the analysis. Digitised soil types, phases and lithology mapped at a scale of 1:10 000 is ideal but coverage is incomplete. Research has begun to establish whether soil quality for ESC can be derived from alternative sources, such as satellite imagery and models based on topography and coarse soil maps.

An ESC-DSS version 2 for detailed stand scale work is planned for 2004. The upgrade will include more plant indicator species for open managed habitats, a soil key (Kennedy, 2002), suitability models for open habitats and an NVC type assessment program.

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