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An Ecological Site Classification for Forestry in Great Britain

with special reference to Grampian, Scotland

D. Graham Pyatt and Juan C. Suárez

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KEYWORDS: Ecology, Climate, Forestry, Soils

Front cover: Coniferous and broadleaved woodland types,
Balmoral Estate, Deeside. *(Forest Life Picture Library: 1005416.020)*

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CONTENTS

List of tables

List of figures

Chapter 1

Introduction

1.1 Recent changes in forest policy reflect the Government's multiple purpose approach to forestry and the desire that the products and benefits of the forest should be sustainable (Forestry Commission, 1991; Anon., 1994). At the same time we have become aware that man-made forests consist of ecosystems just as much as do natural forests, and that they should be treated with an equal degree of attention to their ecology. This is exemplified in the new policy with regard to biodiversity (Ratcliffe, 1993; Anon., 1995).

1.2 This classification is intended to provide a sound ecological basis for the management of forests for timber production, wildlife conservation and other benefits. It is applicable to all kinds of woodlands, from plantations of a single species through the range to semi-natural woodlands of many species. ESC incorporates the existing classification of soil types that has been used as the basis of silviculture for many years (Pyatt, 1970, 1977, 1982).

1.3 The Paper introduces the broad methodology of the classification as it is applicable throughout Great Britain. This is then worked through in more detail for one region, namely Grampian in north-east Scotland. Although no attempt has been made here to show how the classification might be used at the forest scale (e.g. on maps of 1:10 000 or 1:25 000 scale), there is sufficient detail in the methodology to enable the forest manager to understand how the system could be applied to individual stands or local site types.

1.4 ESC provides a method of assessing site quality in a practical, cost-effective and, as far as is possible, quantitative way. The classification assumes that three principal factors determine site quality: climate, soil moisture regime (SMR) and soil nutrient regime (SNR). The three factors can be thought of as forming the axes of a cube (Figure 1). For Britain as a whole the climate axis is divided into eight zones, and there are eight classes of soil moisture regime (SMR) and six classes of soil nutrient regime (SNR). The combination of SMR and SNR is referred to as soil quality, the grid formed from these axes being the soil quality grid. This three dimensional approach to site classification is similar to that adopted in the Biogeoclimatic Ecosystem Classification (BEC) of British Columbia (Pojar *et al.*, 1987) and will strike a chord in those readers who are familiar with the work in Britain of Mark Loudon Anderson and W. Fairbairn (Anderson, 1950; Anderson and Fairbairn, 1955; Fairbairn, 1960). Similar soil quality grids but with less formal climatic classifications are in widespread use in Europe (Ellenberg, 1988; Anon., 1991a and b; Rameau *et al.*, 1989, 1993).

1.5 In terms of climate and soil quality an individual site type, typically a homogeneous stand of ground vegetation or patch of soil with an area as small as a few tens of square metres or as large as a few hectares, will occupy one, or at most two cells of the cube of Figure 1. Thus, within whichever climatic zone it lies, it will have a range of soil quality encompassed by one class (or at most two adjacent classes) of SMR and SNR.

1.6 Use of the classification for an individual site involves three stages: the first is to identify the site type, the second is to consider the various silvicultural and conservation options available for that site type, the third is from this to decide on the appropriate management of the site in the light of the objectives. This guide provides the means to accomplish the first step of the process and the second step as far as choice of species or native woodland type. The advice on choice of species or of native woodland type is based on the concept of ecological suitability.

1.7 Many aspects of forest management that are related to site are not dealt with in this Paper. Once ESC is firmly established as the new method of site classification, advice on other aspects of forest management (such as ground preparation, regeneration techniques and management of open space) will naturally refer to it and use it as appropriate.

1.8 This Paper represents a stage in the development of ESC. The classification will continue to be developed, tested, employed in other research and demonstrated to potential users. Over the next two years (1997-98), we plan to produce a software version of ESC (a Decision Support System) together with a manual or Field Book applicable to the whole of Great Britain. Further regional guides will be produced with a similar level of detail to that accorded to Grampian in this Paper.

1.9 The application of Geographic Information Systems to forest management will be of crucial importance to the effective use of ESC. One of the means of promoting the use of ESC will be through one or more demonstration forests where climatic and soil data have been added to topographic and forest data, in the form of maps and databases, and used to examine the potential effects of different management strategies. The use of GIS will also enable ESC effectively to be extended from the individual site to the landscape scale.

1.10 The classification is entered by identifying the climatic zone, in other words deciding which coloured slice of the cube is applicable (Figure 1). This is done by locating the site on climatic maps. The second step is to identify where the site lies on the soil quality grid, using one or more methods, such as soil type, plant indicators, humus form or determination of soil nutrient regime by soil analysis.

Chapter 2

Climate

2.1 The classification of climate uses two primary variables and two secondary ones. The primary variables are (i) accumulated temperature (AT) and (ii) moisture deficit (MD), the secondary ones are (iii) oceanicity and (iv) windiness. Accumulated temperature and moisture deficit are not wholly independent of each other, because temperature influences evaporation. Nevertheless they are considered to be better bioclimatic variables than say, mean annual (or seasonal) temperature and mean annual (or seasonal) rainfall. A fifth climatic factor of silvicultural importance, frost, is not used to define climatic zones, but will be referred to in relevant contexts.

2.2 Accumulated temperature expresses the degree of warmth or available heat energy (Birse and Dry, 1970; Bendelow and Hartnup, 1980) and is measured by the number of degree-days above a threshold of 5.6°C (Figure 2 for Britain and Figure 3 for Grampian). The data for Figure 3 have been derived from those of Figure 2 using elevation and distance from the sea as interpolating variables, and plotted using a Geographic Information System (GIS). Accumulated temperature has been shown to be one of the best predictors of forest yield in Britain (Worrell and Malcolm, 1990a and 1990b; MacMillan, 1991). Accumulated temperature is strongly (and of course inversely) related to elevation, it is also, but less strongly, inversely related to distance from the sea. It is also influenced by aspect and slope. Thus a steep slope with a south-west aspect has a higher accumulated temperature than a level site in the same locality and the opposite applies on north-east facing slopes. At the moment it is not possible to quantify the slope and aspect effects, but there are prospects of being able to do so.

2.3 Moisture deficit is a measure of the dryness of the climate and is expressed as the maximum accumulated amount that monthly potential evaporation exceeds rainfall (Bendelow and Hartnup, 1980) (Figure 4 for Britain and Figure 5 for Grampian). The data for Figure 5 have been interpolated from those of Figure 4 by a similar method to that used for Figure 3. Moisture deficit is useful in combination with soil properties in predicting the soil droughtiness (the likelihood that the soil will dry out in any year). Although it may appear to ignore the raininess of the winter, which may be important, for example, when considering soil erosion, moisture deficit is in fact quite strongly correlated with annual rainfall.

2.4 Eight climatic zones for Britain are defined using a combination of accumulated temperature and moisture deficit as shown in diagrammatic form in Figure 6 and shown in map form as Figure 7. Grampian contains seven of the eight zones, the missing one being Warm wet. By far the most important zone in Grampian is Cool moist. The occurrence of these and the other zones is shown on the grid in Figure 8 and in map form as Figure 9. For greater accuracy at the regional scale the columns and rows of Figure 8 have been split into halves. The areas of the seven climatic zones in Grampian are given in Table 1.

2.5 Figure 7 also shows four classes of oceanicity (O1 to O4) expressed by an index related to the annual range of temperature (*viz* the Conrad Index (Bendelow and Hartnup, 1980)). Oceanicity (or its converse, continentality) reflects the length and intensity of the growing season and is influenced by the distance to the sea. It is also related to windiness at a regional scale (the 'wind zones' of Quine and White, 1993), atmospheric humidity and accumulated frost (Birse and Robertson, 1970). Oceanicity classes 1, 2 and 3 occur in Grampian, although O1 is confined to the extreme coast between Banff and Fraserburgh and for most purposes can be ignored. Oceanicity class O2 forms a band within 10–20 km of the coast, the bulk of the region lying within class O3. The Cool moist zone could be subdivided into two variants according to whether it lies within oceanicity class O2 or O3. Oceanicity has not been shown on Figure 9 but an overlay is provided in the pocket of the back cover. The overlay can be used on Figures 3, 5, 9 and 10.

Table 1 Areas of climatic zones in Grampian

Zone	Area (km^2)
Alpine	230.0
Subalpine	528.5
Cool wet	898.7
Cool moist	6466.2
Cool dry	183.9
Warm moist	75.8
Warm dry	387.8
Total	**8770.9**

2.6 Windiness (as measured with tatter flags, see below) as used here refers mainly to the effect of strong winds in causing mechanical and physiological damage to the crown of the tree, typically loss of leaves and shoots which may include the leader, the development of an asymmetical crown or a leaning stem. This damage leads either to loss of yield or loss of timber quality, or both. It is assumed that this damage is caused by both moderate and severe gales and that the severity is as dependent on duration through the year as it is on wind speed. Around the coast the damage to leaves is much exacerbated when the wind carries particles of salt. Windthrow (uprooting) and windsnap (stem breakage) are more catastrophic examples of wind damage and are very dependent on wind speed.

2.7 The recent research of Quine and co-workers at the Forestry Commission's Northern Research Station has provided an improved method of expressing windiness in terms of the rate of attrition of tatter flags (Quine and White, 1993; Mackie and Gough, 1994) and of predicting windiness for any site given certain topographic information (Quine and White, 1994). The use of a GIS has made possible the interpolation necessary for the preparation of the detailed map of windiness in Grampian shown as Figure 10 (Bell *et al.*, 1995). The Detailed Aspect Method of Scoring (or DAMS) scores shown derive from the method of Quine and White (1993) and are a measure of relative windiness directly related to the rate of attrition of flags. Windiness varies with 'wind zone' and within each zone increases with elevation, lack of topographic shelter and nearness to the coast. Tree species vary considerably in their sensitivity to windiness, and this factor restricts species choice on exposed sites. Windiness is not used in the definition of climatic zones, but is included as a factor in choice of tree species (see Chapter 7).

2.8 Figures 3, 5, 9 and 10 of Grampian are printed to a scale of approximately 1:625 000 (10 miles to 1 inch) on the 10 x 10 km National Grid. A transparent grid is supplied in the pocket of the back cover, which should allow sites to be located to the nearest 500 m or so.

2.9 In addition to the four climatic variables so far discussed (AT, MD, oceanicity and windiness), frost can be a damaging agent particularly when it occurs unseasonably. Unseasonable frosts occur during calm conditions with clear skies and are exacerbated by an insulating layer of ground vegetation or snow. Frosts are more frequent and more intense with decreasing oceanicity (Meteorological Office, 1952), as expressed in the term accumulated frost (Birse and Robertson, 1970). Damage to plants caused by frost is not restricted to the more continental parts of the country. On the contrary, some of the most widespread or severe damage has been recorded near to the coast where, for example, abnormally mild early spring weather has preceded the frost (D. B. Redfern, personal communication). In the national or regional context topographical 'frost hollows' have not been considered, because the major events of severe frost damage are by no means restricted to such sites. In spite of these difficulties of frost prediction, there is considerable evidence that the severity and frequency of frosts in inland parts of Grampian both restricts the choice of tree species and should influence silvicultural methods. Appropriate comments are made in Chapter 7.

Chapter 3

Soil quality

3.1 Soil moisture regimes and soil nutrient regimes form the axes of the soil quality grid (Figure 11). Although nutrient availability and moisture availability will have some relationship with each other, it is important in site classification to view them as separate variables. In other words, it is possible to find soils with the same moisture regime that have different nutrient availability and vice versa. Nevertheless, the 8 x 6 = 48 combinations are not equally common, and indeed a few appear to be quite rare.

3.2 While SNR appears to be unrelated to climate in British conditions, SMR is clearly as much dependent upon climatic wetness as on soil and topographic conditions.

3.3 The eight classes of SMR are defined in Tables 2 and 3. Classes Fresh to Very wet are defined by the mean depth of the water-table in winter (October to March inclusive). These classes are equivalent to wetness classes II to VI as defined by Hodgson (1974) and Robson and Thomasson (1977) that are widely used in agricultural soil science. The mean depth of the water-table in winter is a good predictor of rooting depth for trees in soils without mechanical restrictions to rooting (Ray and Nicoll, 1995; Nicoll and Ray, 1996) and is an important component of the windthrow hazard of a site (Miller, 1985; Quine *et al.*, 1995; Nicoll and Ray, 1996). It is generally thought that in these soils the water-table supplies a substantial proportion of the water required by the tree during the growing season (Klinka *et al.*, 1989).

Table 2 Soil moisture regimes and wetness classes

Soil moisture regime	Wetness class	Duration of wet states	Winter water-table§
Very dry-slightly dry	I	The soil profile is not wet within 70 cm depth for more than 30 days* in most years†	>100
Fresh	II	The soil profile is wet within 70 cm depth for 30-90 days in most years	80-100
Moist	III	The soil profile is wet within 70 cm depth for 90-180 days in most years	60-80
Very moist	IV	The soil profile is wet within 70 cm depth for more than 180 days, but not wet within 40 cm depth for more than 180 days in most years.	40-60
Wet	V	The soil profile is wet within 40 cm depth for more than 180 days, and is usually wet within 70 cm for more than 335 days in most years.	20-40
Very wet	VI	The soil profile is wet within 40 cm depth for more than 335 days in most years	<20

* The number of days specified is not necessarily a continuous period.

† 'In most years' is defined as more than 10 out of 20 years.

§ Approximate mean depth of the water-table between October and March inclusive.

3.4 SMR classes Fresh to Very wet can be identified easily during the winter by digging a hole and measuring the depth to the water-table. Some allowance should be made for exceptional weather conditions, e.g. if it has been mainly dry for a fortnight the water-table may have fallen to near its lowest winter level. Similarly if the weather has been exceptionally wet for a week or more, the water-table may be near its shallowest limit. Remember that after water has begun to seep into the hole it may continue to rise for several minutes. With experience it is possible to relate the mean depth of the winter water-table to the degree of mottling or pale grey coloration caused by gleying. Gleying symptoms will normally occur well above the depth of the winter water-table, often by more than 50 cm. Soils in classes Very wet, Wet and even Very moist will be gleyed to the surface, although this will often be masked by organic matter in the topsoil. Gleying is usually not visible in peat, although the smell of anaerobic conditions may be diagnostic of a Very wet or Wet SMR.

3.5 SMR classes Very dry to Slightly dry all fall within wetness class I (Hodgson, 1974) and are unlikely to have rooting depths that are restricted by the water-table. These classes are therefore additionally defined by their droughtiness. Droughtiness depends on the balance between the amount of plant-available water the soil can hold (the available water capacity) and the summer dryness of the climate (the moisture deficit) as in Table 3. This classification is a simplified version of the scheme introduced by Hodgson (1974), in which drought was considered to be possible in soils of wetness classes I to IV.

3.6 Available water capacity is estimated via Figure 17. Again, this is a simplification of the method described by Hodgson (1974) and Hall *et al.* (1977), but is considered valid for use with trees due to their relatively permanent root system compared with arable crops.

Table 3 Soil mosture regimes of freely draining soils

Available water capacity (mm)*	Moisture deficit (mm)							
	0-10	11-40	41-60	61-80	81-100	101-140	141-180	>180
<50	Slightly dry	Slightly dry	Moderately dry	Moderately dry	Moderately dry	Very dry	Very dry	Very dry
50-100	Fresh	Slightly dry-fresh	Slightly dry	Moderately dry-slightly dry	Moderately dry	Very dry-moderately dry	Very dry-moderately dry	Very dry
100-150	Fresh	Fresh	Fresh	Fresh	Slightly fresh	Moderately dry-slightly dry	Very dry-moderately dry	Very dry-moderately dry
150-200	Fresh	Fresh	Fresh	Fresh	Fresh	Slightly dry-fresh	Moderately dry-slightly dry	Moderately
>200	Fresh	Fresh	Fresh	Fresh	Fresh	Fresh	Slightly fresh	Moderately dry

* See Figure 17.

3.7 Soil droughtiness is not a major problem in Grampian because of the predominantly cool moist climate and the rarity of very shallow soils. Nevertheless, the combination of low rainfall and sandy or gravelly soils with low available water capacity is a feature of the Moray Firth lowland and some of the major river valleys and the possibility of droughtiness in these areas should not be discounted. Few of our tree species are well suited to soils of Moderately dry to Very dry SMR.

3.8 Provisional definitions of the six classes of SNR are given in Table 4. Research involving laboratory analysis of soil cores from over 70 plots is being carried out to improve these definitions. Carbonate soils have a topsoil that is rich in finely divided calcium carbonate so that it fizzes visibly or audibly when dilute acid is added. Such soils appear to be uncommon in old woodland sites, and may be confined to new woodlands on former agricultural land with reduced organic matter. Classes from Very poor to Very rich form a continuum where the main variation is in a combination of pH and nitrogen availability. These variables are considered to be the most important in nutrient availability and are inter-related.

3.9 It is evident from Table 4 that soils in the Very poor class prior to afforestation are normally deficient in available phosphorus (P) and nitrogen (N) and may be deficient in potassium (K). Only a few tree species are suited to these soils and initial applications of P fertiliser will normally be necessary even for them. The use of more demanding species would probably require repeated application of P and probably use of K and N fertilisers. Soils in the Poor class may require fertiliser for demanding species, but will be unlikely to require fertiliser for species regarded as suitable for them (see below). Soils in the Medium, Rich or Very rich classes are unlikely to require fertiliser for most types of forestry. The exception would be short rotation coppice, which places a very high demand on nutrient availability. Soils in the Carbonate class may give rise to nutrient deficiency symptoms and will lead to lime-induced chlorosis on some tree species.

3.10 An attempt to relate the soil nutrient regimes to the nitrogen availability site categories of Taylor and Tabbush (1990) is given in Appendix 1.

Table 4 Provisional characteristics of soil nutrient regimes

	Soil nutrient regime					
	Very poor	Poor	Medium	Rich	Very rich	Carbonate
Humus form†	mor	moder, oligomull	oligomull, mesomull	mesomull	eumull	eumull
N availability	very low, only NH_4	low, mainly NH_4 with a little NO_3	moderate, both NH_4 and NO_3	high, mainly NO_3	very high, NO_3 only	low to moderate NO_3 only
pH in water at 10 cm depth	3.5-4.5	3.5-5.0	4.0-5.5	5.0-6.5	5.5-7.5	7.5-8.5
P fertiliser requirement*	1. likely 2. possible	1. likely except for pines 2. unlikely	unlikely except for basic igneous and some shale lithologies	unlikely	none	uncertain
N fertiliser requirement*	1 and 2 likely for for species other than pines and larches	1 and 2 possible for species other than pines and larches	unlikely	none	none	uncertain

* 1. First rotation, 2. second and subsequent rotations. †For explanation of humus forms see Figure 18.

Chapter 4

Identification of soil quality using soil types

4.1 The relationship between soil types and SNR is not precise. Figure 12 presents a rather idealised and simplified relationship using soil type names that can be found in the Forestry Commission soil classification (Pyatt, 1982; see Appendix 2). Soils of 'high base status' have not often been recognised in surveys, and rarely if ever in forest soil mapping. Consequently brown earths in the broad sense, as mapped by most soil surveyors, can be seen to cover SNRs from Poor to Very rich. The definition of calcareous soils (nominally with a pH >7.0) is broader than that of Carbonate soils. The definition of Very rich SNR includes some soils with pH over 7.0 provided that nitrogen availability is high.

4.2 The relationship between soil types and SMR is fairly clear as indicated in Figure 12, but soil types do not specify moisture regime with much precision or readily link to climatic dryness. It is particularly difficult to assign an SMR to ironpan soils, because they can have a perched watertable but do not usually have a true watertable within the profile depth. Because ironpan soils are effectively being converted to freely draining soils, either of the podzol or brown earth type, by afforestation (Pyatt and Craven, 1979) their SMR may become less moist than shown.

4.3 Even in forests where soil types have been mapped at the 1:10 000 scale using Forestry Commission Site Survey methods, it is unlikely that there will be a simple conversion from each soil type (or phase) to one class of SMR and one class of SNR. (If this were so, there would be little point in making the conversions.) Rather is it likely that a set of local rules will be worked out, taking into account soil type, lithology of parent material, slope, aspect and indicator species. Clearly, it will be advantageous if these rules can be expressed in such a way that the conversions can be made using a GIS rather by a great deal of fieldwork. This process of converting maps of soil types to maps of soil quality is going to be a major task in the implementation of ESC. Within Grampian, methods will be developed at Clashindarroch Forest during 1997. Similar work will take place in other regions as and when other regional ESC guides are produced.

4.4 In spite of the imprecision it is still worthwhile attempting a correlation between soil quality and soil types, or rather soil series, for Grampian as soil series maps are available for the whole region at a scale of 1:50 000. In addition, groups of soil series are mapped at a scale of 1:250 000. These maps are available from the Macaulay Land Use Research Institute (MLURI), Craigiebuckler, Aberdeen, AB9 2QJ. The assignment of soil nutrient regimes to soil series is facilitated by taking account of the lithology of the parent material of the soil, given by the soil association. Table 5 lists for Grampian the main soil associations and soil series on MLURI maps and relates them to Forestry Commission soil types and to classes of SMR and SNR. Digital data on soils in Grampian are available at present only for 1 km squares. Macaulay Research and Consultancy Services Ltd have supplied data for the 'predominant soil series' in each km square. Using Table 5 these data have been converted to soil parent materials, soil types, soil moisture regimes and soil nutrient regimes (Figures 13 to 16). It should be appreciated that these conversions have been made purely as a desk exercise and have not been validated in the field.

Table 5 Predicted moisture regimes (SMR) and nutrient regimes (SNR) of main soil associations and series in Grampian

Soil association	Parent material	Main soil series	FC soil type*	SMR[†]	SNR[†]
Alluvial soils	Sandy or gravelly alluvium	Undifferentiated	Brown groundwater gley 5b	VM	R
Organic soils	Peat Peat	Basin peat Blanket peat	Raised bog 10a Unflushed bogs 11, 9	VW VW	P VP
Aberlour	Mixed drifts of acid schists, granulites and granite	LM Lynmore LU Luig AR Aberlour	Podzol 3 Surface-water gley, 7 Ironpan soil 4z	M W M	VP P VP
Ardvanie	Sandy morainic drift, acid schists & ORS	AV Ardvanie	Podzol 3	F	P
Arkaig (see Strichen)	Till, Moine schists	Gordonbush Kildonan Badanloch, Tombain Arkaig Kichanroy Armine	Podzol 3 Ironpan soil 4z, 4zp Peaty gley 6 Peaty ranker 13p Subalpine podzol 13z Alpine soils 13	F M W F M M	VP VP P VP VP P
Auchenblae	Red fluvioglacial sand and gravel	AB Auchenblae	Brown earth 1, 1z	SD-F	P-M
Balrownie	Till, ORS sandstone	BL Balrownie	Brown earth 1g, 7b	VM	M
Bogtown	Interglacial clays	BT Bogtown	Surface-water gley 7	W	M
Boyndie	Fluvioglacial sand	BY Boyndie	Brown earth 1, 1z	SF	P
Brightmony	Sands & gravels, ORS & acid schists	BT Brightmony	Podzol 3	SD	P
Corby	Fluvioglacial & morainic gravels	CY Corby TT Tarbothill	Brown earth 1z, Podzol 3 Ironpan soil 4z	SD F	VP VP
Corriebreck	Mixed ultrabasic, basic and acid rocks	CK Corriebreck	Brown earth 1	F	M
Countesswells	Till, granite and granitic gneiss	CW Countesswells SJ Saighdeir Spinneag RR Rinnes TV Terryvale CR Charr	Brown earth 1z, Podzol 3 Alpine podzols 13z Peaty ranker 13p Alpine soils 13 Surface-water gley 7 Ironpan soil 4z	F M F M W M	P P VP P P VP
Craigellachie	Compact fluvioglacial silt	CG Craigellachie	Podzol 3g	VM	P
Cromarty	Till, Middle ORS	NV Navity	Surface-water gley 7	W	P
Deecastle	Drifts, Dalradian limestone & calc-silicate rocks	DC Deecastle	Brown earth 1	F	M
Dinnet	Till with fluvioglacial pebbles	DT Dinnet	Brown earth 1	F	P
Dulsie	Water sorted sands, acid schists	DU Dulsie DG Drumguish	Podzol 3 Ironpan soil 4z	F M	VP VP
Durnhill	Till, Dalradian quartzite, quartz	DH Durnhill KY Kilbady SC Scraulac CP Corryhabbie Dubhain	Ironpan soil 4z Surface-water gley 7 Subalpine podzol 13z Alpine soils 13 Peaty ranker 13p	M W F M F	VP P VP P VP
Elgin	Till, Upper ORS and Permo-Trias sandstone	EL Elgin MT Monaughty TJ Teindland	Podzol 3 Surface-water gley 7 Ironpan soil 4z	F W M	VP P VP
Forfar	Water sorted drift over till, ORS sediments	FO Forfar VG Vigean	Iron podzol 1zg Surface-water gley 7	VM W	P M
Foudland	Drifts, Dalradian slates & fine schists	FD Foudland ET Ettenbreck FH Fisherford Cireineach VE Veann SI Suie	Podzol 3 Brown earth 1, 1u Surface-water gley 7 Subalpine podzol 13z Alpine soils 13 Ironpan soil 4, 4z	F F W F M M	P M M VP P VP
Fraserburgh	Coastal shelly sand	FR Fraserburgh	Brown earth 1	SD	R
Glenalmond	Till, mainly ORS sandstones	Spallander	Peaty gley 6	VW	P

Soil association	Parent material	Main soil series	FC soil type*	SMR†	SNR†
Gleneagles	Fluvioglacial sands & gravels, ORS sediments, lavas & Highland schists	GE Gleneagles	Podzol 3	SD	P
Hatton	Till, ORS conglomerate	HT Hatton WY Windyheads	Brown earth 1, 1z Ironpan soil 4z	F M	P VP
Insch	Till, basic igneous rocks	IN Insch BU Bruntland MR Myreton WO Whorlish ME Morven	Brown earth 1 Brown earth 1u? Surface-water gley 7 Ironpan soil 4 Alpine soils 13	F M W M M	M M M P P
Kindeace	Water-sorted drift over till, ORS	KC Kindeace	Podzol 3g	VM	P
Laurencekirk	Till, Lower ORS marls	LK Laurencekirk	Brown earth 1g	M	M
Leslie	Till, ultrabasic rocks, mainly serpentine	LE Leslie CL Charleston	Brown earth 1 Surface-water gley 7	F W	P M
Links	Littoral sand & gravel	LN Links Fettersloch	Littoral sand 15e Littoral sand 15w	SD VW	P P
Mountboy	Till, Lower ORS lava & sediments	MY Mountboy	Brown earth 1g	M	M
Nigg	Raised beach deposits, sandy	PJ Pithogarty OA Ankerville	Imperfectly drained 15i Poorly drained 15g	VM-W W	P P
Nochty	Fluvioglacial gravels, basic rocks	NO Nochty	Brown earth 1	F	M
North Mormond	Till, acid schists & ORS	NM North Mormond	Brown earth 1g	VM	P
Ordley	Till, ORS and argillaceous schists	OD Ordley BH Boghead	Iron podzol 1z Surface-water gley 7	F W	P M
Orton	Till, ORS sediments and acid schist	ON Orton PU Phorp RO Romach	Ironpan soil 4 Podzol 3 Surface-water gley 7	M F W	VP VP P
Peterhead	Red clayey till, ORS	PE Peterhead BC Blackhouse	Surface-water gley 7 Brown earth 1g	W VM	M M
Saltings	Salt marsh deposits	SA Saltings	Groundwater gley 5	VW	P
Skelmuir	Till with Cretaceous flints and quartzite cobbles	SK Skelmuir BG Bogengarrie	Ironpan soil 4 Surface-water gley 7	M W	VP P
Stirling	Raised beach silts and clays	SG Stirling CU Cauldside	Ground-water gley 5 Brown ground-water gley 5b	W VM	M M
Stonehaven	Till, Lower ORS conglomerate	SN Stonehaven BQ Balhagarty	Brown earth 1g Surface-water gley 7	VM W	M M
Strathfinella	Till, Lower ORS sandstone with granite & schist	SF Strathfinella	Brown earth 1z	F	P
Strichen	Till, Dalradian quartz-mica-schist, Moine schist on old maps	Quaich GR Gaerlie ES Ealasaid AE Anniegathel SQc Straloch	Podzolic ranker 13z Ironpan soil 4, 4z Alpine soils 13 Surface-water gley 7 Ranker-podzol complex 13	F M M W F	VP VP P P VP
Tarves	Till, mixed acid igneous & schists basic igneous	EE Ernan FC Fiactach PD Pitmedden PS Pressendye TN Tillypronie TR Tarves	Alpine soils 13 Subalpine podzols 13z Surface-water gley 7 Ironpan soil 4 Podzol 3 Brown earth 1	M M W M F F	P P M P M M
Tipperty	Red lacustrine clay & silt	TP Tipperty	Brown gley 7b	VM	R
Tomintoul	Drifts, Middle ORS conglomerate and sandstone	QR Quirn	Peaty gley 6	W	P
Tynet	Till, Middle ORS conglomerate	TY Tynet WT Whiteash OE Ordiequish	Podzol 3 Surface-water gley 7 Ironpan soil 4z	F W M	VP P VP

* Pyatt (1982). † Where not agriculturally improved.

4.5 These assessments of soil quality are applicable to 'unimproved' land. They do not apply to land that is in arable or improved grassland use. A brief survey of recently planted (about 5 years old) Woodland Grant Scheme sites in Grampian suggests that most of such soils are behaving as if they fall into the Very rich or Rich SNR, irrespective of their soil series or association. They can, however, have SMRs ranging from Moderately dry to Very wet. It remains to be seen how far soil quality of these recently improved sites will change during the first rotation. It is possible that nitrogen availability will decrease after a few years and it is probable that the effectiveness of subsurface drainage networks will decrease over a somewhat longer period. The Forestry Commission soil classification has long included a 'cultivated' soil phase for soils that have at some time in the past (usually several decades ago) been 'improved' through agricultural use. The benefit has been roughly equivalent to one class of SNR. The difficulty is to compare the intensity and duration of the effects of former agricultural practices with those of the present.

4.6 Many regions of Britain are less fortunate than Grampian in the coverage of soil maps at the 1:50 000 scale. In England and Wales maps and digital data are supplied by the Soil Survey and Land Research Centre, Cranfield University, Silsoe, Bedford, MK45 4DT.

Chapter 5

Identification of soil quality using indicator plants

5.1 The use of indicator plants to assess SMR or SNR within forests is well established in Europe, Canada and elsewhere and dates back at least to Cajander's 'Theory of forest types' in Finland (Cajander, 1926). More recently the methods have been extended both in scope and in practical terms both in the near continent and in British Columbia (Noirfalise, 1984; Ellenberg, 1988; Klinka *et al.*, 1989; Rameau *et al.*, 1989, 1993; Anon., 1991 a and b). In Britain, although the usefulness of indicator species was recognised in the 19th century (Gilchrist, 1872) there has been little progress in practical applications since Anderson (1950) used plant communities to help choice of tree species for afforestation.

5.2 In the applications of indicator plants referred to above the user is provided with a small number of 'indicator groups' with large numbers of species in each group. The areas of the ESC soil quality grid normally occupied by these indicator species groups may be small (e.g. two cells) or large (more than 10 cells) and there is usually some overlap between groups. Therefore using indicator species requires a detailed knowledge of the ecology of the forests and may only be feasible in countries where semi-natural forests are extensive. In Britain, although there is a great deal of knowledge of the ecology of plants, the information does not seem to be very quantitative in terms of SMR and SNR.

5.3 Consequently it has been decided to make use of the extensive quantitative information provided by Ellenberg *et al.*, 1992 (see Glossary 'Ellenberg numbers'). Lists of plants according to their SMR and SNR classes are given their common names in Table 6 and their scientific names in Table 7. Research is under way to test the applicability of Ellenberg numbers in British forest conditions and to produce improvements where possible. This involves comparing detailed descriptions of ground vegetation with soil analytical data.

5.4 The cell in which the species is listed is deemed to be the centre of that species' distribution in terms of soil quality. The plant community on a given site will usually contain plants from a range of cells, e.g. three adjacent classes of SMR and SNR. From the relative abundance of the different species a weighted average may be determined. This can be done at various levels of formality, but for practical purposes it is sufficient to identify at least five major species present in the field layer (and shrub layer if present) and to see where the 'centre of gravity' of the group lies. For example a site with abundant bracken and bramble with frequent wood sorrel and a little creeping soft grass would average out at Fresh SMR and Medium SNR. This would be a fully acceptable diagnosis in spite of the fact that no species from the Medium SNR column of the lists was present.

5.5 The use of indicator plants seems to be more reliable for SNR than for SMR. This is fortunate, because the diagnosis of SMR is relatively easy by other methods.

5.6 In British forests there are, of course, many stands of shade-bearing trees that permit little or no ground vegetation to develop. Faced with this problem, the classifier should make use of any opportunity that arises to link soil type (and humus form, see below) with vegetation in open areas within the forest (rides, glades, etc.) or under light canopy stands. When a link has been established, preferably for one lithology at a time, it will then be possible to predict SNR from soil type and humus form in the absence of ground vegetation. Note that roadside vegetation should not be used, because road material introduces abnormal substrate and seeds and the vegetation is usually unrepresentative of the rest of the forest.

Table 6 Common names of indicator species for Grampian (all climatic zones). Nomenclature follows Stace (1991)

Soil moisture regime	Soil nutrient regime: Very poor	Poor	Medium	Rich	Very rich	Carbonate
Very dry	early hair-grass					biting stonecrop (wall pepper)
Mod.dry	hare's-foot clover	bearberry*, sheep's sorrel				marjoram
Sl. dry	bell-heather, cowberry*	creeping lady's tresses*, field woodrush, wood sage*	yarrow, broom, common speedwell*	fat hen, petty spurge*	smooth sow-thistle, hedge mustard, Aaron's rod	common agrimony, cowslip
Fresh	heather (ling), bell-heather	wavy hair-grass*, heath bedstraw, creeping soft-grass*, slender St John's wort*, common cow-wheat*, bracken*, betony, chickweed wintergreen*, gorse, blaeberry*	common bent, common mouse-ear, pignut, crested dog's tail, hairy woodrush*, greater woodrush*, wood millet*, golden-rod*	slender false-brome*, cocksfoot, male fern*, broad-leaved willowherb*, common hemp-nettle, herb robert*, wood avens*, wild hyacinth (bluebell)*, common forget-me-not*, wood-sorrel*, bramble*, raspberry	Jack-by-the-hedge*, cow parsley, burdock, cleavers, hog-weed, white dead-nettle, nipplewort*, dog's mercury*, elder, chickweed*	
Moist	heather (ling)	hard fern*, crowberry, thyme-leaved milkwort, common tormentil*, blaeberry*	oak fern*, yorkshire fog, honeysuckle*, lemon-scented fern*	bugle*, enchanter's night-shade*, creeping thistle, scaly male fern*, broad buckler-fern*, wood cranesbill*, ground ivy*, beech fern*, lesser celandine*, sorrel, common figwort*	moschatel*, ground elder*, ramsons*, broad-leaved dock, red campion*, stinging nettle*	
Very moist	heath rush, green-ribbed sedge	tufted hair-grass*, compact rush, purple moor-grass, devil's-bit scabious	wood horsetail*, marsh cudweed, soft rush	lady-fern*, tall brome*, yellow pimpernel*, rough meadow-grass*, creeping buttercup*, curled dock, marsh woundwort, hedge woundwort*, wood speedwell*	cuckoo-pint, hemp agrimony, sharp dock, comfrey	
Wet	cloudberry	star sedge, marsh thistle, marsh horsetail, cross-leaved heath, lousewort, eared sallow	wild angelica, wood bitter-cress*, meadow-sweet, water avens*, water forget-me-not, wood club-rush, marsh ragwort, bog stitchwort*	reed canary-grass, bird cherry*, red-veined dock*, crack willow*	great willowherb, pale persicaria*, bittersweet	
Very wet	few-flowered sedge, round-leaved sundew, cotton-grass (hare's-tail), bog asphodel, deer grass, cranberry	marsh willowherb, common cotton-grass, bog myrtle, red-rattle, lesser spearwort, marsh violet*	opposite-leaved golden saxifrage*, marsh bedstraw*, blinks, common sallow	marsh marigold, reed, skullcap, brooklime	reed-grass	

* Species that will stand some shade.

Table 7 Scientific names of indicator species for Grampian (all climatic zones). Nomenclature follows Stace (1991)

Soil moisture regime	Soil nutrient regime: Very poor	Poor	Medium	Rich	Very rich	Carbonate
Very dry	*Aira praecox*					*Sedum acre*
Mod.dry	*Trifolium arvense*	*Arctostaphylos uva-ursi**, *Rumex acetosella*				*Origanum vulgare*
Sl. dry	*Erica cinerea*, *Vaccinium vitis-idaea**	*Goodyera repens**, *Luzula campestris*, *Teucrium scorodonia**	*Achillea millefolium*, *Cytisus scoparius*, *Veronica officinalis**	*Chenopodium album*, *Euphorbia peplus**	*Sonchus oleraceus*, *Sisymbrium officinale*, *Verbascum thapsus*	*Agrimonia eupatoria*, *Primula veris*
Fresh	*Calluna vulgaris*, *Erica cinerea*	*Deschampsia flexuosa**, *Galium saxatile*, *Holcus mollis**, *Hypericum pulchrum**, *Melampyrum pratense**, *Pteridium aquilinum**, *Stachys officinalis*, *Trientalis europaea**, *Ulex europaeus*, *Vaccinium myrtillus**	*Agrostis capillaris*, *Cerastium fontanum*, *Conopodium majus*, *Cynosurus cristatus*, *Luzula pilosa**, *Luzula sylvatica**, *Milium effusum**, *Solidago virgaurea**	*Brachypodium sylvaticum**, *Dactylis glomerata*, *Dryopteris filix-mas**, *Epilobium montanum**, *Galeopsis tetrahit*, *Geranium robertianum**, *Geum urbanum**, *Hyacinthoides non-scripta*, *Myosotis arvensis**, *Oxalis acetosella**, *Rubus fruticosus**, *Rubus idaeus*	*Alliaria petiolata**, *Anthriscus sylvestris*, *Arctium minus*, *Galium aparine*, *Heracleum sphondylium*, *Lamium album*, *Lapsana communis**, *Mercurialis perennis**, *Sambucus nigra*, *Stellaria media**	
Moist	*Calluna vulgaris*	*Blechnum spicant**, *Empetrum nigrum*, *Polygala serpyllifolia*, *Potentilla erecta**, *Vaccinium myrtillus**	*Gymnocarpium dryopteris**, *Holcus lanatus*, *Lonicera periclymenum**, *Oreopteris limbosperma**	*Ajuga reptans**, *Circaea lutetiana**, *Cirsium arvense*, *Dryopteris affinis**, *Dryopteris dilatata**, *Geranium sylvaticum**, *Glechoma hederacea**, *Phegopteris connectilis**, *Ranunculus ficaria**, *Rumex acetosa*, *Scrophularia nodosa**	*Adoxa moschatellina**, *Aegopodium podagraria**, *Allium ursinum**, *Rumex obtusifolius*, *Silene dioica**, *Urtica dioica**	
Very moist	*Juncus squarrosus*, *Carex binervis*	*Deschampsia cespitosa**, *Juncus conglomeratus*, *Molinia caerulea*, *Succisa pratensis*	*Equisetum sylvaticum**, *Gnaphalium uliginosum*, *Juncus effusus*	*Athyrium filix-femina**, *Festuca gigantea**, *Lysimachia nemorum**, *Poa trivialis**, *Ranunculus repens**, *Rumex crispus*, *Stachys palustris*, *Stachys sylvatica**, *Veronica montana**	*Arum maculatum**, *Eupatorium cannabinum*, *Rumex conglomeratus*, *Symphytum officinale*	
Wet	*Rubus chamaemorus*	*Carex echinata*, *Cirsium palustre*, *Equisetum palustre*, *Erica tetralix*, *Pedicularis sylvatica*, *Salix aurita*	*Angelica sylvestris*, *Cardamine flexuosa**, *Filipendula ulmaria*, *Geum rivale**, *Myosotis scorpioides*, *Scirpus sylvaticus**, *Senecio aquaticus*, *Stellaria uliginosa**	*Phalaris arundinacea*, *Prunus padus**, *Rumex sanguineus**, *Salix fragilis**	*Epilobium hirsutum*, *Persicaria lapathifolia**, *Solanum dulcamara*	
Very wet	*Carex pauciflora*, *Drosera rotundifolia*, *Eriophorum vaginatum*, *Narthecium ossifragum*, *Trichophorum cespitosum*, *Vaccinium oxycoccus*	*Epilobium palustre*, *Eriophorum angustifolium*, *Myrica gale*, *Pedicularis palustris*, *Ranunculus flammula*, *Viola palustris**	*Chrysosplenium oppositifolium**, *Galium palustre**, *Montia fontana*, *Salix cinerea*	*Caltha palustris*, *Phragmites australis*, *Scutellaria galericulata*, *Veronica beccabunga*	*Glyceria maxima*	

* Species that will stand some shade.

Chapter 6

Identification of soil quality using humus form

6.1 The fact that most British forests are recent plantations on previously agricultural land, and have not yet developed humus that is in equilibrium with the new vegetation and soil moisture regime, has made it difficult to develop a classification of humus forms. Two examples serve to illustrate the variety of conditions: forest humus may be developing on top of a peat layer that was formed under a wetter regime, or may be forming on a previously tilled topsoil that had been enriched with additions of lime or fertilisers. Detailed classifications of humus forms exist for British Columbian forests (Green *et al.*, 1993) and for French soils in general (Brethes *et al.*, 1992; Jabiol *et al.*, 1995). Unfortunately these are not particularly compatible with each other, nor does either classification serve Britain's needs very well.

6.2 It is nevertheless considered worthwhile to identify whether the developing humus is mull, moder or mor, and a simple key is provided in Figure 18. Humus form provides a check on SNR derived from indicator plants and/or soil type. In the absence of ground vegetation due to excessive shade it will be most useful, but practice in associating humus form with ground vegetation and soil type together is invaluable.

Chapter 7

Choice of tree species

7.1 Choice of species is one of the most important silvicultural decisions the manager makes, and it is affected by ecological, financial and practical considerations. The advice that follows is intended to provide a list of species that are ecologically suited to particular climates and soil qualities in Grampian and capable of producing good quality timber. The timber-producing capability does not, however, extend to the Sub-alpine zone.

7.2 For each species the range of each of the primary climatic variables AT and MD is divided into *optimal, suitable* and *unsuitable* parts. These are combined in a climate diagram similar to Figure 6 and shown in the upper left part of Figures 25 to 51. For simplicity the Alpine Zone has been omitted from the climatic zone diagrams. The range of windiness (DAMS score) is also divided into *optimal, suitable and unsuitable* parts and shown in the lower left part of Figures 25 to 50. The ratings for AT, MD and windiness are then combined according to the method shown in Figure 19a.

7.3 A similar procedure is followed for SMR and SNR, these ratings being combined in diagrams in the upper right part of Figures 25 to 50. Finally the climatic and soil ratings are combined in the assessment of a particular site as shown in Figure 19b.

7.4 In *optimal* conditions a tree species is expected to grow at a rate given by the upper part of the range of general yield class shown in the Yield Models (Forestry Commission, 1981) and to do so without undue risk of disease or pest attack to an age well above that of normal financial maturity. It may thus also be an appropriate species to use for long-term retention for landscape or wildlife reasons. The species will also be capable of natural regeneration in appropriate soil conditions. In *suitable* conditions a tree species is either expected to grow at a rate given by the lower part of the range of yield class in the Yield Models, or it is expected to grow well early in its life but with an increased risk of health problems especially in the later part of the rotation. Where rate of growth is limited by lack of warmth or excessive windiness, the species should still be capable of growing to biological maturity, but natural regeneration will be less reliable than in optimal conditions. Where there are increased risks of injury from pests, disease or drought, then the species is considered incapable of growing to normal biological maturity. It should not be considered appropriate for long-term retentions. Whichever of these alternatives applies is stated in the notes attached to Figures 25 to 50.

7.5 It is assumed that climatic and soil factors cannot compensate for one another. Thus an optimal climate cannot compensate in terms of yield for a sub-optimal soil quality, and vice versa. Similarly, if any one factor, climatic or soil, is unsuitable, a favourable rating of any or all of the other factors cannot make the site suitable for the species. This does not, of course, preclude the possibility that appropriate management of a site could be used to upgrade soil quality to achieve a higher rating. (See also paragraph 4.4).

7.6 All three climatic variables and both of the soil quality variables are considered to have continuous scales. Classes of accumulated temperature and moisture deficit have been subdivided where it is possible to be that precise for a particular species. Similar subdivision of windiness classes would also be desirable, but lack of knowledge for most species has prevented this. Whilst classes of soil moisture regime and soil nutrient regime were split in the prototype ESC, it was finally abandoned because soil series could not be converted with the necessary precision. As a consequence, some of the refinement in the species suitability criteria for soil quality has been lost. Partly to compensate for this, an attempt has been made for some species to indicate an ideal soil quality (notes in Figures 25 to 50).

7.7 Figures 20 to 24 show the suitability ratings of each species for each of the five climatic and soil factors, and make clearer the comparisons between species.

7.8 Predictions of general yield class are made in Figures 25 to 50 for all species for which there is adequate local information. These predictions are based on data derived from the Forest Enterprise subcompartment database in the three Forest Districts, Moray, Buchan and Kincardine. Yield classes of stands over 40 years old were examined in relation to the three climatic variables AT, MD and windiness. The highest yield classes found within each climatic zone or subzone were assumed to occur on soils of optimal quality for the species. Within the same climatic zone a lower range of yield classes was assumed to occur on soils of suitable quality for the species.

7.9 The species suitability criteria are essentially subjective and draw on personal experience in Britain and abroad, in particular British Columbia, together with a variety of literature too numerous to list completely. Clearly, the combined experience of British foresters should increase with every passing year, but it is often surprising to find how much was known 40 or 50 years ago. The older literature contains a mixture of good sense that has not dated and less well founded notions that have not stood the test of time. It is to be hoped that this account combines the wisdom of the past with the knowledge that could only have been gained since. Some of the more useful literature, in alphabetical order, is as follows: Aldhous and Low, 1974; Anderson, 1950; Anon., 1991a; Anon., 1991b; Day, 1957; Evans, 1984; Franklin and Dyrness, 1973; Krajina, 1969; Lines, 1987; Macdonald, 1952; Macdonald *et al.*, 1957; Savill, 1991; Schmidt, 1957; Weissen *et al.*, 1994; Wood, 1955; Wood and Nimmo, 1962. The authors welcome comments on these suitability criteria, being conscious of the fact that few people have as yet been able to examine them in detail, especially outside Grampian (see Acknowledgments).

Chapter 8

Native woodlands

8.1 The following woodland sub-communities of the National Vegetation Classification occur within Grampian conservancy according to the maps and descriptions given in *British plant communities: 1: Woodlands and scrub* (Rodwell, 1991).

W3 *Salix pentandra-Carex rostrata* woodland

W4c *Betula pubescens-Molinia caerulea* woodland, *Sphagnum* sub-community

W7b *Alnus glutinosa-Fraxinus excelsior-Lysimachia nemorum* woodland, *Carex remota-Cirsium palus*tre sub-community

W8e *Fraxinus excelsior-Acer campestre-Mercurialis perennis* woodland, *Geranium robertianum* sub-community

W9a *Fraxinus excelsior-Sorbus aucuparia-Mercurialis perennis* woodland, typical sub-community

W9b *ditto, Crepis paludosa* sub-community

W10e *Quercus robur-Pteridium aquilinum-Rubus fruticosus* woodland, *Acer pseudoplatanus-Oxalis acetosella* sub-community

W11c *Quercus petraea-Betula pubescens-Oxalis acetosella* woodland, *Anemone nemorosa* sub-community

W11d *ditto, Stellaria holostea-Hypericum pulchrum* sub-community

W17d *Quercus petraea-Betula pubescens-Dicranum majus* woodland, *Rhytidiadelphus triquetrus* sub-community

W18a *Pinus sylvestris-Hylocomium splendens* woodland, *Erica cinerea-Goodyera repens* sub-community

W18b *ditto, Vaccinium myrtillus-Vaccinium vitis-idaea* sub-community

W18c *ditto, Luzula pilosa* sub-community

W18d *ditto, Sphagnum capillifolium/quinquefarium* sub-community

W19a *Juniperus communis-Oxalis acetosella* woodland, *Vaccinium vitis-idaea-Deschampsia flexuosa* sub-community

W19b *ditto, Viola riviniana-Anemone nemorosa* sub-community.

W20 *Salix lapponum-Luzula sylvatica* scrub

8.2 For two broad climatic zones, i.e. 'lowland' and 'upland' as illustrated by Rodwell and Patterson (1994) the relationships in terms of soil quality between some of these communities are provisionally shown in Figures 51 to 52. These diagrams have been constructed using Ellenberg ecological indicator values for soil moisture (F value), soil reaction (=acidity/alkalinity) (R value) and soil nitrogen (N value) (Ellenberg *et al.*, 1992). The size of the rectangle for each community depends on the scatter of the component sub-communities and represents *optimal* soil conditions. If *suitable* conditions had also been shown, there would often be some overlap between the communities. The results have been checked against the comments on habitats and distribution etc., in Rodwell (1991) and Whitbread and Kirby (1992). The relationships will become less provisional as and when Ellenberg numbers are replaced by ones validated for British conditions.

8.3 The climatic and soil requirements of nine of the communities are dealt with in more detail in Figures 53 to 61. The suitability ratings may differ from those used for plantations of the same principal tree species because different considerations apply to native woodlands. Growth rate and tree form are not the main objectives when creating native woodlands and so the climatic criteria have been relaxed. The main consideration has been the ability of the tree species to regenerate. Seed production will be more regular within the area regarded as optimal than in the suitable area. It is important to appreciate that so-called oak-birch woodlands W17 and W11 exist or could exist in many places where oak species are or will be absent because they are incapable of regenerating due to climatic limitations.

8.4 As regards soil suitability, the main consideration has been the development of characteristic ground vegetation. This is most likely to be achieved in the 'optimal' soil quality shown. The 'suitable' range of soil quality will allow the relevant tree species to grow satisfactorily, but the ground vegetation may be transitional to other communities. For example, for pine woodland to develop one of the five types of ground vegetation characterising the sub-communities of W18, the soil should not be richer than shown in Figure 59 as suitable. Soil suitability criteria have thus been drawn more tightly than would be appropriate for successful growth of the main tree species. All of the native woodland communities have more than one tree species and these may have different soil preferences. For example, in Scots pine woodland W18 downy birch, silver birch and rowan may be present. Downy birch in particular is suitable for more moist soil conditions than is Scots pine. This is not, however, allowed for in the soil criteria shown for the woodland, the criteria used are those provided by Figures 51–52.

8.5 As mentioned in paragraph 7.6 for crop species, it is tempting to split the classes of soil moisture regime and soil nutrient regime to achieve an apparently better fit of some of the woodland communities. As shown in Figures 51 and 52 several of the woodlands appear to have their optimal conditions between classes rather than within a single class. But since it is not possible to convert soil series to soil quality with this level of precision, such refinement has been eschewed.

8.6 The suitability criteria for the five factors, accumulated temperature, moisture deficit, windiness, soil moisture regime and soil nutrient regime for all 20 of the NVC woodland communities are summarised in Figures 62–66.

Chapter 9

Site diagnosis: a worked example

9.1 Site diagnosis is a term used for the process of estimating the quality, i.e. ecological character and/or silvicultural potential, of a site. In this context it is the process of estimating the climatic conditions and the soil quality and thence predicting the suitability of the site for a tree species or woodland type.

9.2 Site diagnosis is illustrated in Table 8. This table was produced for field demonstrations of Ecological Site Classification and refers to actual stands in forests near Huntly in 1995. The diagnostic information is in the shaded columns, i.e. accumulated temperature, moisture deficit, windiness, soil moisture regime and soil nutrient regime. In column 2 the first grid reference gives the location to the nearest 100m. The second grid reference converts the letters to numbers and gives the location (to the nearest 1km) for use on Figures 3, 5, 9, 10, 14–17.

9.3 Using the the grid reference of the site and the transparent grid overlay, the values for accumulated temperature, moisture deficit and windiness (DAMS score) are read off the maps (Figures 3, 5 and 10). Using the tree species suitability charts, the three columns can be shaded in to show the climatic suitability for each tree species of interest.

9.4 The soil moisture and soil nutrient regimes are assessed either by a direct site visit or indirectly via soil type or soil series using Figure 12 or Table 5. The indirect method should not be regarded as reliable for an individual site. Using the tree species suitability chart, the SMR and SNR columns can then also be shaded in to show the soil suitability for each species of interest.

9.5 The five assessments (columns) are combined using the diagrams of Figures 19a and 19b. There are five steps in the process:

1. Use the AT and MD values to decide the suitability class for this combination of factors.
2. Use the windiness value to decide the suitability class for that factor.
3. Combine 1 and 2 using Figure 19a.
4. Use SMR class and SNR class to decide the suitability class for soil quality.
5. Combine 3 and 4 using Figure 19b.

9.6 The values for accumulated temperature and moisture deficit in Table 8 have actually been obtained using a computer program, given the grid reference and elevation as inputs. This is at present only possible within Grampian. It is hoped that it will soon become possible to extend this to the whole of Britain and to refine the data by making an adjustment for slope and aspect. Windiness (DAMS) data are also available from Silviculture (North) Branch at Forestry Commission, Northern Research Station for any grid reference in upland Britain. It will also be possible to predict soil series from the grid reference, when soil maps have been digitised and when the data are made available.

Table 8 Examples of site diagnosis and choice of species (Clashindarroch Forest, Grampian)

	Location					Climate			Soil						Silviculture			
Site	Forest block	Grid ref.	Elevation (m)	Slope degrees	Aspect	Acc temp. (day-deg)	Moist def. (mm)	Wind (DAMS)	Geology (all Dalradian)	Soil association	Soil type, humus form	Indicator species	SMR	SNR	Tree species	P year	Actual GYC	Overall suitability Predicted GYC
1	Brown Hill	NJ 466395 347839	210	10	NW	1137	68	12.8	Basic igneous & mica schist	Insch/ Strichen	Brown earth, oligomull	Wavy hair-grass, creeping soft-grass	Fresh	Poor	SP	33	10	10 to 12
2	Brown Hill	NJ 469401 347840	180	5	NW			10.8	Mica schist	Strichen	Brown earth, mesomull	Wood sorrel nettle, elder	Moist	Medium/ rich	GF	38	20	
3	Gartly	NJ 523332 352833	180	15	SW			11.6	Slates	Foudland	Brown earth (ex agric.)	Timothy, cocksfoot, creeping buttercup	Fresh	Rich/ very rich	DF (NF, SS larch)	90?		
4	Kirkney	NJ 487317 349832	210	1	NE			12.5	Slates	Foudland	Alluvial brown earth, mesomull	Wood sorrel, oak fern, hard fern tufted hair-grass	Moist	Rich	GF	36	20-22	
4a	ditto	ditto	ditto	ditto	ditto	ditto	ditto	ditto	ditto	ditto	ditto	Tufted hair-grass, soft rush	Very moist/ wet	Rich	NS	36	16	16 to 20
5	Kirkney	NJ486315 349831	220	10	NW	1126	65	12.0	Slates	Foudland	Brown earth, oligomull	None	Moist		SS	36	18	
6	Kirkney	NJ 487315 349831	230	5	NW	1111	64	12.7	Slates	Foudland	Ironpan soil, mor	Wavy hair-grass, blaeberry, cowberry	Fresh/ moist	Poor/ very poor	SP	38	10	10 to 12
7	Kirkney	NJ485313 349831	230	25	WNW			11.0	Slates	Foudland	Brown earth mesomull	Wood sorrel	Fresh	Medium	DF	67	12	
8	Kirkney	NJ480310 348831	250	25	S			11.5	Slates	Foudland	Brown earth, mesomull	Wood sorrel, common violet, hard fern, tufted hair grass, primrose	Fresh	Medium	BE, SY	58		
9	Kirkney	NJ478317 348832	370	3	NE				Slates	Foudland	Podzol/ Ironpan soil, mor	Heather, blaeberry, cowberry, heath rush, wavy hair-grass	Moist		SS*	39	10	
10	Kirkney	NJ470309 347831	290	10	SE			12.5	Slates	Foudland	Brown earth, oligomull	Wavy hair-grass, creeping soft-grass	Fresh	Poor/ medium	JL	32	8	

KEY Optimal

*Planted as a 1:3 mixture of Scots pine and Sitka spruce.

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Appendix 1

Nitrogen availability

In Forestry Commission Bulletin 89, *Nitrogen deficiency in Sitka spruce plantations,* Charles Taylor and Paul Tabbush described four site categories with potential for causing nitrogen deficiency symptoms in Sitka spruce and differing in the way the problem should be treated. The site categories are widespread on unimproved land in Grampian Conservancy. They provide a refinement of the very poor and poor soil nutrient regimes (see Table 9).

Table 9 Categories of nitrogen availability

Site category	ESC soil nutrient regime	Comments
A (best)	Poor, occasionally medium	Soils are usually brown earths or surface-water gleys. Plant indicators of poor or medium SNR always present. Heather *(Calluna vulgaris)* has usually been promoted by land use and should not reinvade after felling.
B	Very poor or poor	Wide range of soils within these two classes of SNR. Plant indicators of poor SNR usually present. These sites are likely to upgrade to poor SNR during the first rotation and heather reinvasion should not be a serious problem after that.
C	Very poor	Soils range from the least fertile brown earths through podzols and ironpan soils to deep peats. Plant indicators of poor SNR are rare or absent. The better soils (brown earths) are likely to upgrade to poor SNR by the second rotation, but some heather reinvasion after clearfelling is likely.
D (worst)	Very poor	Soils are podzols, ironpan soils and unflushed deep peats. Plant indicators of poor SNR are usually absent. These sites will not upgrade to poor SNR during the first rotation and low availability of nitrogen will remain a severe limitation in the second rotation. Heather reinvasion is likely.

Appendix 2

Soil classification

This classification is based on *Soil classification*, Forestry Commission Research Information Note 68/82/SSN (Pyatt, 1982).

Table 10a The main mineral and shallow peaty soils (peat < 45 cm)

	Soil group	Soil type	Code
Soils with well-aerated subsoil	1. Brown earths	Typical brown earth	1
		Basic brown earth	1d
		Upland brown earth	1u
		Podzolic brown earth	1z
	3. Podzols	Typical podzol	3
		Hardpan podzol	3m
	4. Ironpan soils	Intergrade ironpan soil	4b
		Ironpan soil	4
		Podzolic ironpan soil	4z
Soils with poorly aerated subsoil	5. Groundwater gley soils	Groundwater gley	5
	6. Peaty gley soils	Peaty gley	6
		Peaty podzolic gley	6z
	7. Surface-water gley soils	Surface-water gley	7
		Brown gley	7b
		Podzolic gley	7z

Table 10b Peatland types (peat 45 cm or more)

	Soil group	Soil type	Code
Flushed peatlands	8. *Juncus* bogs (basin bogs)	*Phragmites* bog *Juncus articulatus* or *acutiflorus* bog *Juncus effusus* bog *Carex* bog	8a 8b 8c 8d
	9. *Molinia* bogs (flushed blanket bogs)	*Molinia, Myrica, Salix* bog Tussocky *Molinia* bog; *Molinia, Calluna* bog Tussocky *Molinia, Eriophorum vaginatum* bog Non-tussocky *Molinia, Eriophorum vaginatum, Trichophorum* bog *Trichophorum, Calluna, Eriophorum, Molinia* bog (weakly flushed blanket bog)	9a 9b 9c 9d 9e
Unflushed peatlands	10. Sphagnum bogs (flat or raised bogs)	Lowland *Sphagnum* bog Upland *Sphagnum* bog	10a 10b
	11. *Calluna, Eriophorum, Trichophorum* bogs (unflushed blanket bogs)	*Calluna* blanket bog *Calluna, Eriophorum vaginatum* blanket bog *Trichophorum, Calluna* blanket bog *Eriophorum* blanket bog	11a 11b 11c 11d
	14. Eroded bogs	Eroded (shallow hagging) bog Deeply hagged bog Pooled bog	14 14h 14w

(Explanatory comments in parentheses)

Table 10c Other soils

Soil group	Soil type	Code
2. Man-made soils	Mining spoil, stony or coarse textured Mining spoil, shaly or fine textured	2s 2m
12. Calcareous soils (soils on limestone rock)	Rendzina (shallow soil) Calcareous brown earth Argillic brown earth (clayey subsoil)	12a 12b 12t
13. Rankers and Skeletal soils (rankers = shallow soils < 30 cm to bedrock (skeletal = excessively stony)	Brown ranker Gley ranker Peaty ranker Rock Scree Podzolic ranker	13b 13g 13p 13r 13s 13z
15. Littoral soils (coastal sand and gravel)	Shingle Dunes Excessively drained sand Sand and moderately deep water-table Sand with shallow water-table Sand with very shallow water-table	15s 15d 15e 15i 15g 15w

Table 11 Phases occurring within types of Table 10a

Suffix	Name*	Description
a	shallow	Predominately 30-45 cm depth of soil to bedrock
c	cultivated	Considerable alteration to physical or chemical properties or to vegetation by former agricultural use
e	ericaceous	Vegetation contains sufficient *Calluna* (dominant to frequent) to become a weed problem after planting
f	flushed	Considerable enrichment with nutrients from flush water, as as indicated by the presence and vigour of tall *Juncus* species, *Deschampsia cespitosa* or *Molinia*
g	slightly gleyed	Subsoil slightly mottled or with grey patches
h	humose	Topsoil contains between 8 and 25% organic matter by weight
i	imperfectly aerated	Applied to gley soils with less prominent grey coloration than usual for the type (but which do not quality as 7b)
l	loamy	Used for surface-water gley soils and peaty gley soils where the texture throughout the profile is not finer than sandy clay loam
p	peaty (or deeper peat phase)	Surface horizon containing more than 25% organic matter by weight Thickness definitions: 3p, 4p and 5p = 5 – 45 cm of peat 6p = 25 – 45 cm of peat (Note that types 6 and 6z have a peaty horizon 5 – 25 cm thick)
s	extremely stony	Stones occupy more than 35% of the soil volume
v	alluvial	Soil developed in recent alluvium of sandy or coarse loamy texture
x	indurated	Has strongly indurated material within 45 cm of surface Implies loamy texture Where indurated material is only moderately developed or is at depths of 45 – 60 cm, (x) is used

* Naming soil types with phases: the preferred form is to give the name of the soil type followed by a comma, then the phase name in the usual order, ending with the word 'phase'. For example: Upland brown earth, shallow phase; peaty gley, deeper peat and loamy phase.

Rules for the use of phases (for brevity, suffixes are used here rather than names):

1. Phases f, h, i and l are used only for gley soils
2. Phase g is used for brown earths, podzols, or ironpan soils
3. Phases which are mutually exclusive: e and f, c and e, h and p, a and x, v and x
4. Unlikely combinations: a and v, f and i
5. When x or v is used, l is unnecessary
6. Where more than one suffix is used they are placed in the order:

   v, l, p, h, x, g, i, s, a, f, c, e
7. A soil type within Table 10a should always be given one or more phase suffixes where these are clearly capable of improving the definition of the unit, but there are numerous occasions where no phase is appropriate
8. The phase suffixes always follow the soil type suffix

Appendix 3

Glossary of terms

Available water capacity The maximum quantity of soil water available for use by the vegetation (assumed to be the tree crop), normally mainly within the rootable depth. The amount (usually expressed in mm depth of water) varies mainly with soil texture, stoniness and organic matter content. It is assumed that plants can extract water between field capacity and wilting point. Field capacity is the condition of the soil after it has been fully wetted and then allowed to drain under gravity alone for a couple of days. It can be thought of as a common condition of the soil, or a soil layer well above the water-table, in winter after a day or two of dry wether. Wilting point is rarely encountered in winter after a day or two of dry weather. Wilting point is rarely encountered in Grampian except in soils of the lowest available water capacity. The soil is so dry that it does not moisten the hands when squeezed. The available water capacity is increased if a water-table remains in reach of the root system, but it is difficult to estimate this contribution. Also, soils towards the base of slopes can be expected to gain moisture by downslope seepage given suitable substrate conditions (e.g. indurated subsoil, impervious bedrock suitably inclined). This can often 'increase' the soil moisture regime by one class, e.g. a freely draining soil that would be Fresh on the basis of its texture, etc, could be Moist where it receives seepage from above.

Ellenberg numbers are scores of a scale of 1 to 9 that give the ecological preferences (in Central Europe) of each species for various climatic and soil factors. A score of 0 for any factor is used when the species shows no clear preference for any part of the range. The relevant factors here are soil moisture, soil reaction (i.e. pH) and soil nitrogen. common vascular plants found in Grampian Conservancy have been allocated to cells of the soil quality grid according to their Ellenberg numbers. SMR classes have been equated with Ellenberg moisture numbers as follows: Very wet = 9; Wet = 8; and so on to Very dry = 2. There are no common plants with moisture score of 1. SNR classes have been equated with combinations of reaction (R) and nitrogen (N) numbers; Very poor = R 1-3, N1; Poor = R 2-4 & 0, N 2-3; Medium R 3-5 & 0, N 4-5; Rich = R 5-7 & 0, N 6-7; Very rich = R 6 - 8 & 0, N 8 - 9, Carbonate = R 8-9, N 1-4.

Lithology The mineralogical composition, grain size and hardness of rock define its lithology. Geological age is not included.

Moisture deficit Is calculated for a station by subtracting potential evaporation from actual rainfall on a monthly basis, and summing the monthly deficits to find the maximum potential deficit for the year. Values are calculated for each year in a run of 20 or 30 years and the mean is taken. MD is similar to the potential water deficit (PWD) of Birse and Dry (1970) but the latter is calculated using long-term mean monthly value of rainfall and evaporation. Indeed, the values of MD for Scotland have been derived using a formula provided by Bendelow and Hartnup (1980) from values of PWD produced and mapped by Birse and Dry (1970).

Oceanicity The Conrad (1946) index of continentality used by Bendelow and Hartnup (1980) is derived from the mean annual temperature range and the geographical latitude and divided into four classes. Thus class 01 is the least continental (and the most oceanic) and has the smallest range of annual temperature and, other things being equal (e.g. latitude, elevation and topographic shelter), will be the most windy, will have the longest growing season, the highest atmospheric humidity and the smallest accumulated frost. Class 04 is the most continental and, again other things being equal, will be least windy, will have the shortest growing season, the lowest humidity and the largest accumulated frost.

Soil reaction Term sometimes used (e.g. by Ellenberg *et al.*, 1992) to denote soil acidity or alkalinity. Thus acid soils would be described as having an acid reaction.

Species abbreviations Forestry Commission usage. Scientific names after Stace (1991) where possible.

SP	Scots pine	*Pinus sylvestris* L.
CP	Corsican pine	*Pinus nigra* Arnold ssp. *laricio* Maire
LP	lodgepole pine	*Pinus contorta* Douglas ex Loudon
	Origins: ILP	Southern interior
	CLP	Central interior
	SLP	South coastal
	NLP	North coastal
	KLP	Skeena (intermediate)
	ALP	Alaskan
SS	Sitka spruce	*Picea sitchensis* (Bong.) Carrière
	Origins: NSS	Oregon
	WSS	Washington
	QSS	Queen Charlotte Islands
	ASS	Alaskan
NS	Norway spruce	*Picea abies* (L) Karsten
EL	European larch	*Larix decidua* Miller
JL	Japanese larch	*Larix kaempferi* (Lindley) Carrière
DF	Douglas fir	*Pseudotsuga menziesii* (Mirbel) Franco
GF	grand fir	*Abies grandis* (Douglas ex D. Don) Lindley
NF	noble fir	*Abies procera* Rehder
WH	western hemlock	*Tsuga heterophylla* (Raf.) Sarg.
RC	western red cedar	*Thuja plicata* Donn ex D. Don
SOK	sessile oak	*Quercus petraea* (Mattuschka) Liebl.
POK	pedunculate oak	*Quercus robur* L.
BE	beech	*Fagus sylatica* L.
AH	ash	*Fraxinus excelsior* L.
SY	sycamore	*Acer pseudoplatanus* L.
WEM	wych elm	*Ulmus glabra* Hudson
SBI	silver birch	*Betula pendula* Roth
DBI	downy birch	*Betula pubescens* Ehrh.
ASP	aspen	*Populus tremula* L.
PO	poplar cultivars	D = *Populus deltoides* Marshall N = *P. nigra* L. T = P. *trichocarpa* Torrey & A. Gray ex Hook
CAR	common alder	*Alnus glutinosa* (L.) Gaertner
NOM	Norway maple	*Acer platanoides* L.
WCH	gean, wild cherry	*Prunus avium* (L.) L.

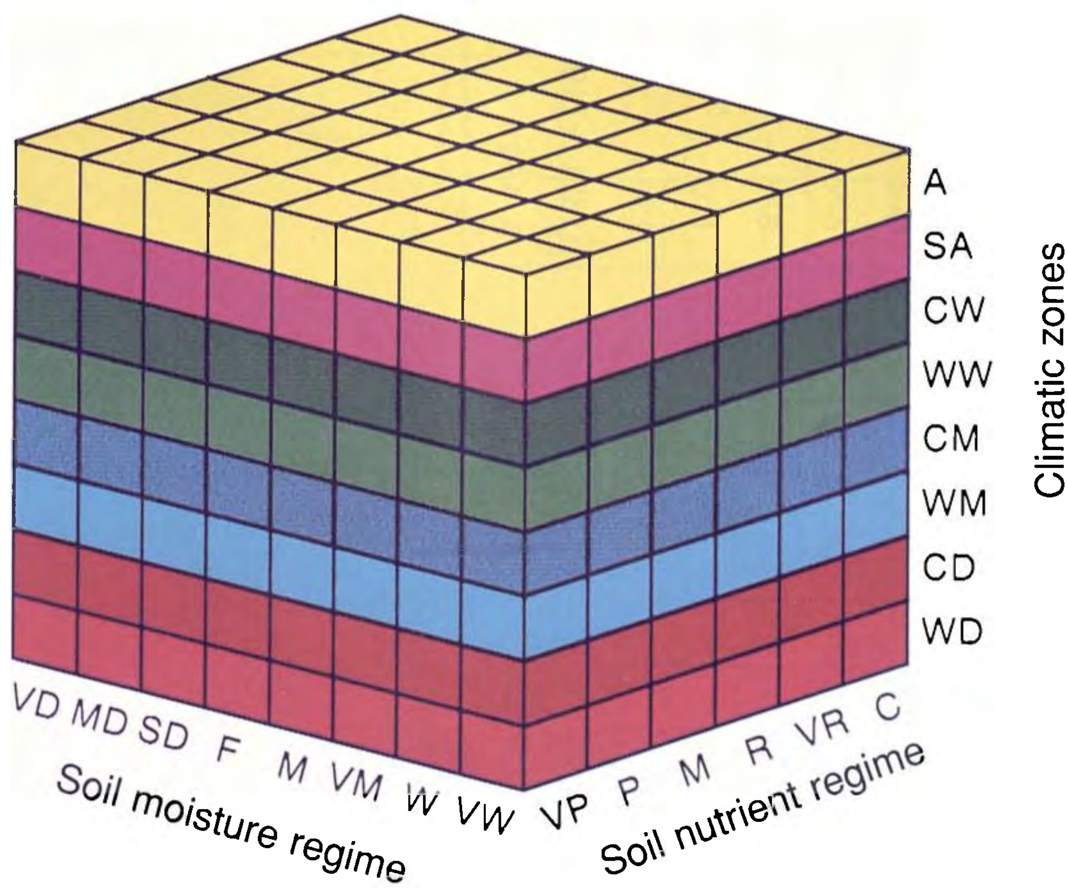


Figure 1 Ecological site classification

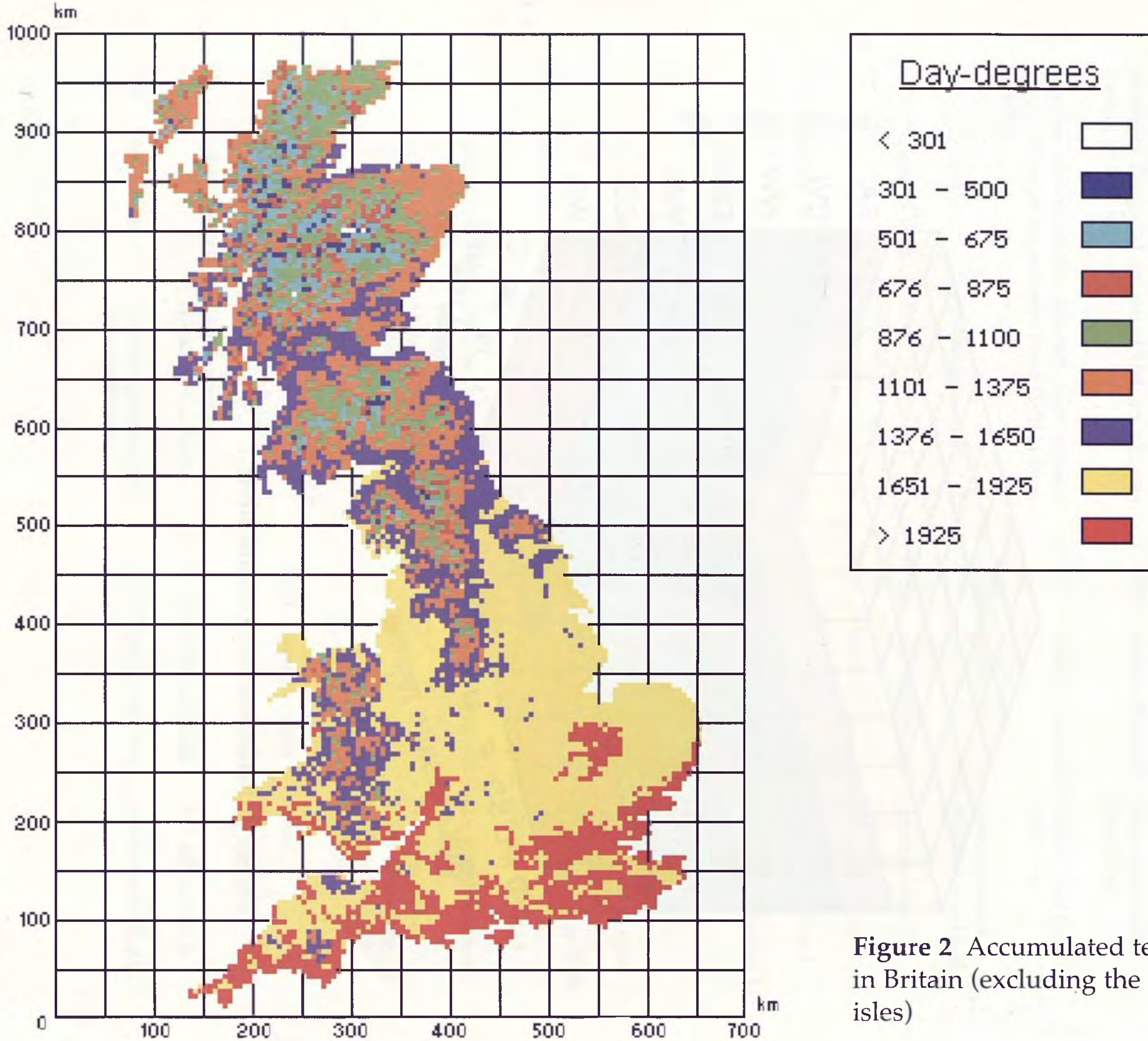


Figure 2 Accumulated temperature in Britain (excluding the northern isles)

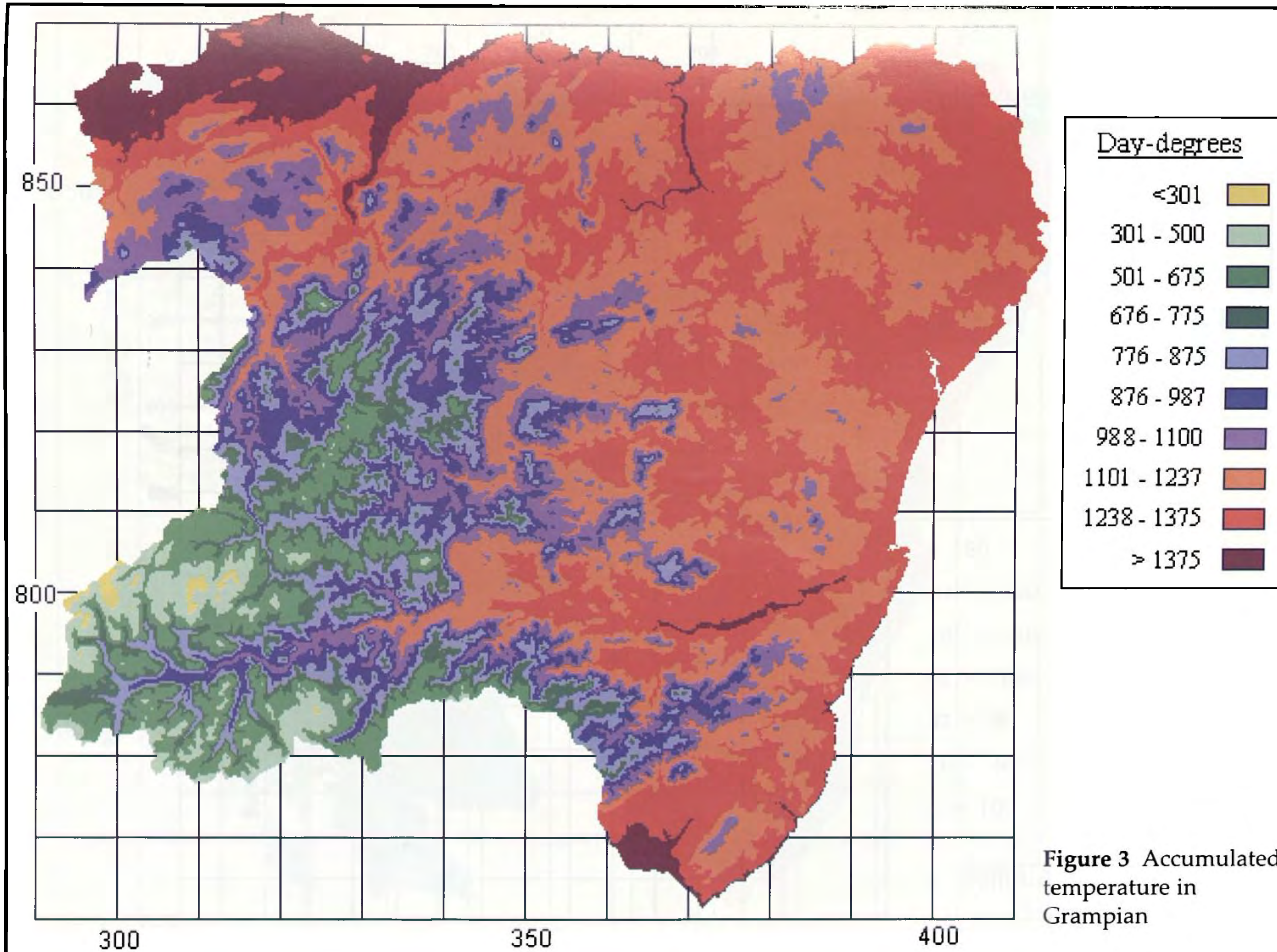


Figure 3 Accumulated temperature in Grampian

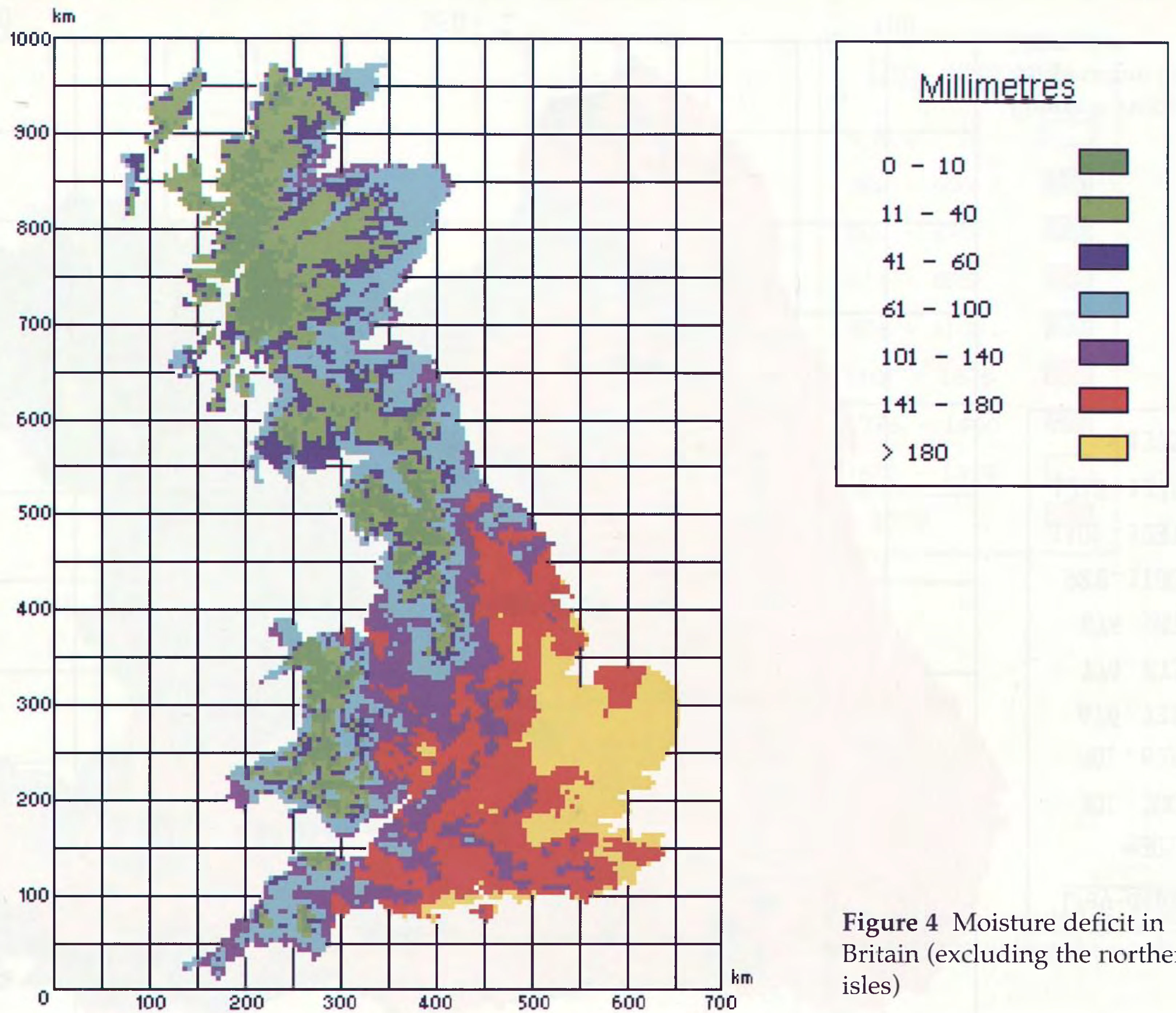


Figure 4 Moisture deficit in Britain (excluding the northern isles)

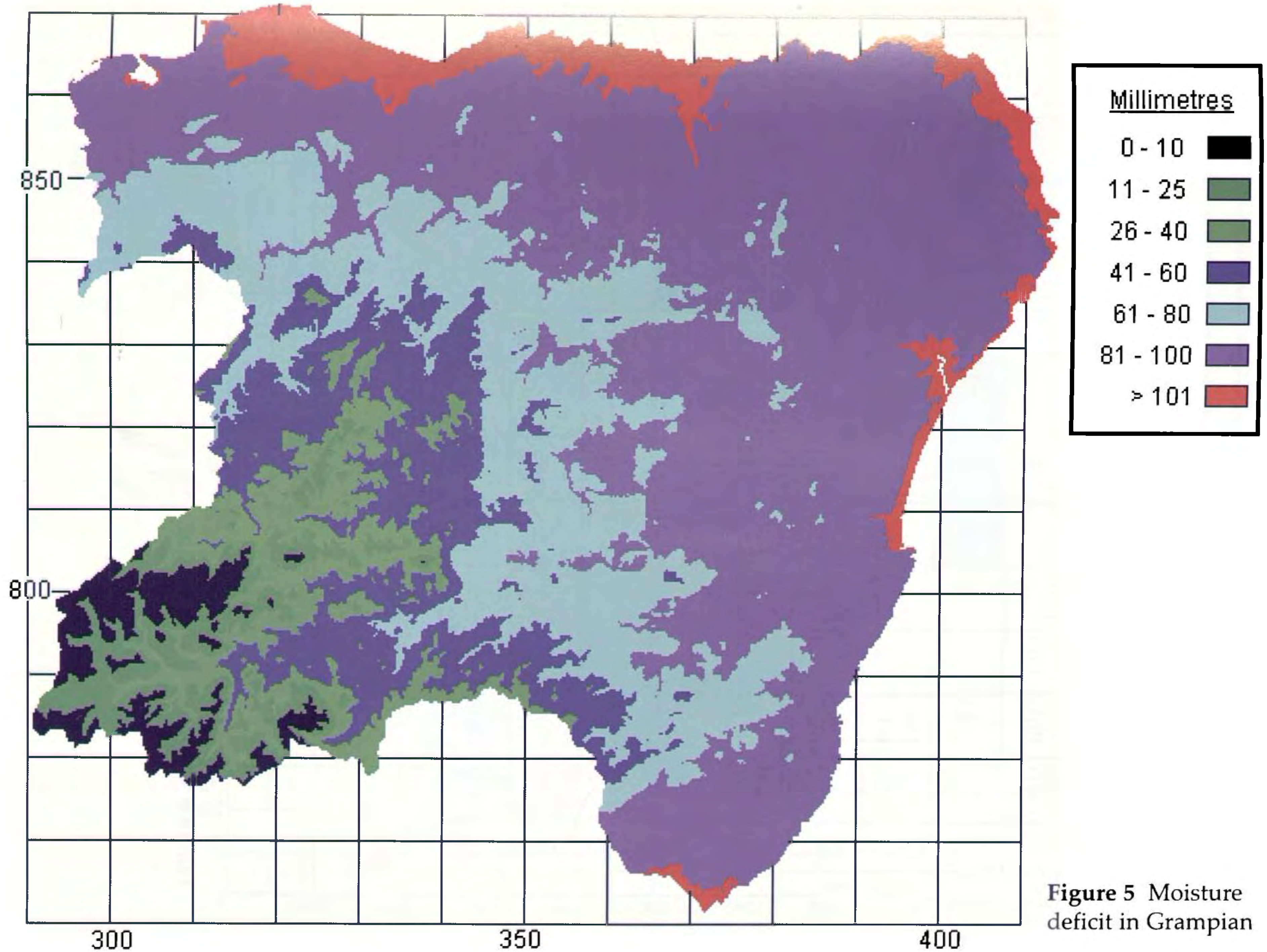


Figure 5 Moisture deficit in Grampian

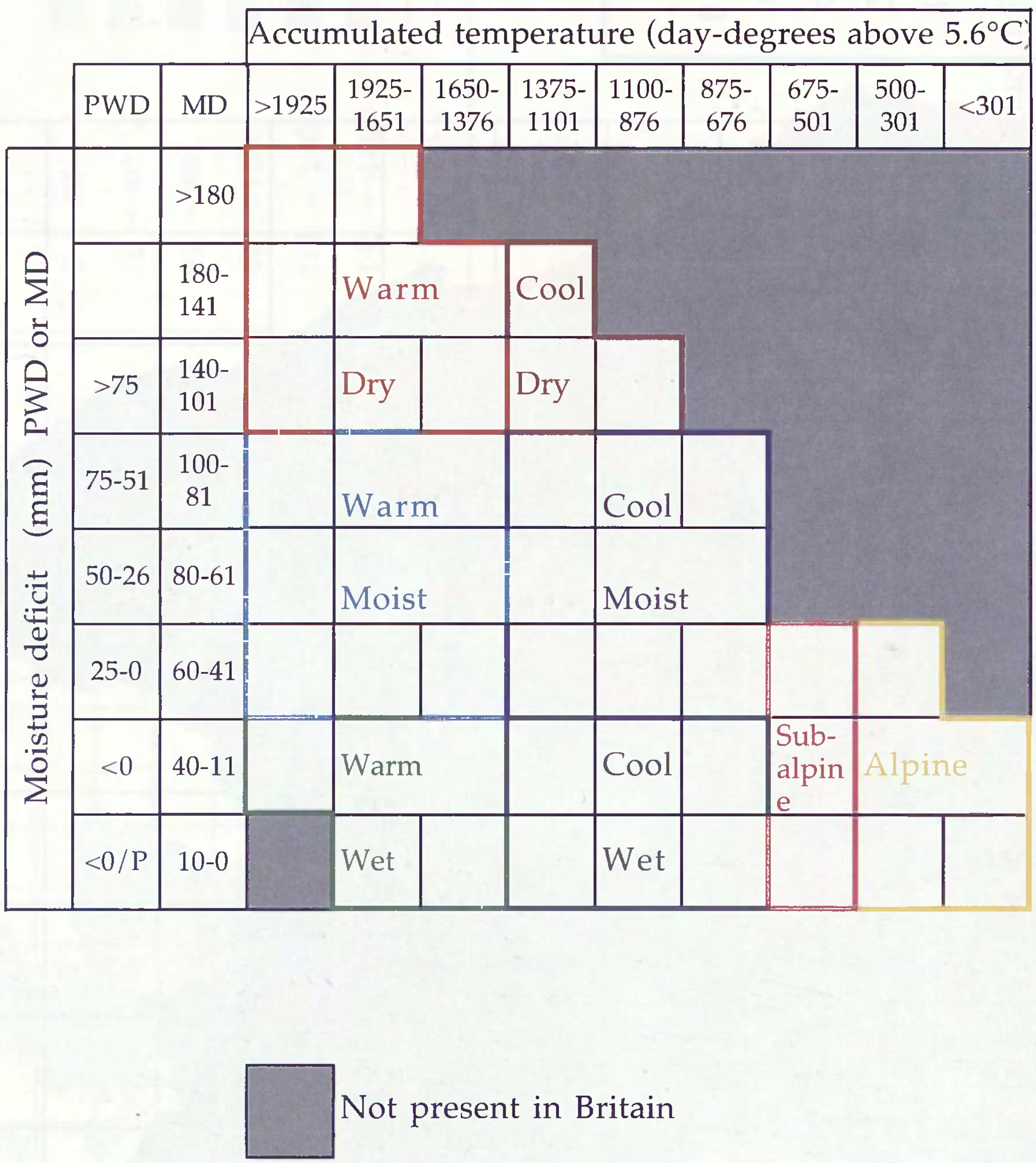


Figure 6 Climatic zones in Britain

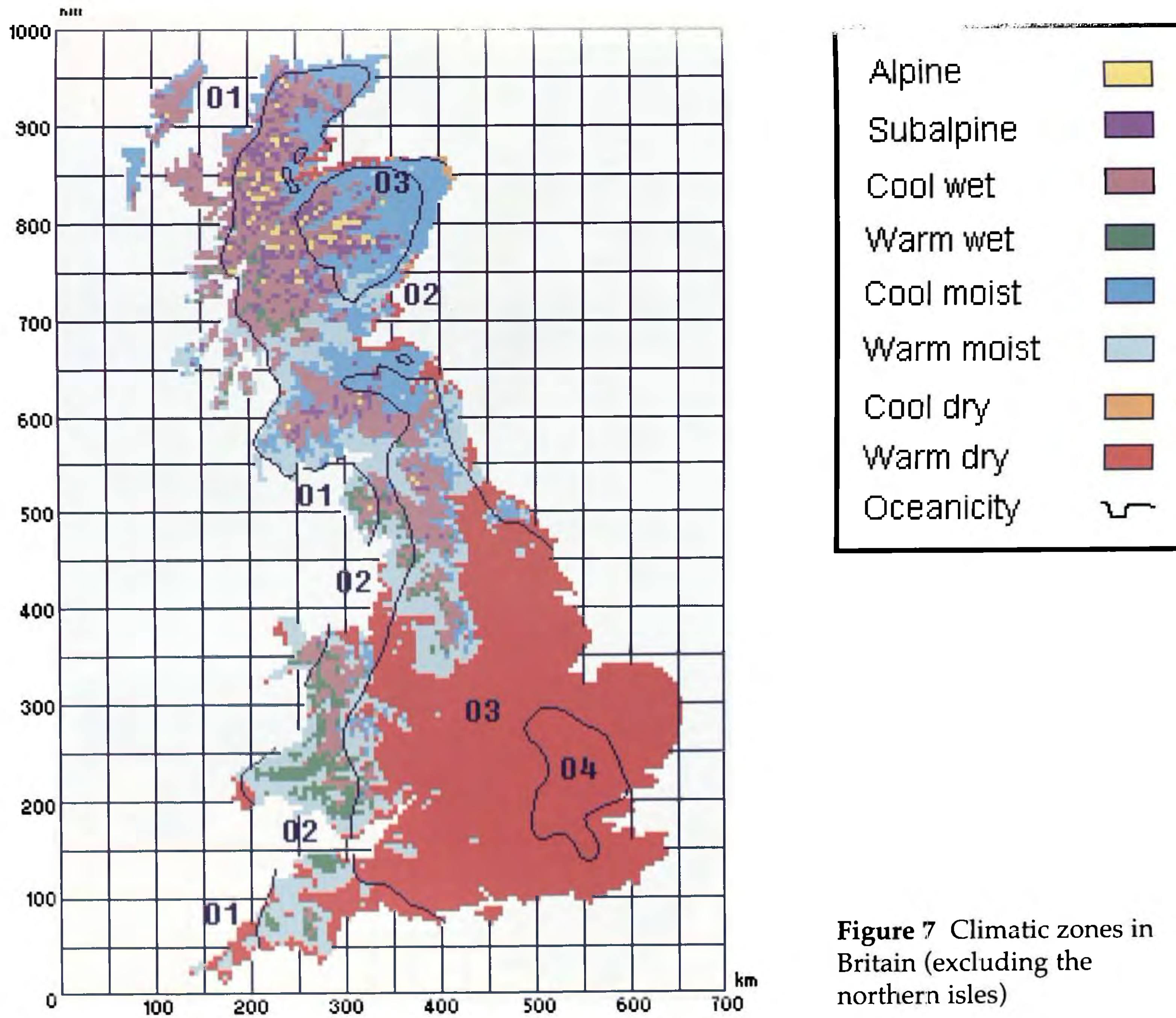


Figure 7 Climatic zones in Britain (excluding the northern isles)

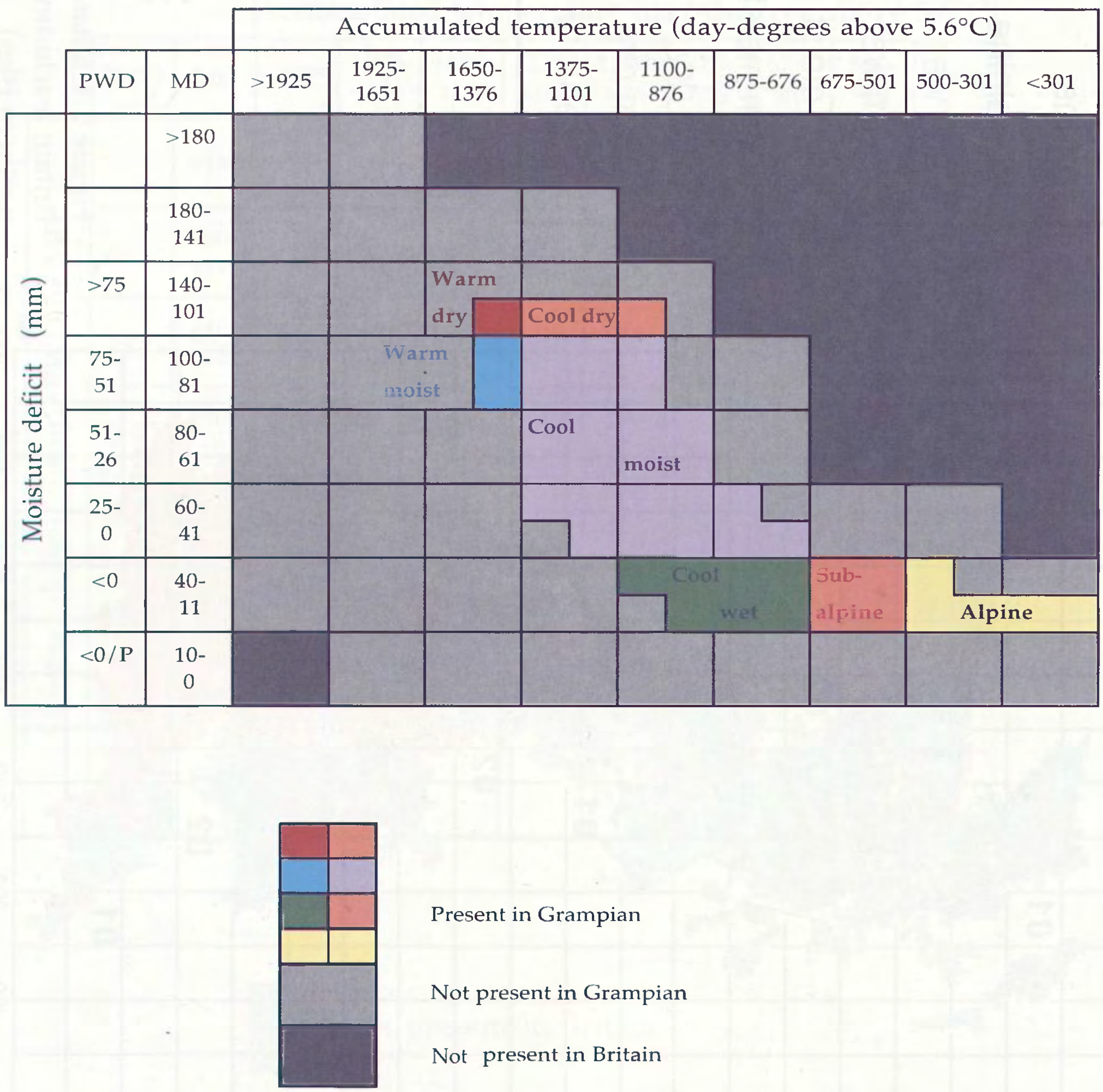


Figure 8 Climatic zones in Grampian

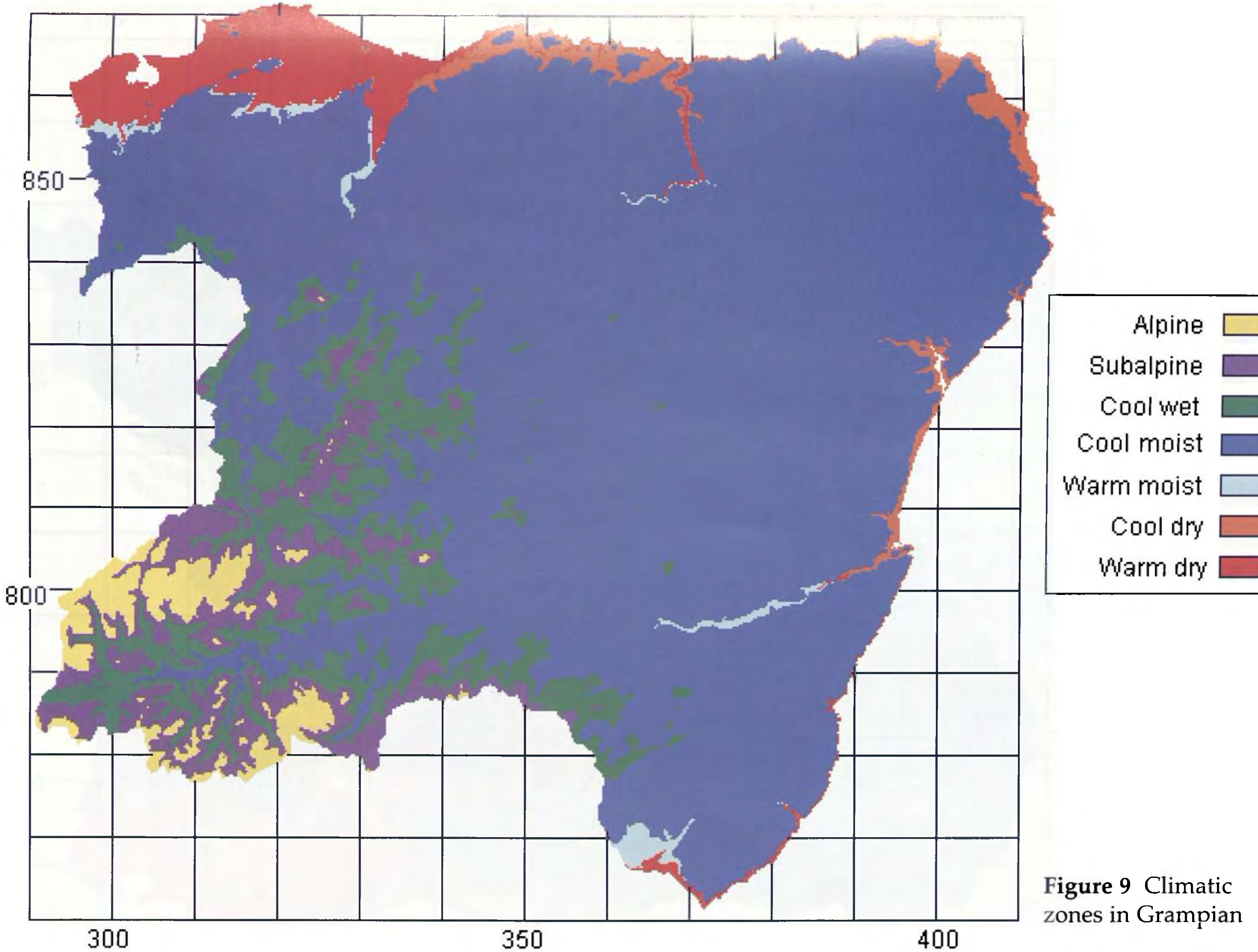


Figure 9 Climatic zones in Grampian

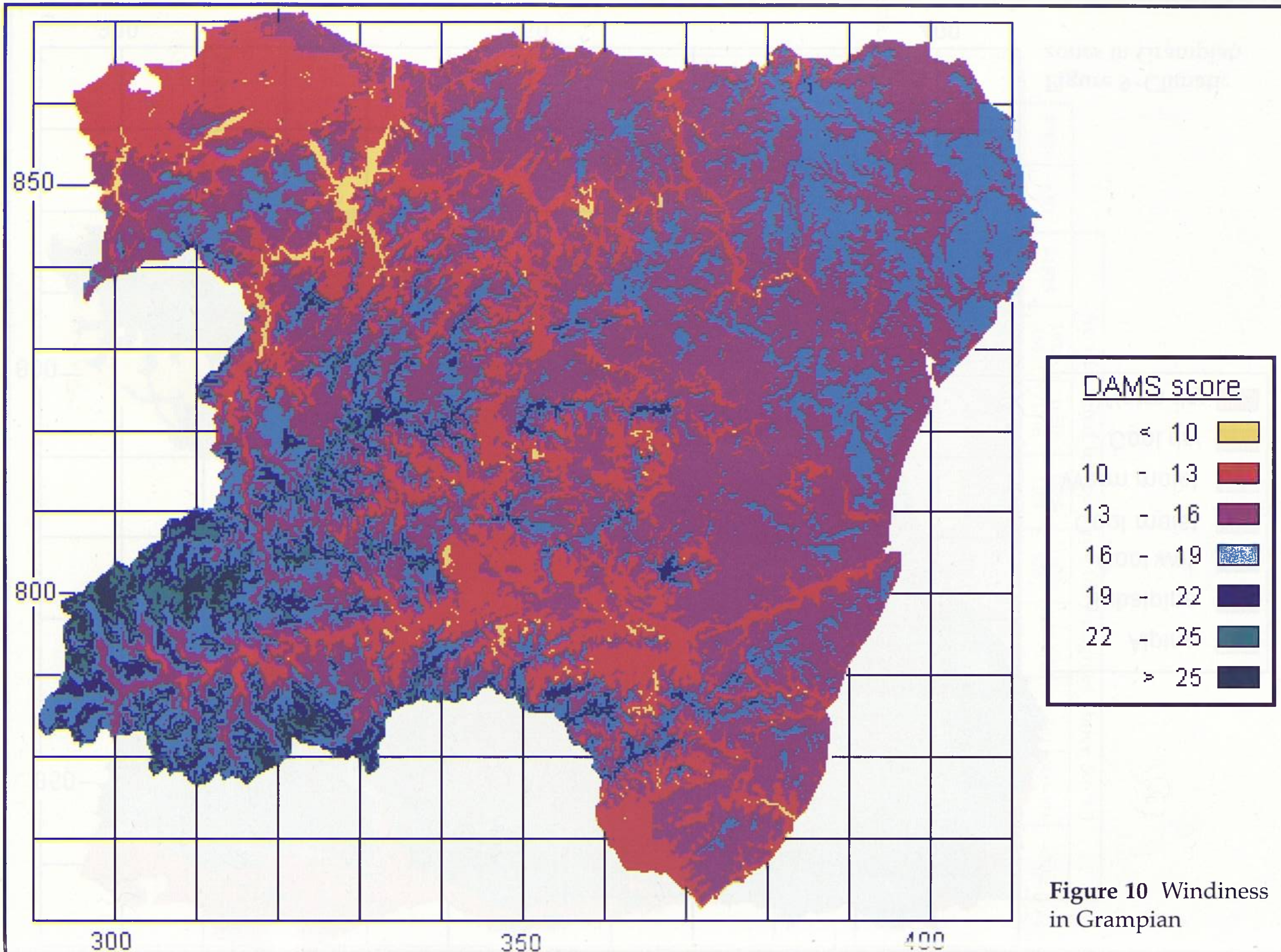


Figure 10 Windiness in Grampian

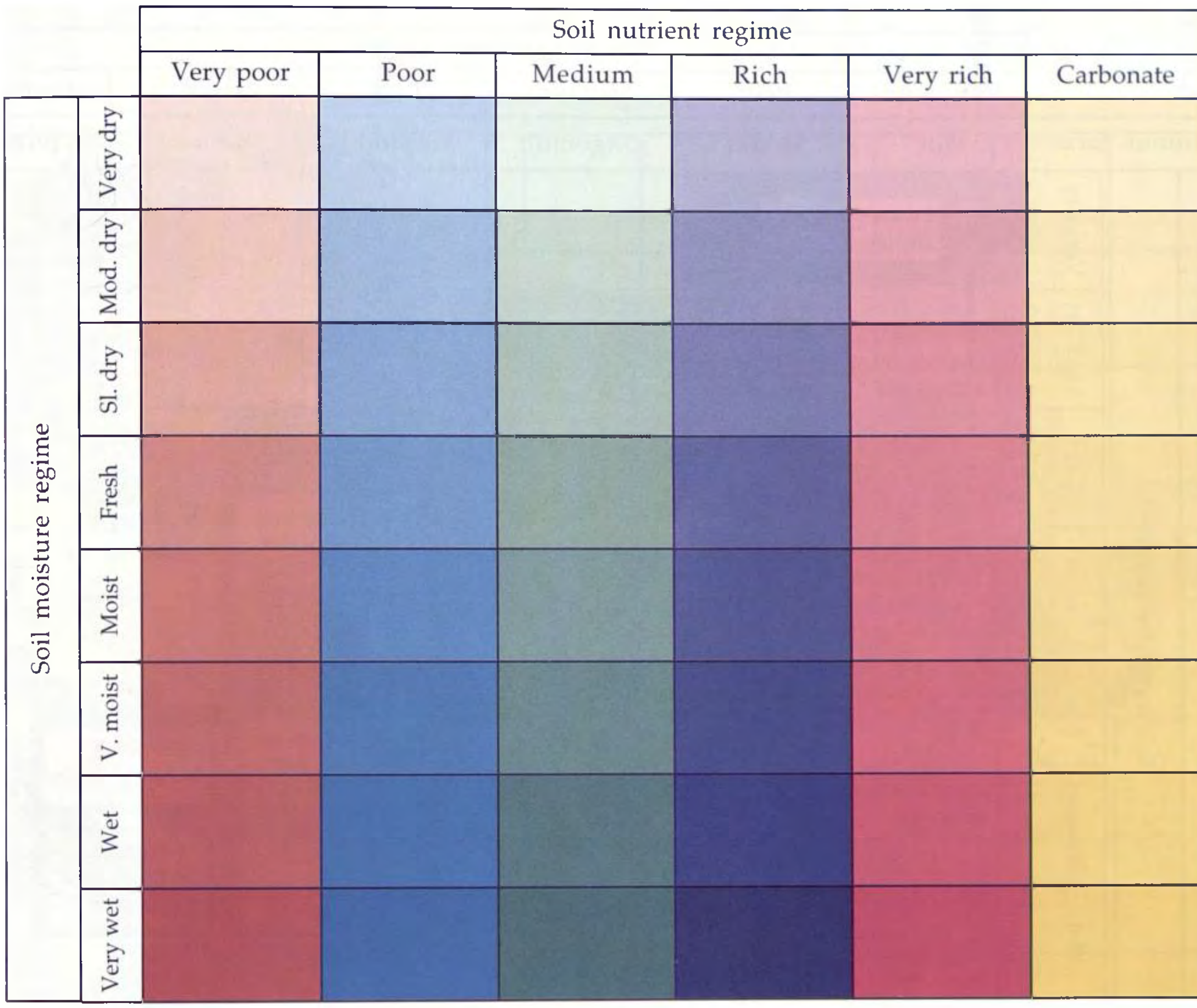


Figure 11 The soil quality grid

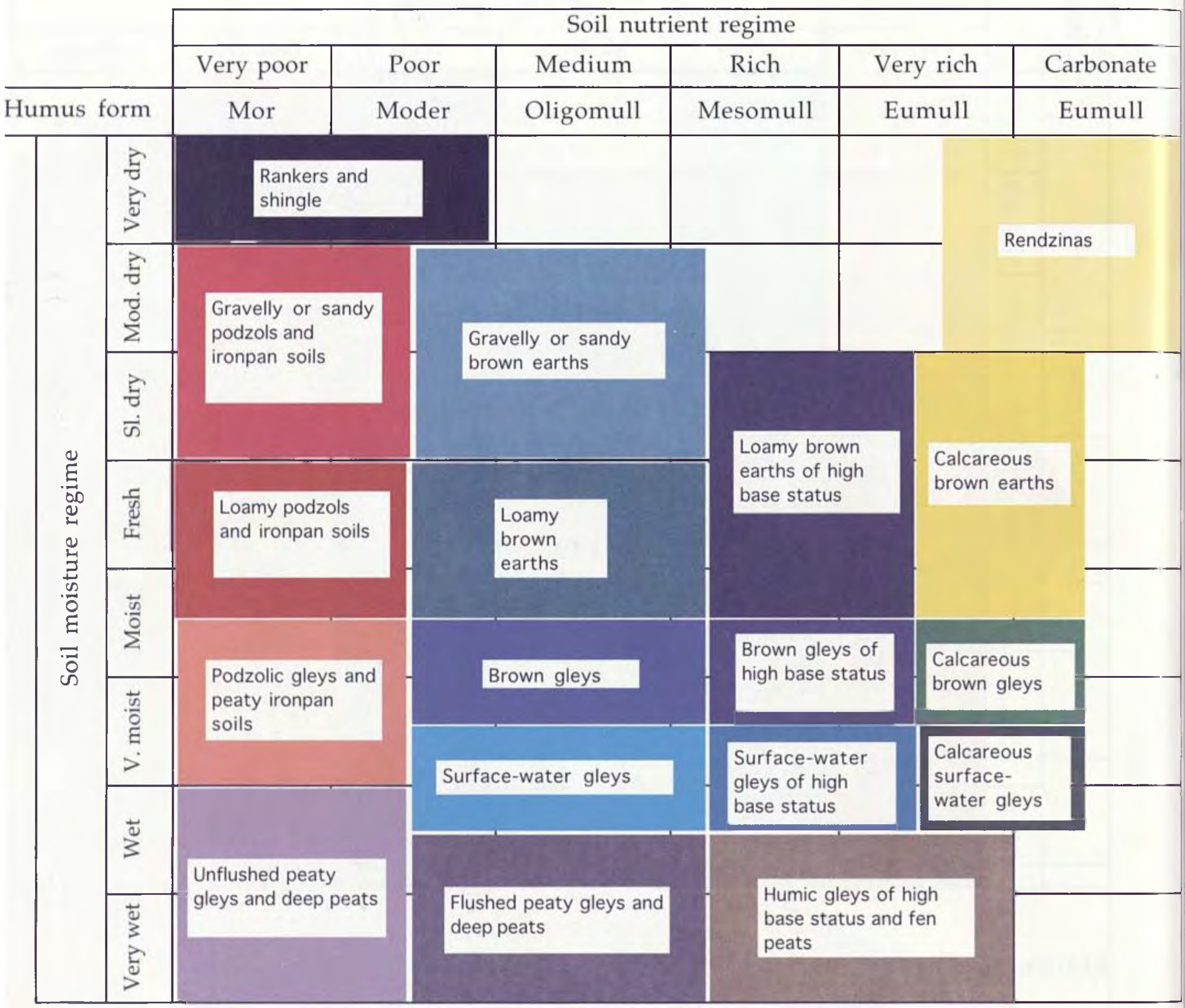


Figure 12 Simplified distribution of soil types and humus forms

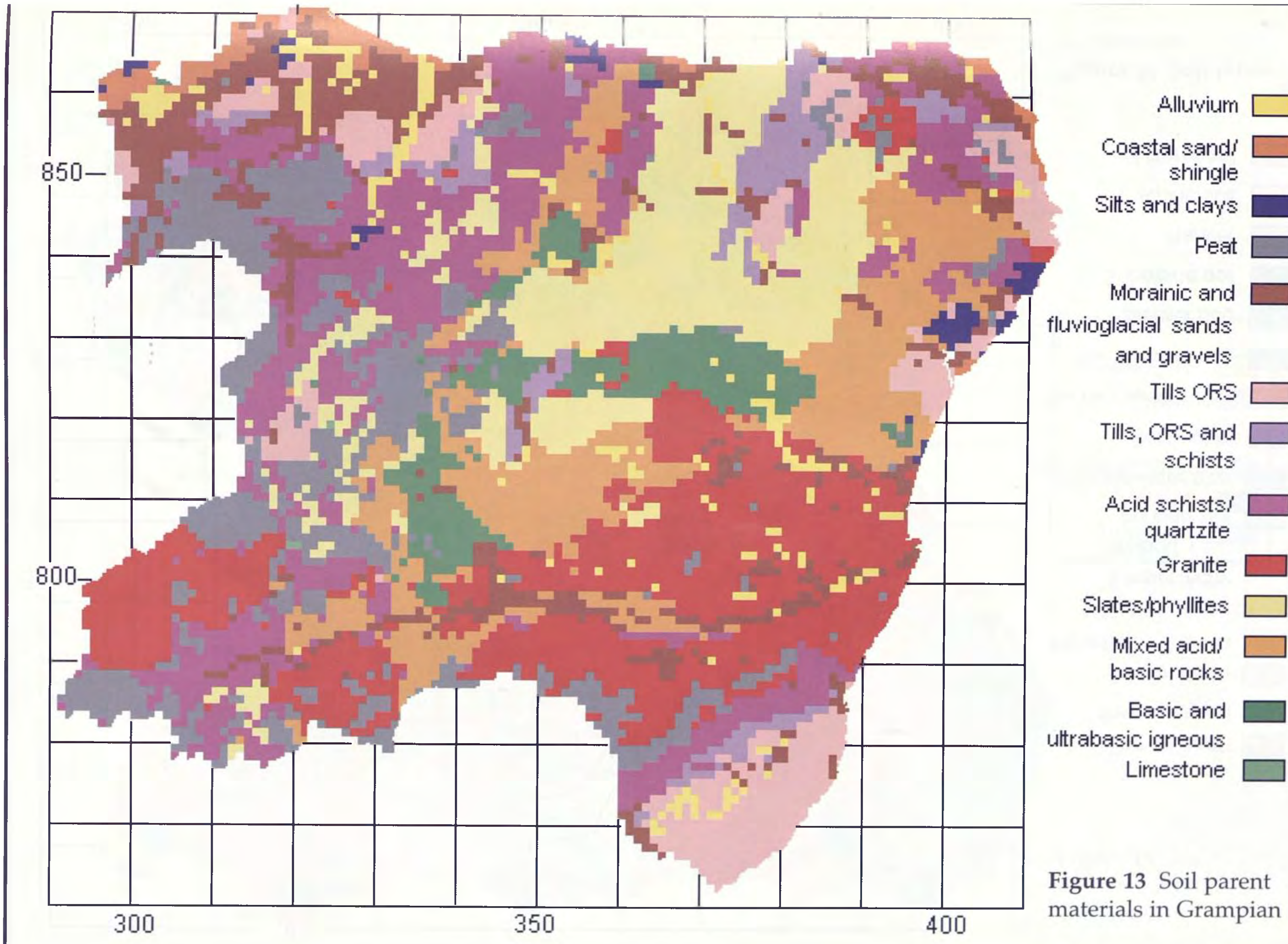


Figure 13 Soil parent materials in Grampian

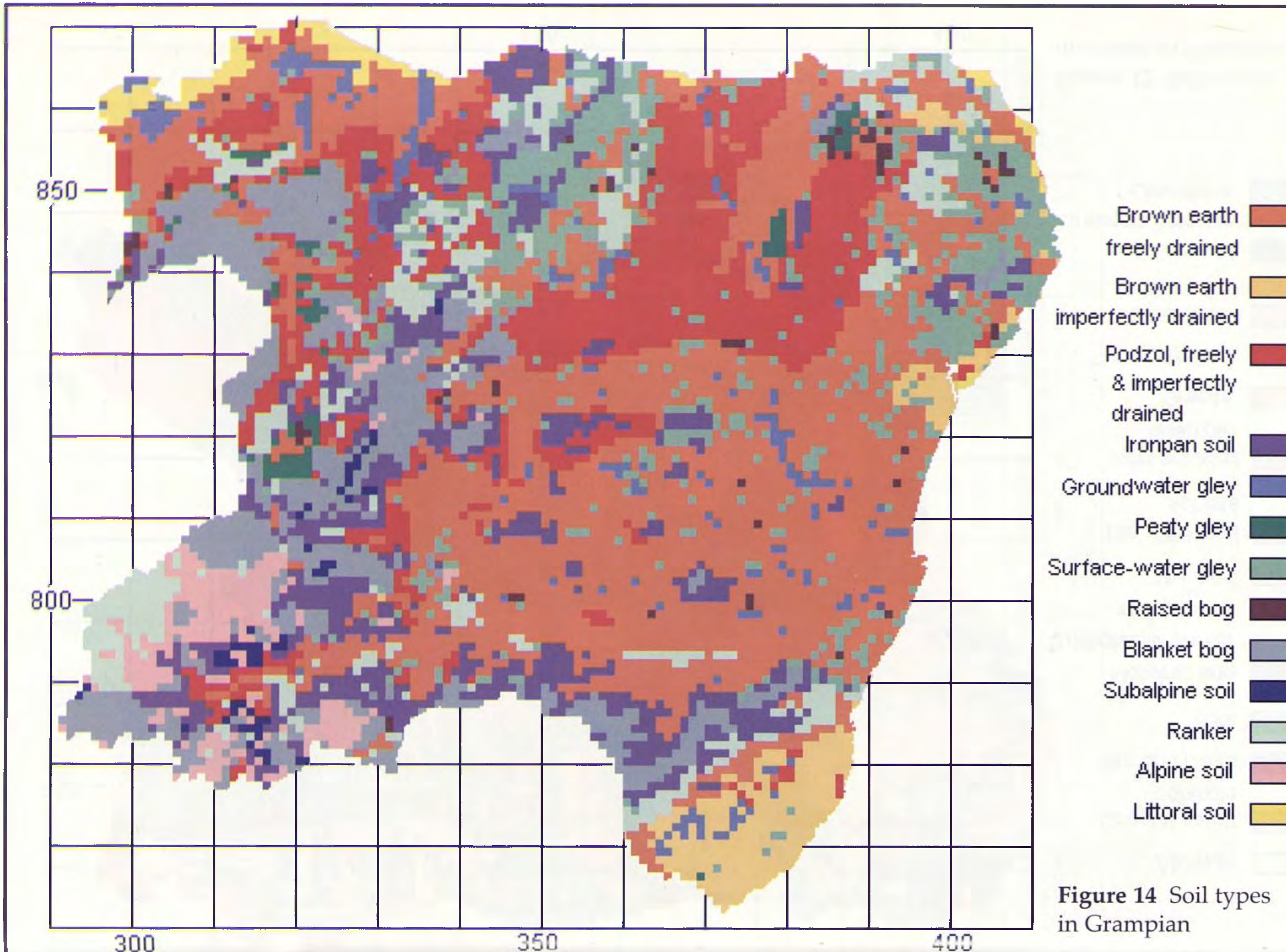


Figure 14 Soil types in Grampian

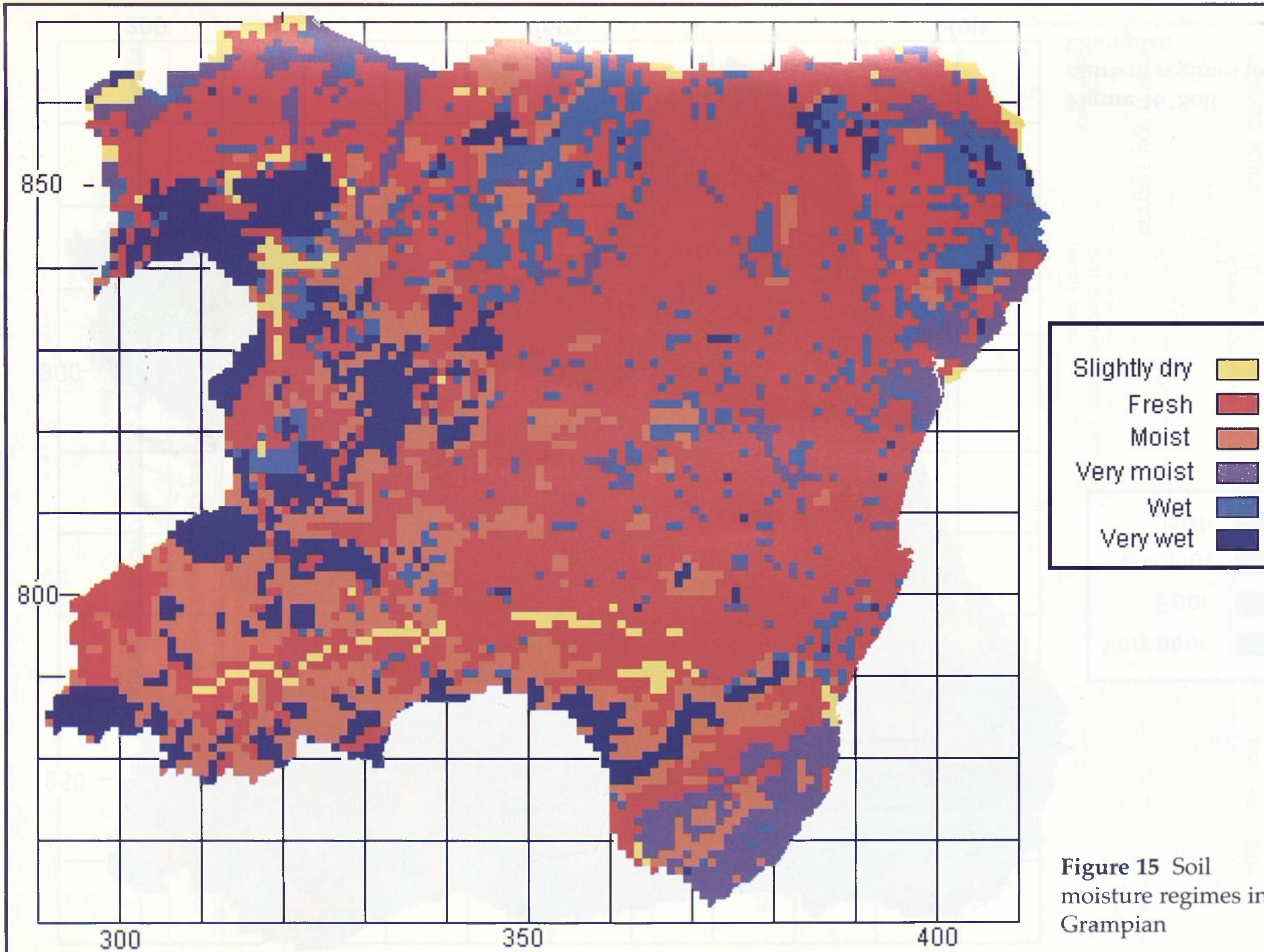


Figure 15 Soil moisture regimes in Grampian

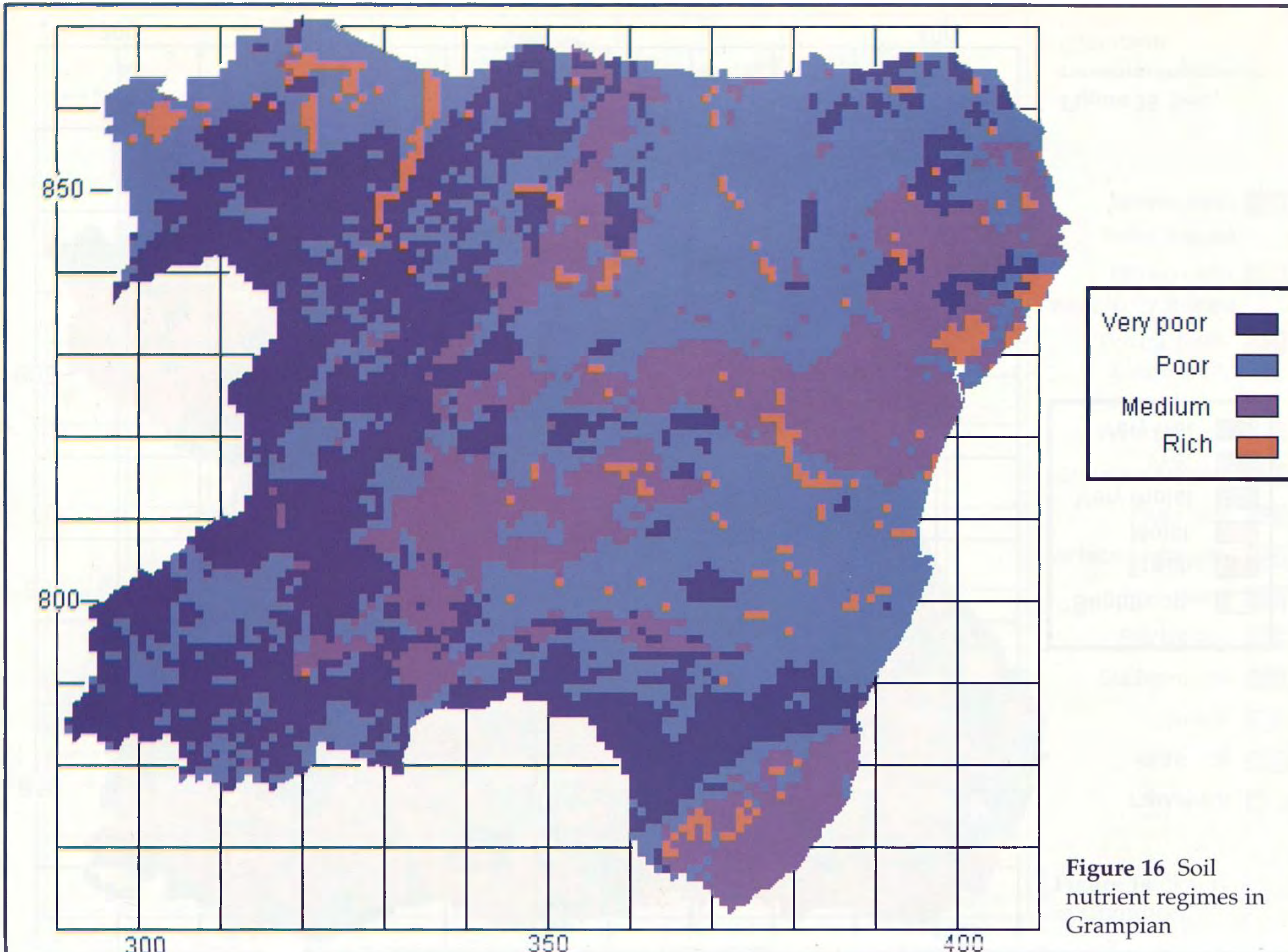


Figure 16 Soil nutrient regimes in Grampian

LAYERED SOILS: For a soil with two very different layers, e.g. a layer of humus or peat over mineral, separate calculations should be made for each layer and summed.

STEP 1: SOIL TEXTURE

Start here		AWC/m (mm)
Soil extremely stony, with sandy matrix	yes	50
no ↓ Soil sand or loamy sand	yes	100
no ↓ Soil loamy or clayey	yes	170
no ↓ Humus layer or soil peaty	yes	400

STEP 2: DEPTH

Multiply the AWC/m by the rootable depth in metres, e.g. if the depth is 50 cm multiply by 0.5.

STEP 3: STONINESS

Soils that are extremely stony (AWC 50 mm/m depth) need no further adjustment.
For other soils reduce the AWC obtained so far by the volumetric proportion of stones.
For example, if there are 15% stones, multiply value by 0.85.
Note that it is easy to over-estimate the volumetric proportion of stones.
Even the extremely stony fluvioglacial gravels with all stones in contact with each other have a maximum of 60% stones by volume, provided the matrix does fill the interstices.

Figure 17 Estimate of available water capacity (AWC) of soil profile

rooting depth   stoniness

400 x .45 x 0 = 180
170 x .20 x .85 = 29
150 x .15 x .75 = 17   loam
47   loam

AWC for this soil profile   226

45 cm   Peat
20   Silty Loam
15   Sandy Clay Loam

AWC	% stones
400	0%
170	15%
150	25%

1a. A horizon (> 2 cm thick) with organic and mineral material blended together in aggregates (crumbs or blocks), earthworms present. OF and OH horizons, if present, <2 cm thick. Sharp break between O and A horizon. **Mull**

1b. OF + OH horizons (jointly) >2 cm thick.

2a. Gradual transition between O and A horizon. A horizon with few earthworms, organic and mineral particles separate (under hand lens). Many faecal pellets. **Moder**

2b. Sharp break between the OH horizon and an organo-mineral horizon which is sometimes black and humic, but often light coloured. Usually fungal mycelium present. Few faecal pellets. Earthworms absent or rare. **Mor**

Mulls can be further subdivided

3a. OL and OF horizon present. Breakdown of litter relatively slow. **Oligomull**

3b. OL present but OF absent.

4a. OLn present and OLv may be present. Breakdown of litter rapid. **Mesomull**

4b. OLn present or absent. Breakdown of litter very rapid. **Eumull**

Definition of humus horizons

OL Fairly fresh plant residues, readily identifiable as to origin. No fine decomposed material.

OLn (n = new): Fresh litter that has not undergone decomposition; the leaves remain whole, only their colour may have changed. In soils with very rapid breakdown of litter, this horizon only exists from autumn to the beginning of spring.

OLv: Litter showing little fragmentation, but changed due to colour, cohesion or hardness. If present, underlies the OLn horizon.

OF Fragmented material in which plant structures are generally recognisable as to origin, and mixed with some (<70%) finely decomposed organic matter (e.g. faecal pellets). Often contains roots and fungal mycelia. Plant remains are densely overlapping.

OH Contains >70% fine organic material (ignoring roots) in which plant structures are generally not recognisable. Reddish brown to black in colour, fairly homogeneous in appearance. Mineral grains may be present. Horizon often more coherent than the underlying horizon. This horizon is distinguished from peat (H horizon) by being formed in conditions that are not saturated with water for more than 6 months in the year.

A Horizons containing a mixture of organic and mineral material.

Figure 18 Key to humus forms (simplified French system, after Jabiol *et al.* ,1995)

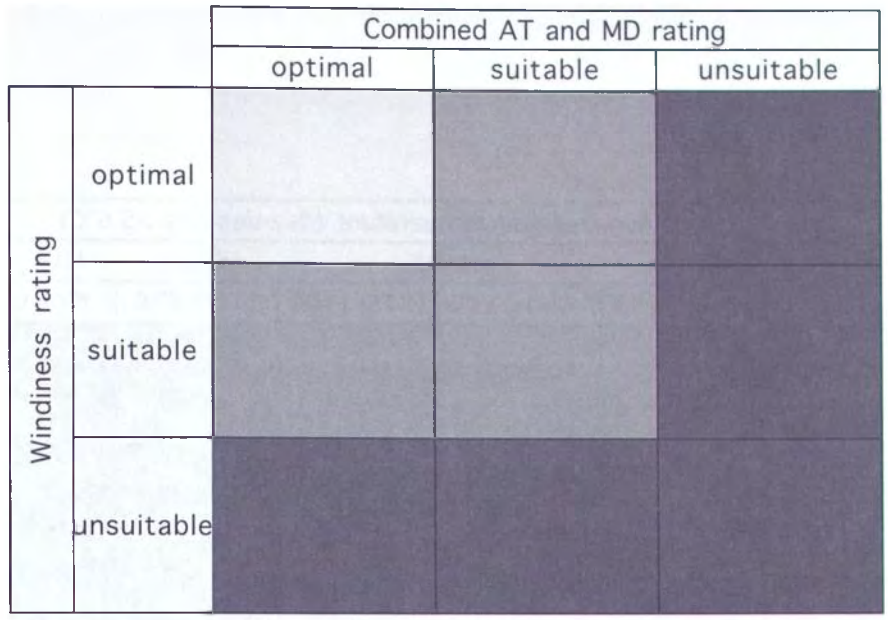


Figure 19a Combining warmth, wetness and windiness ratings in assessing the climatic suitability for a tree species

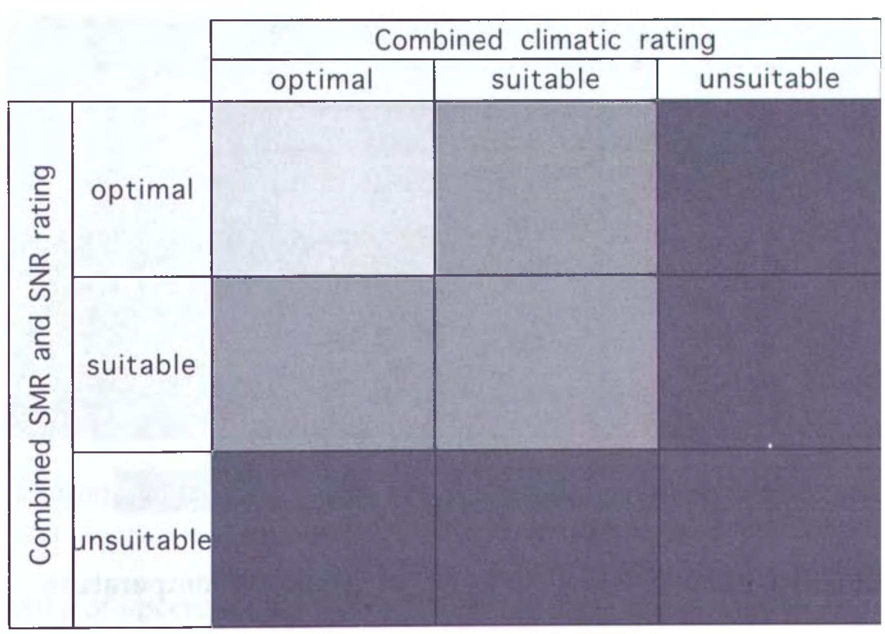


Figure 19b Combining climatic and soil ratings in assessing the suitability of a site for a tree species

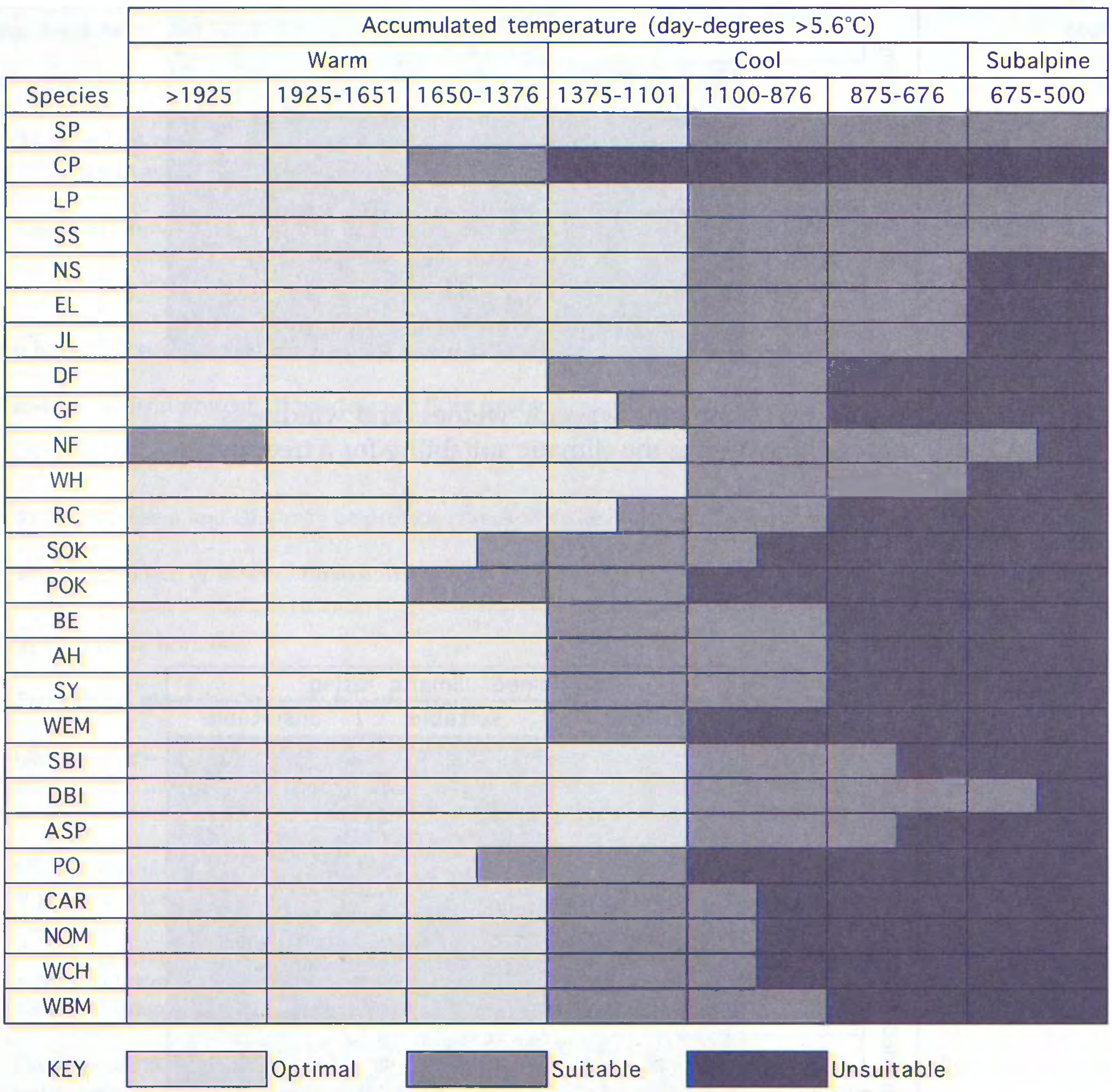


Figure 20 Suitability of species in Britain by accumulated temperature

Figure 21 Suitability of species in Britain by moisture deficit

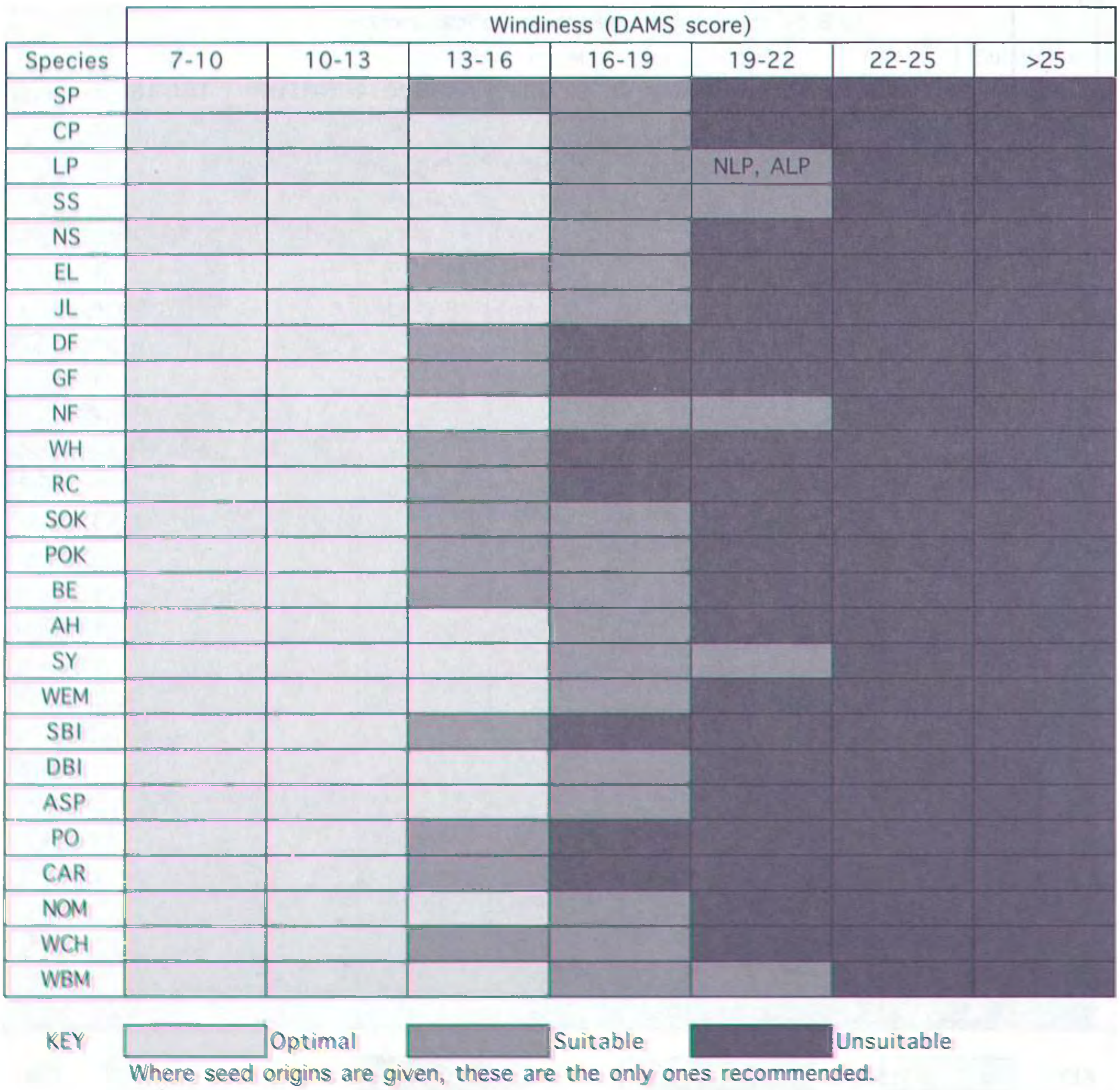


Figure 22 Suitability of species in Britain by windiness

Species	Soil moisture regime							
	Very wet	Wet	Very moist	Moist	Fresh	Slightly dry	Moderately dry	Very dry
SP								
CP								
LP	ALP,NLP	ALP, NLP	ALP, NLP	KLP	CLP, KLP	CLP, KLP	CLP, KLP	CLP
SS								
NS								
EL								
JL								
DF								
GF								
NF								
WH								
RC								
SOK								
POK								
BE								
AH								
SY								
WEM								
SBI								
DBI								
ASP								
PO								
CAR								
NOM								
WCH								
WBM								

KEY Optimal Suitable Unsuitable

Where seed origins are given, these are the only ones recommended.

Figure 23 Suitability of species in Britain by soil moisture regime

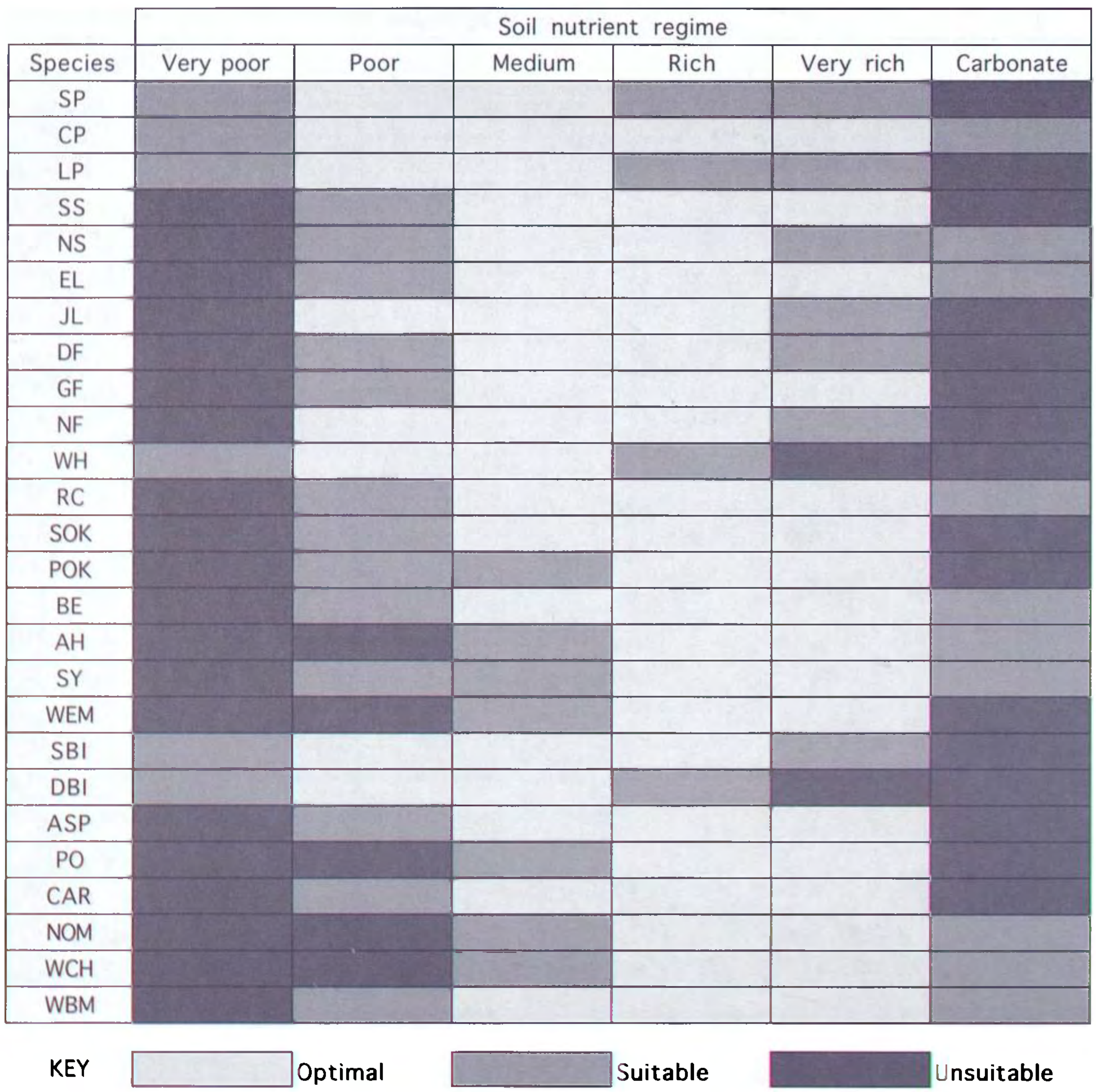
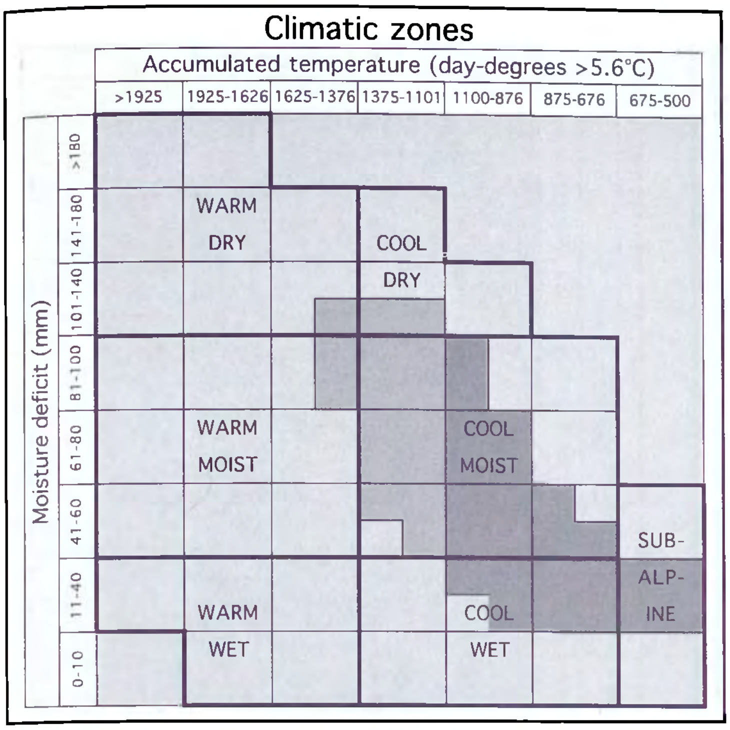
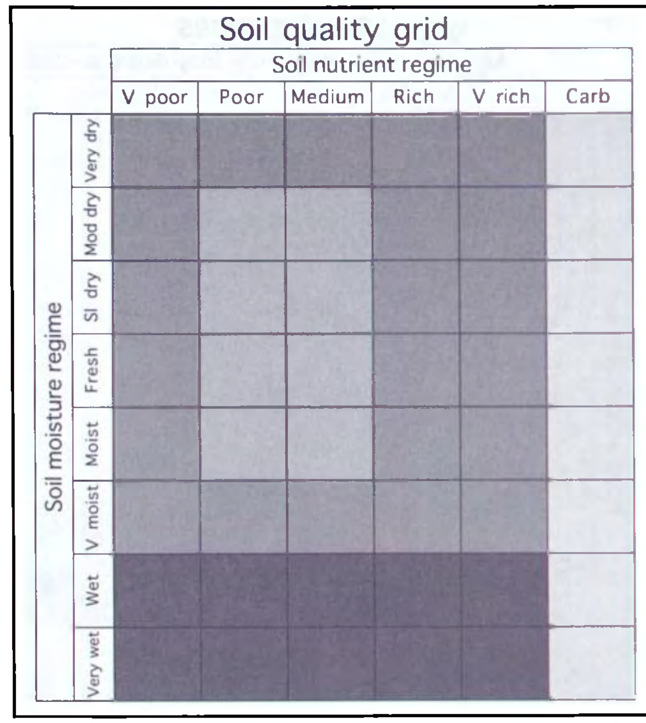


Figure 24 Suitability of species in Britain by soil nutrient regime



Frost hardy. Only Scottish native origins recommended in Wet zone or where AT <876 d-d.

GYC: 10 - 14 in optimal climates and soil qualities,
6 - 10 in suitable climates or soil qualities,
less than 6 in Subalpine zone.



Tolerant of ericaceous vegetation.
Ideal conditions: Slightly dry/Fresh and Poor.
Growth tends to be coarse on richer soils; use not advised on Very rich.

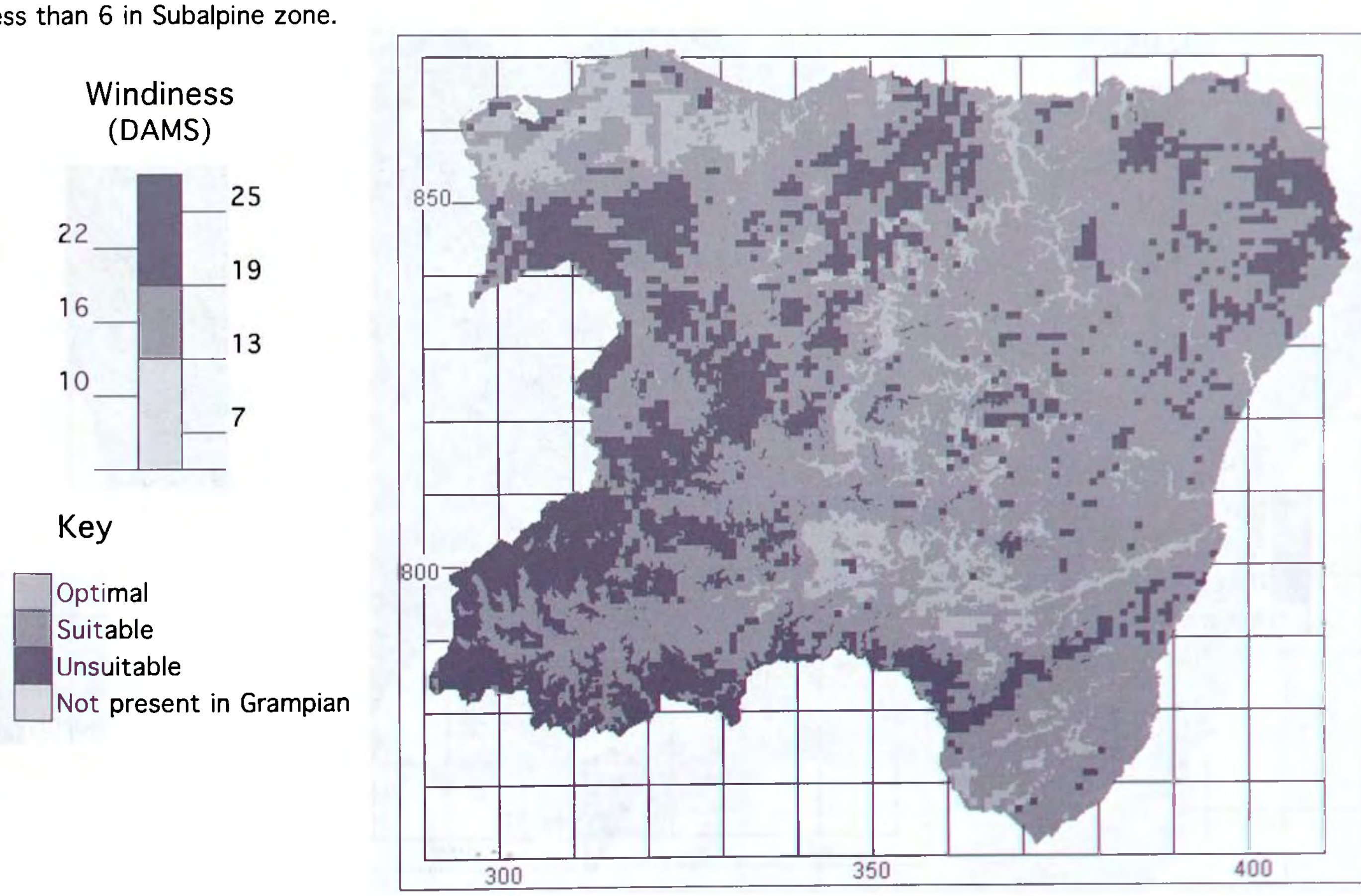
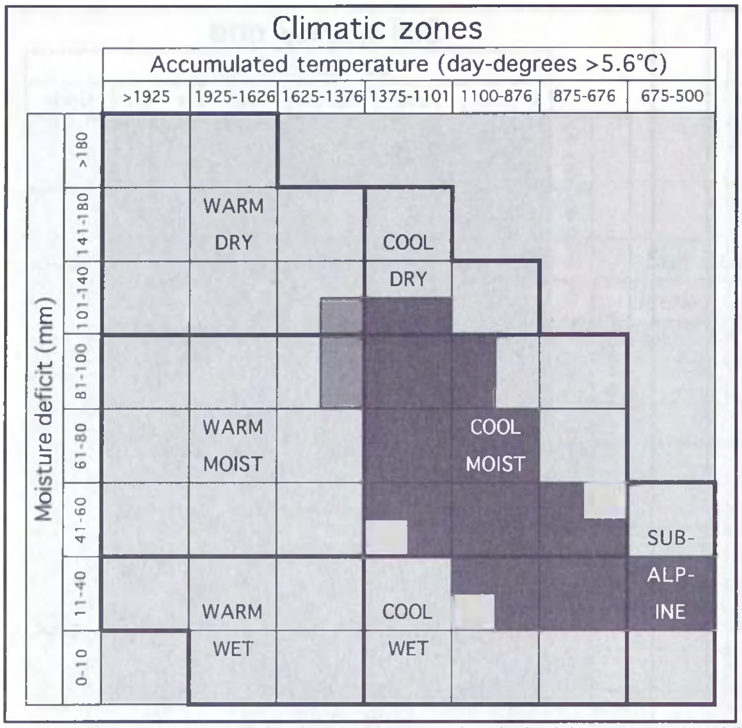
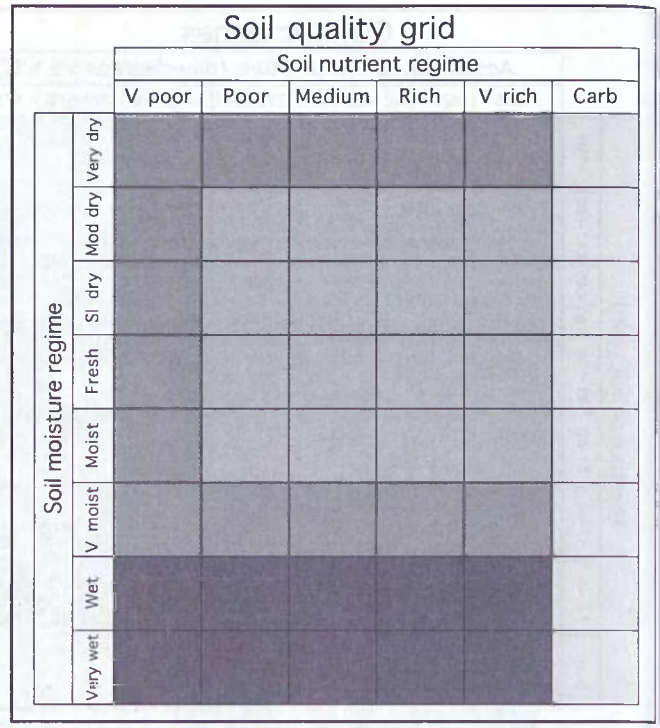


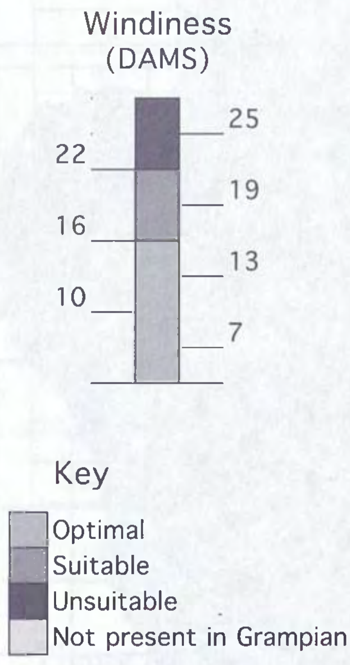
Figure 25 Scots pine





Frost tender when young and may be killed by winter cold.
GYC: 12 - 14 in suitable climates or soil qualities.
Vulnerable to killing by Brunchorstia pinea where AT <1250 d-d.

Ideal conditions: Slightly dry/Fresh and Medium.



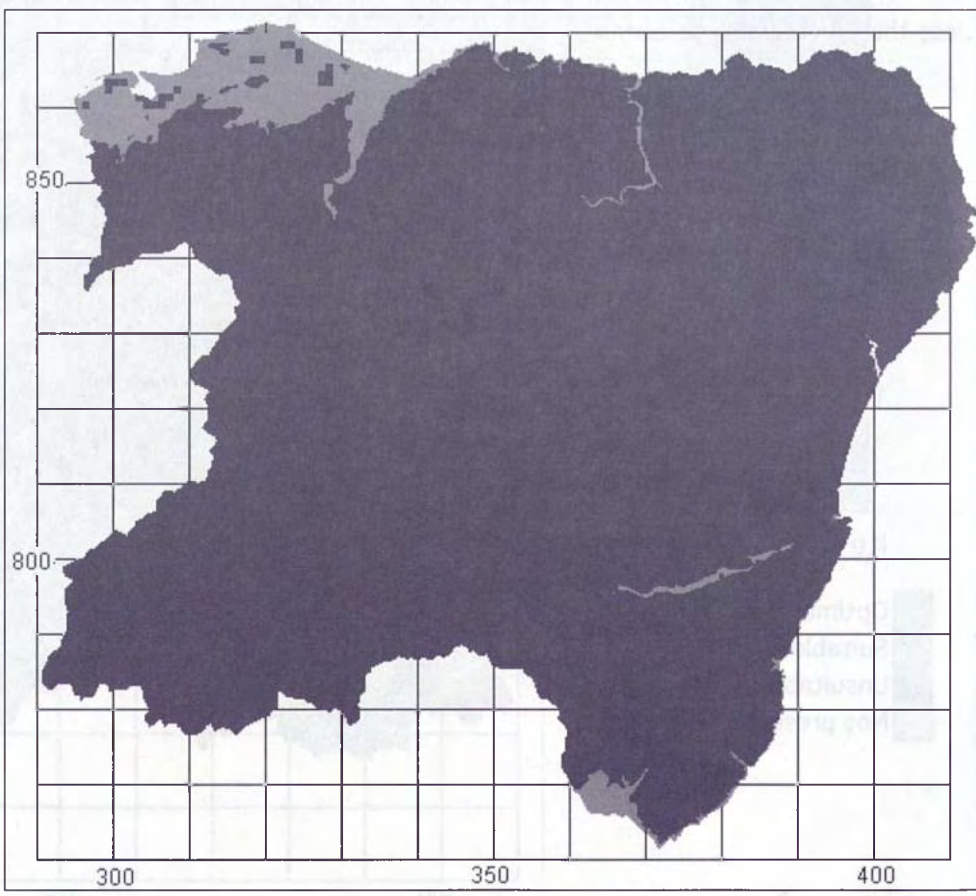
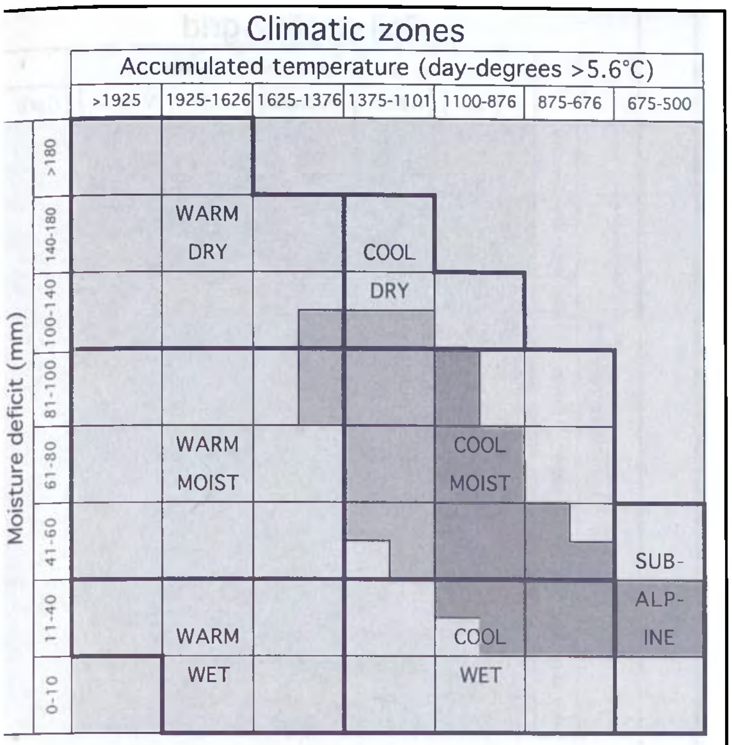
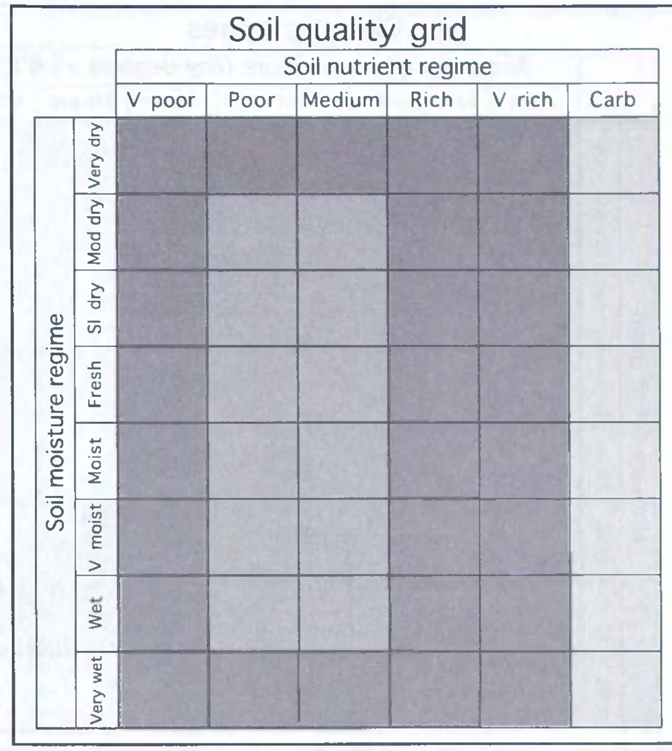


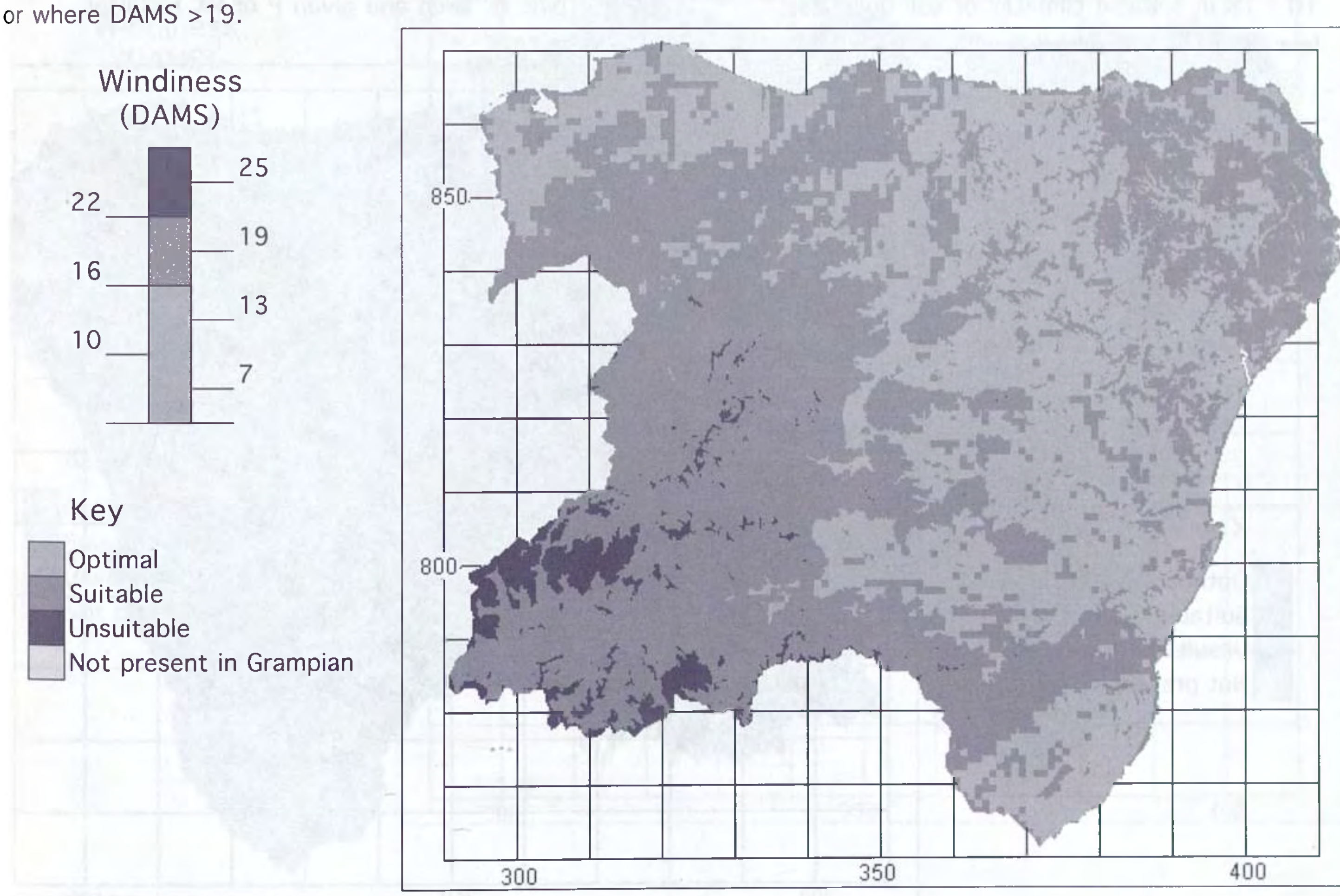
Figure 26 Corsican pine



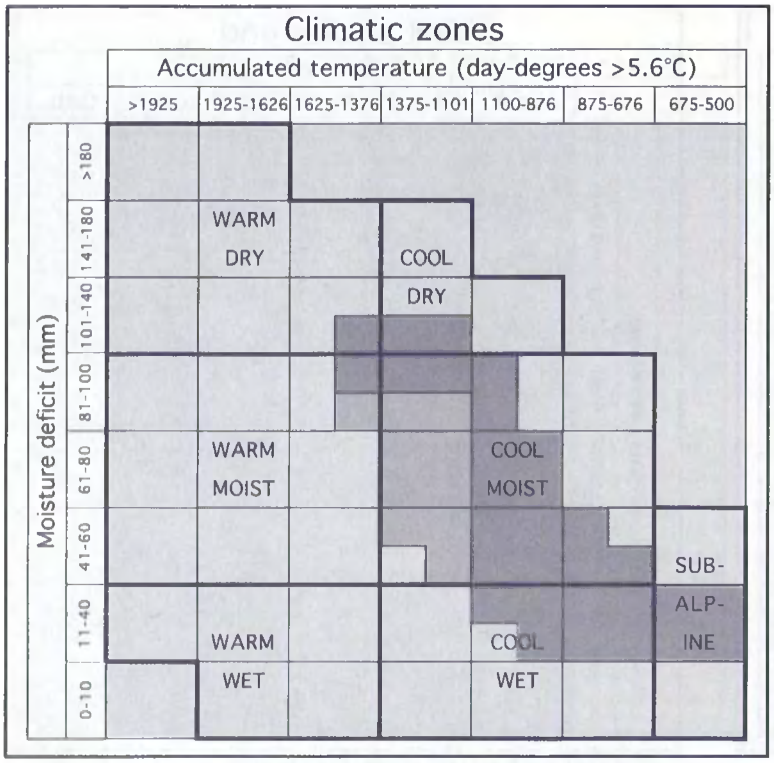
Frost hardy. Coastal origins should be used in Wet climates, Inland origins in Dry climates.
GYC: 10 - 14 in optimal climates and soil qualities, 6 - 10 in suitable climates or soil qualities.
Use only Alaskan origins in Subalpine zone (GYC <6) or where DAMS >19.

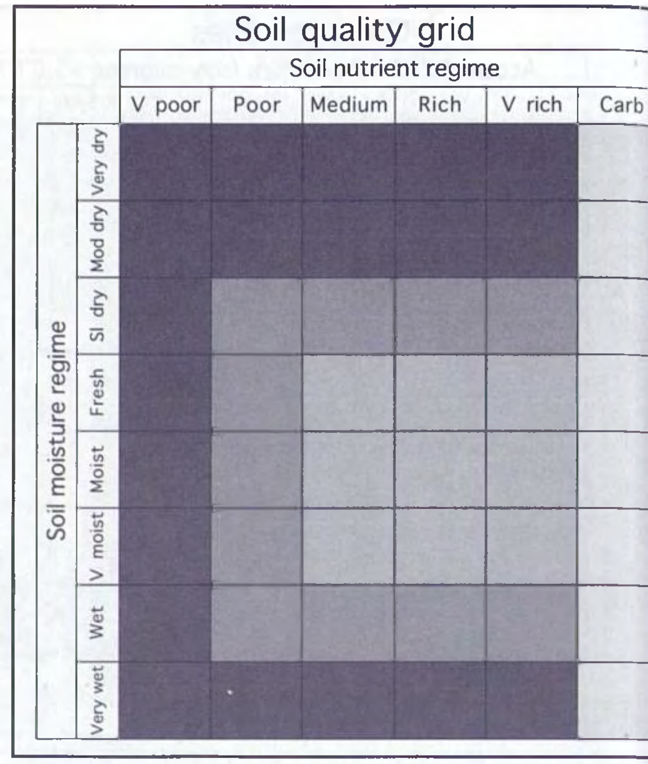


Tolerant of ericaceous vegetation.
On richer soils growth tends to be coarse; use not advised on Very rich soils. North coastal or Alaskan origins recommended for Very wet to Very moist soils, Inland origins for dry soils.



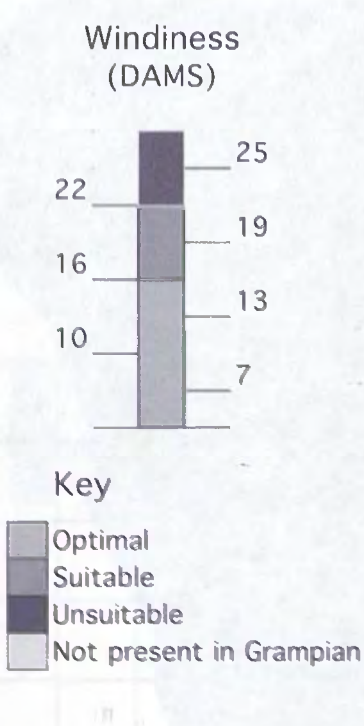
gure 27 Lodgepole pine





Tolerant of salty winds. Frost tender when young.
Only QSS origins recommended, except for Subalpine zone where ASS should be preferred.
GYC: 18 - 24 in optimal climates and soil qualities,
10 - 18 in suitable climates or soil qualities,
less than 10 in Subalpine zone.

Intolerant of ericaceous vegetation.
Ideal conditions: Very moist and Rich/Very rich, but very susceptible to butt-rot.
On Very poor soils can be used in mixture with pine or larch and given P or PK fertiliser.



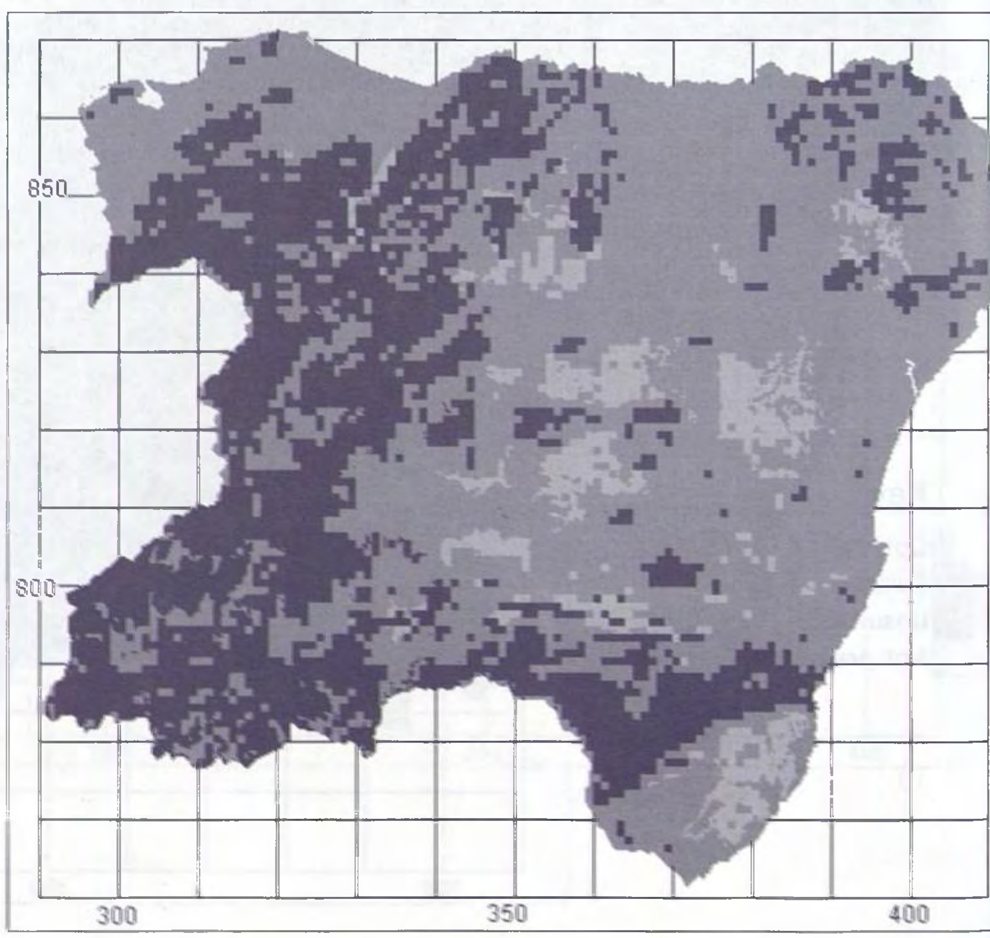
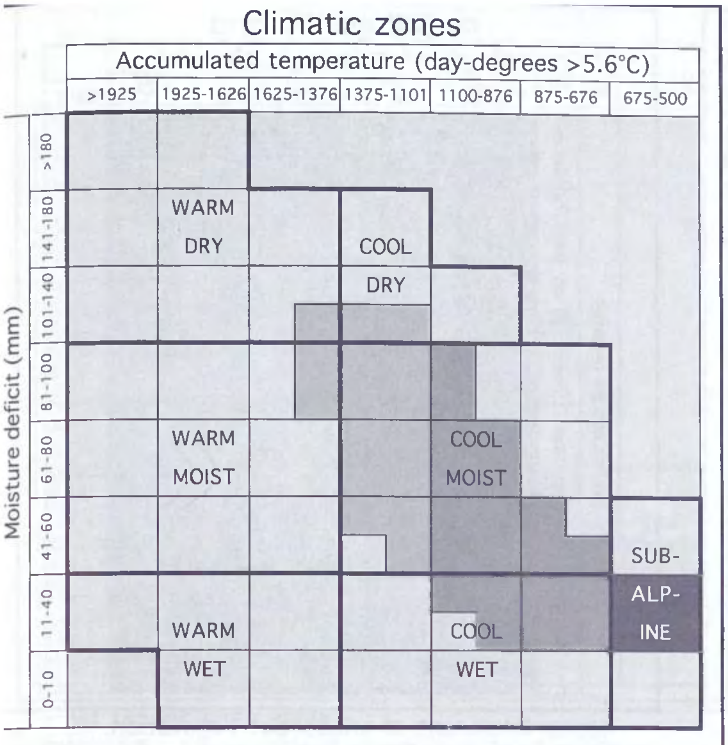
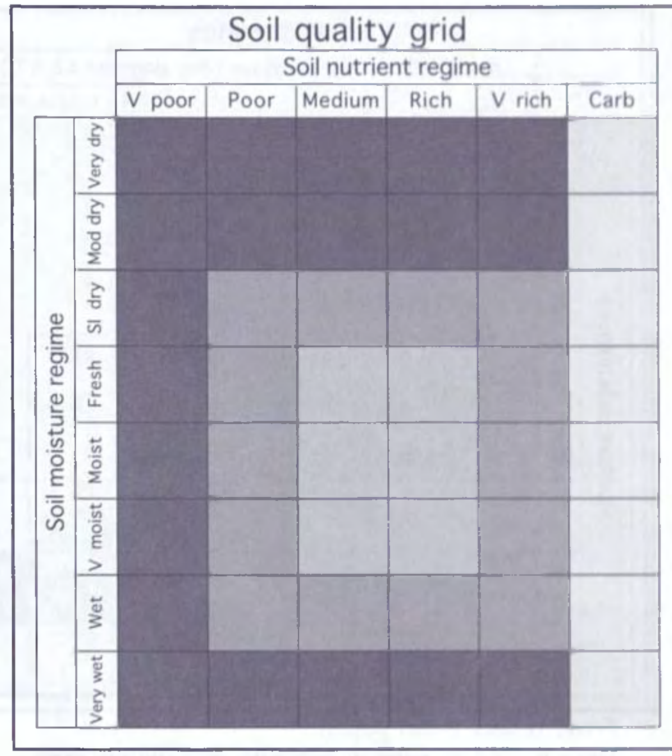


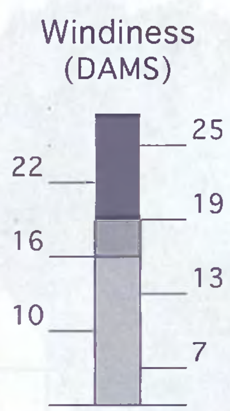
Figure 28 Sitka spruce

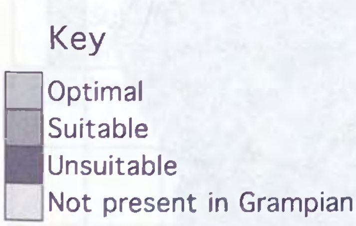


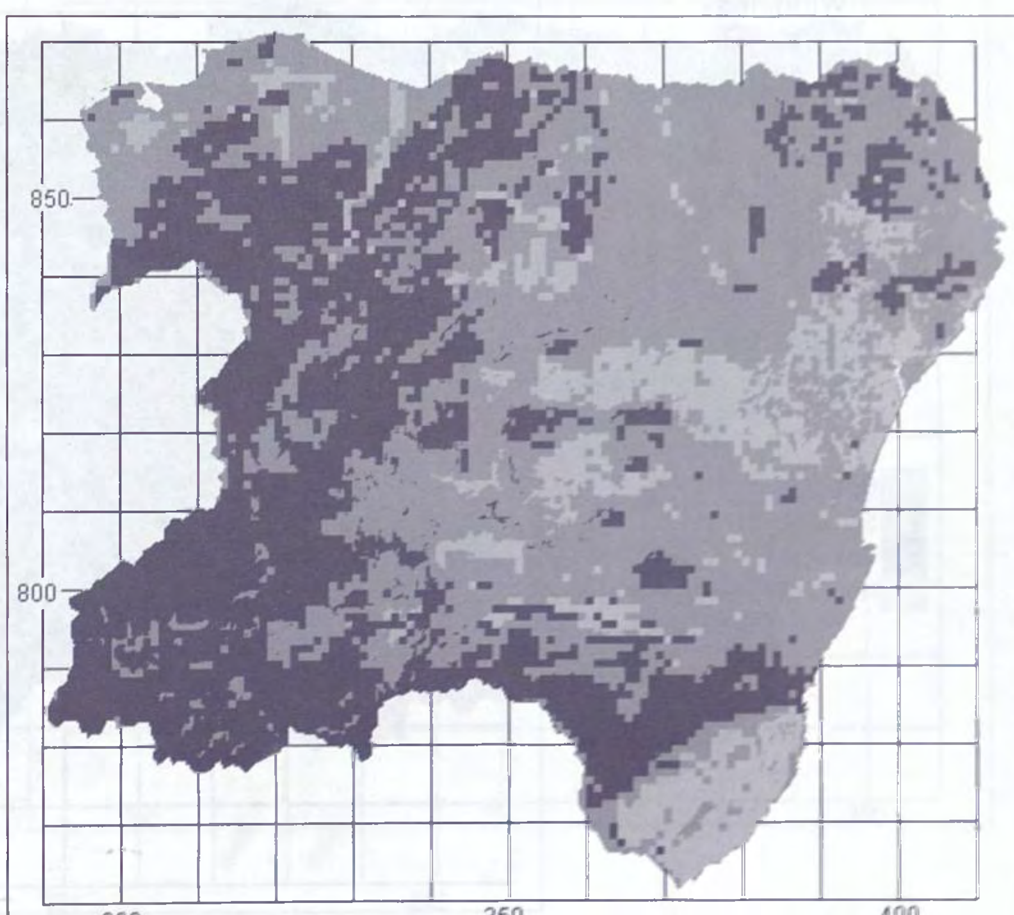
Avoid exposed edges, shelterbelts and copses.
East European origins are fairly frost hardy.
GYC: 16 - 20 in optimal climates and soil qualities,
12 - 16 in suitable climates or soil qualities.



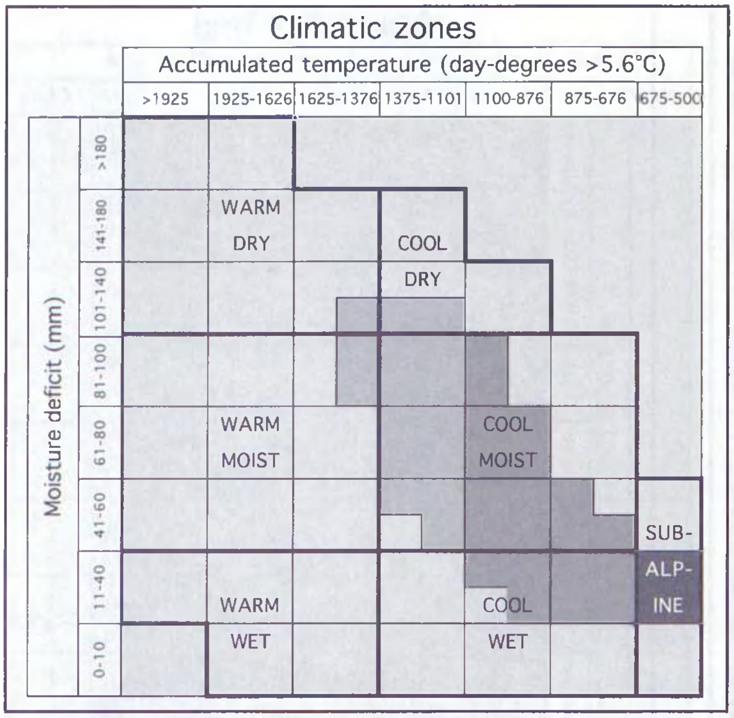
Intolerant of ericaceous vegetation.
On Very rich soils is very susceptible to butt-rot.

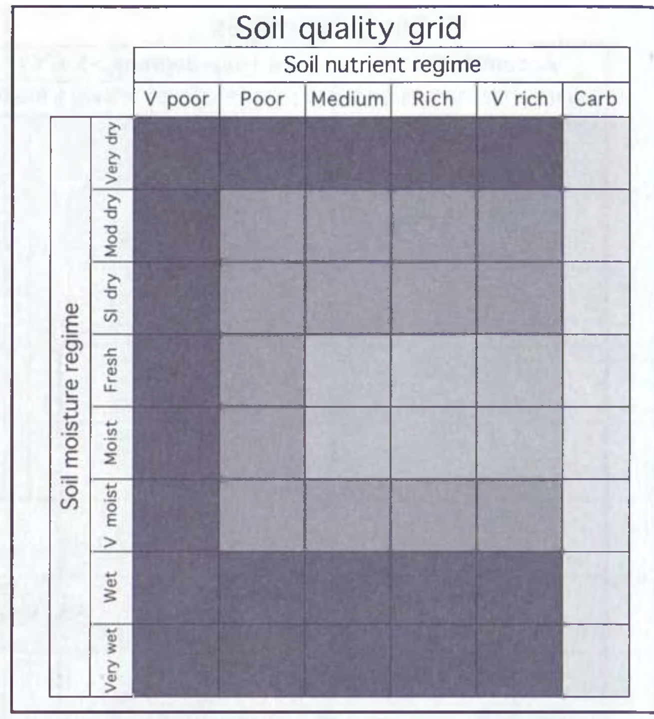






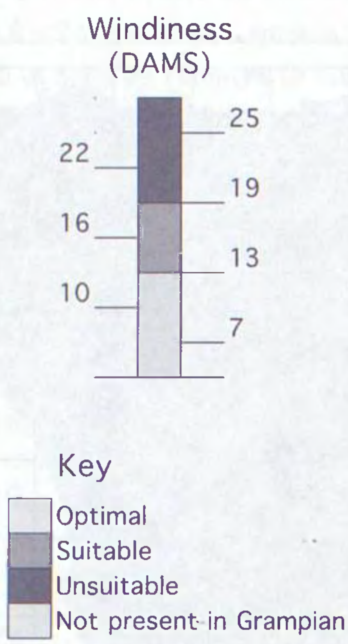
gure 29 Norway spruce





Frost tender when young.
GYC: 8 - 12 in optimal climates and soil qualities,
6 - 8 in suitable climates or soil qualities.

Rather intolerant of ericaceous vegetation.
Ideal conditions: Fresh and Medium.
Susceptible to butt-rot on Rich or Very rich soils.



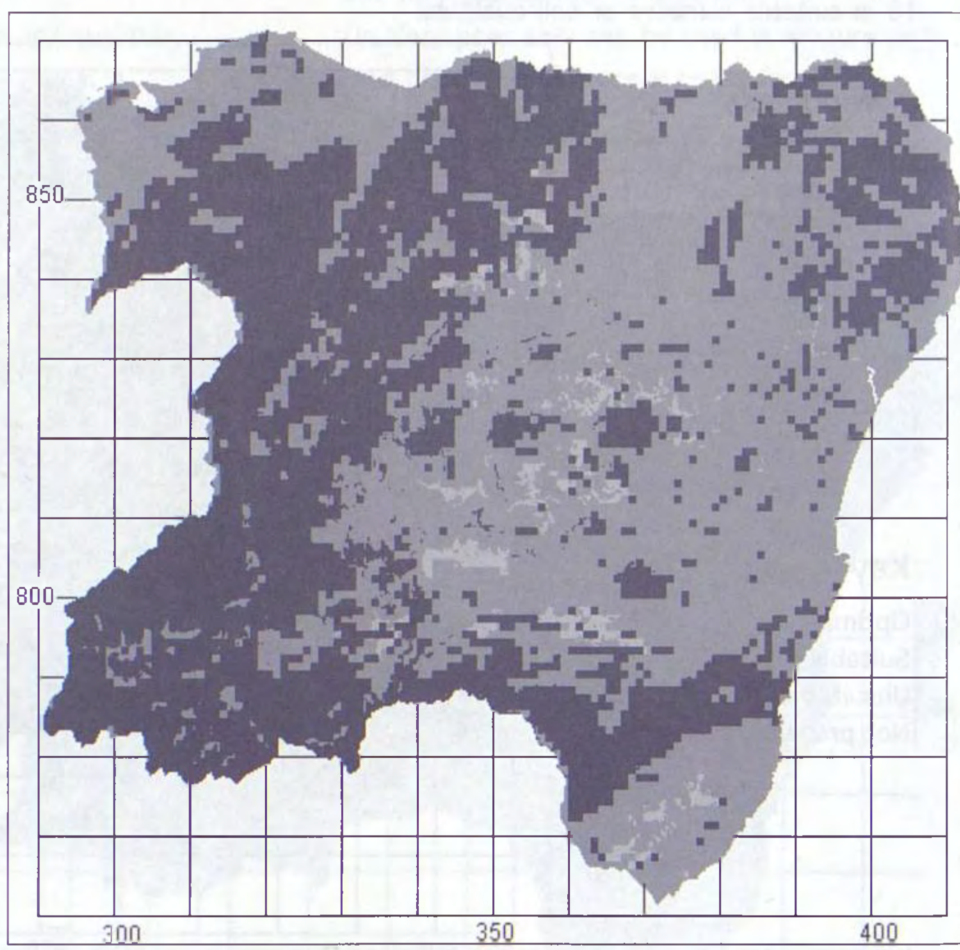
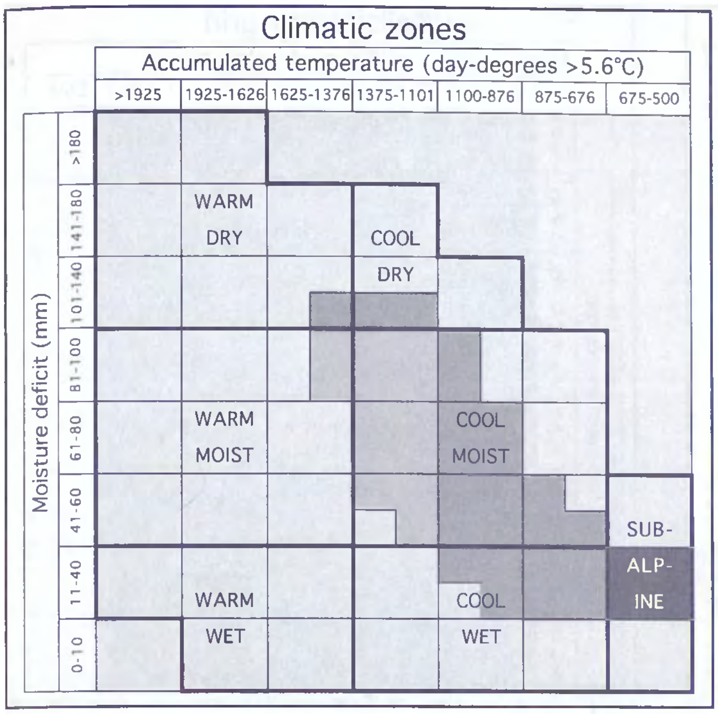
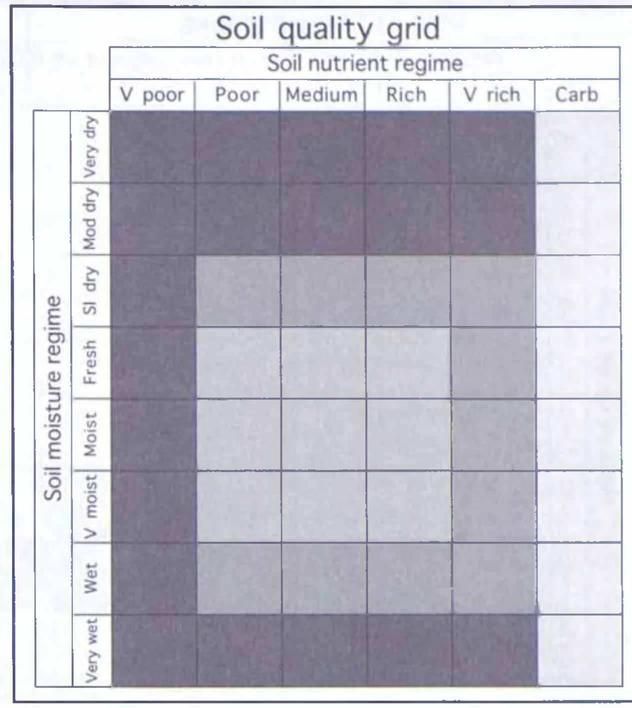


Figure 30 European larch



Frost tender when young.
GYC: 10 - 14 in optimal climates and soil qualities,
6 - 10 in suitable climates or soil qualities.



Fairly tolerant of ericaceous vegetation.
Ideal conditions: Moist and Poor.
Susceptible to butt-rot on Rich or Very rich soils.

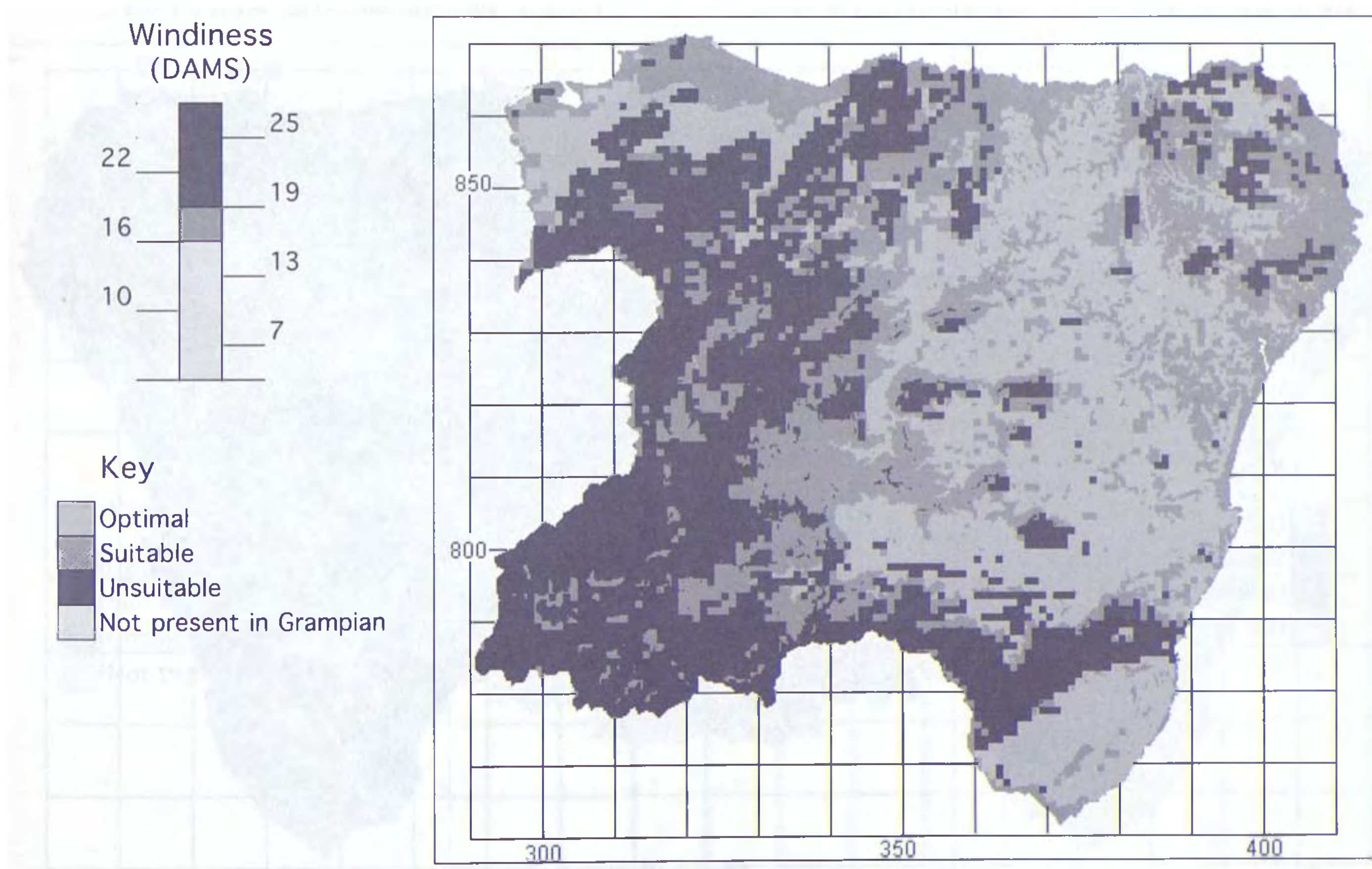
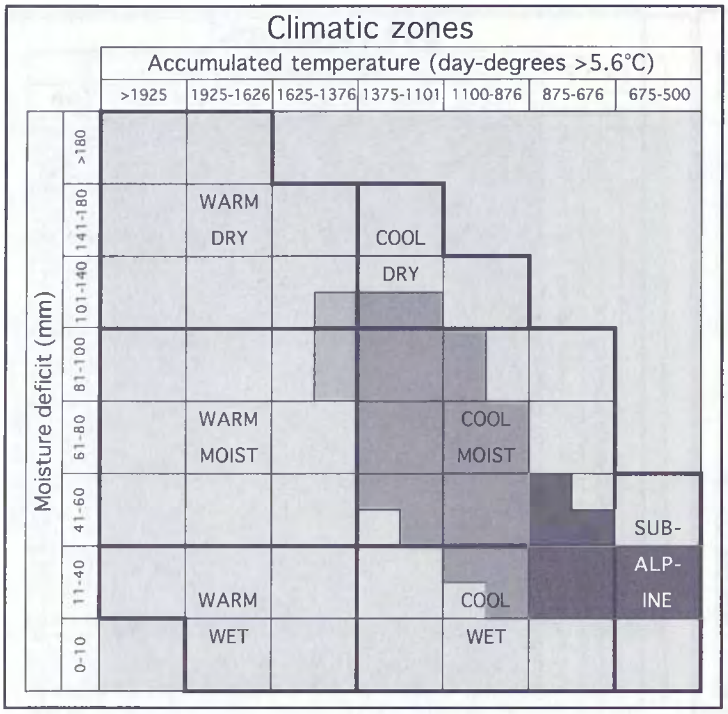
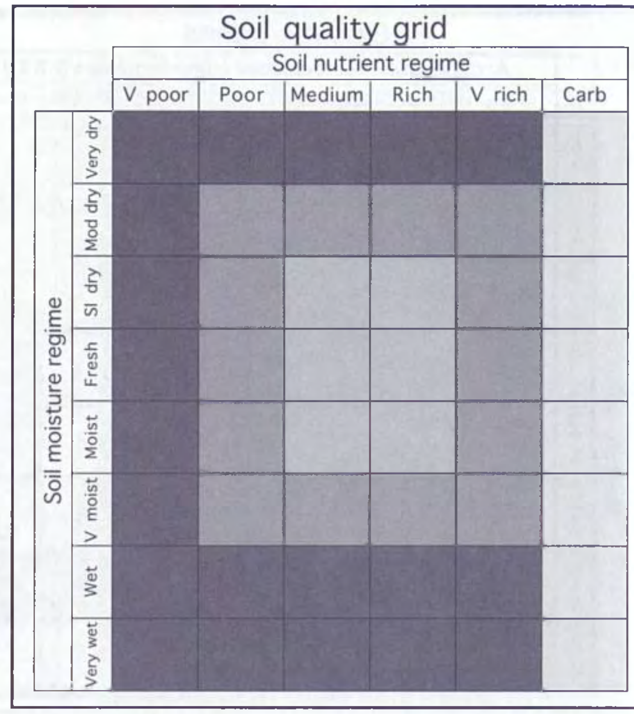


Figure 31 Japanese larch



Frost tender when young.
Suffers defoliation by drying winds in winter.
GYC: 18 - 22 in optimal climates and soil qualities, 12 - 18 in suitable climates and soil qualities.
Warm slopes facing SE-SW-NW are to be preferred.



Very intolerant of ericaceous vegetation.
Ideal conditions: Fresh and Rich. Not recommended for Very moist soils because of coarse growth and poor timber quality.
Natural regeneration better on dry sites.

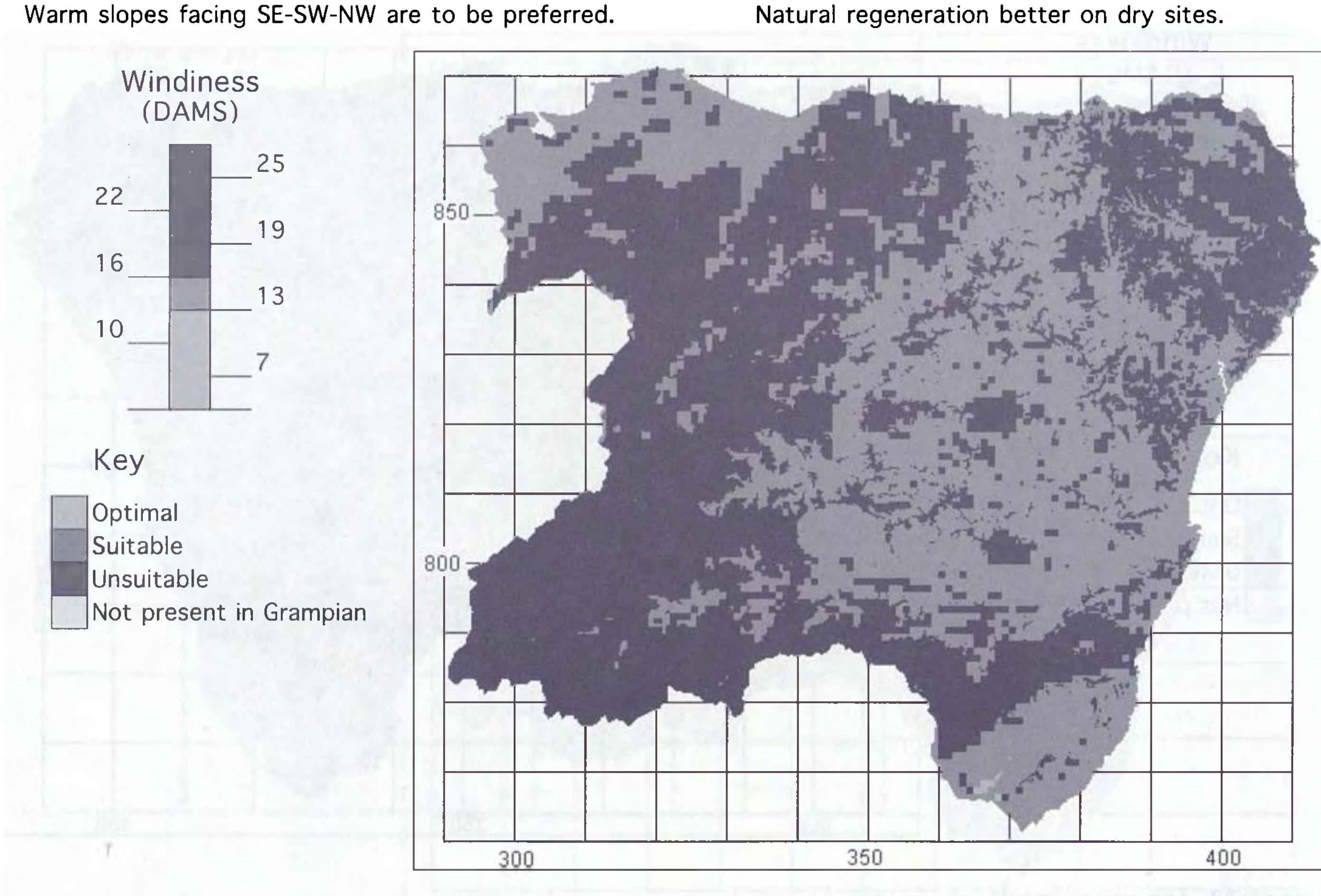
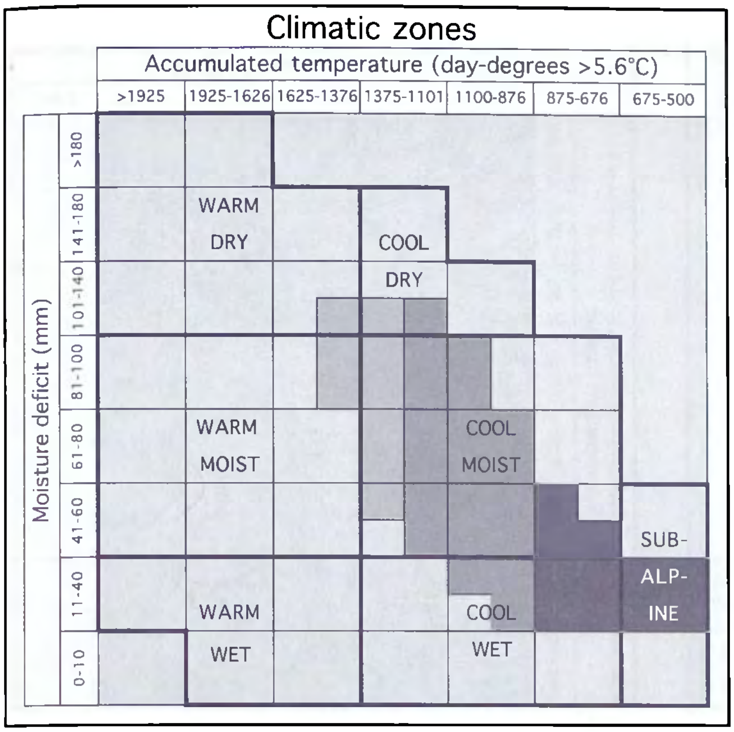
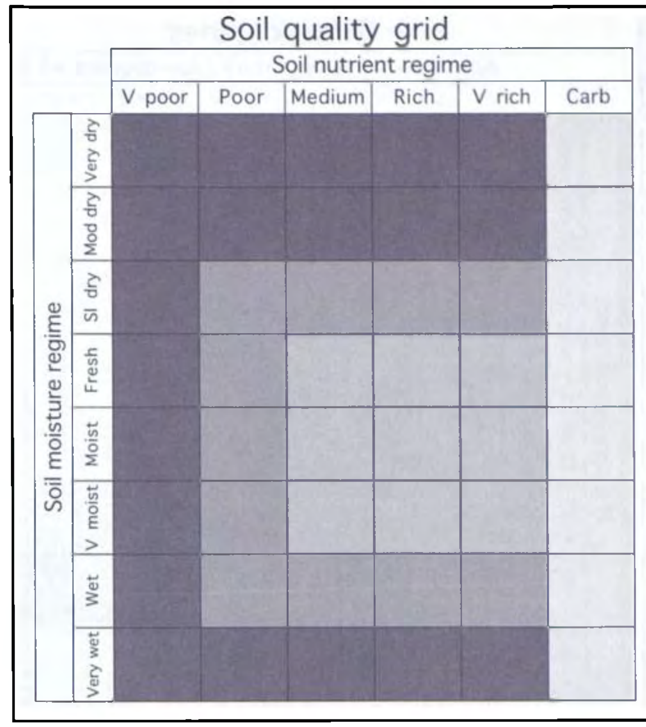


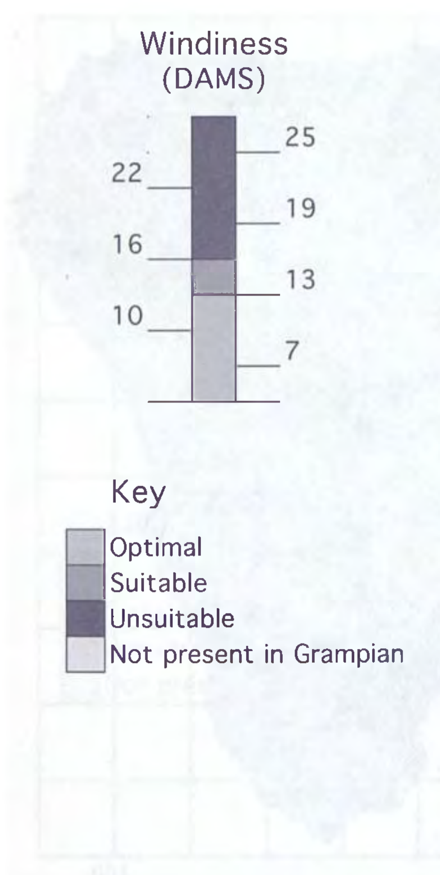
Figure 32 Douglas fir



Frost tender when young.
Suffers defoliation by drying winds in winter.
GYC: 20 - 26 in optimal climates and soil qualities,
16 - 20 in suitable climates or soil qualities.



Intolerant of ericaceous vegetation.
Ideal conditions Moist and Rich.
To avoid drought crack do not plant on slopes facing between SE, SW and NW.



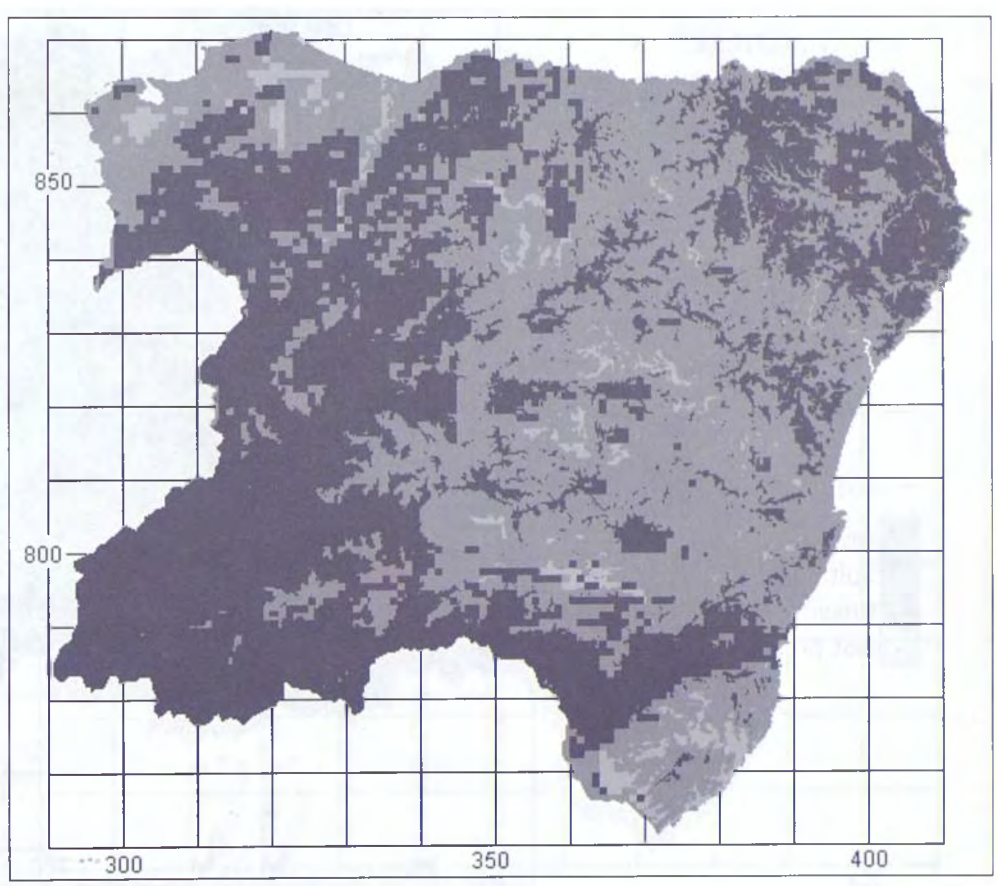
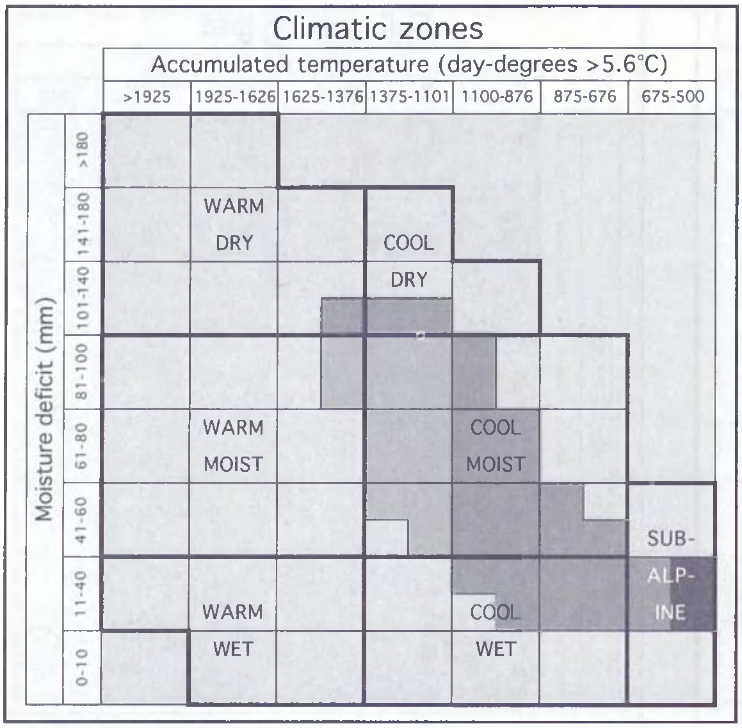
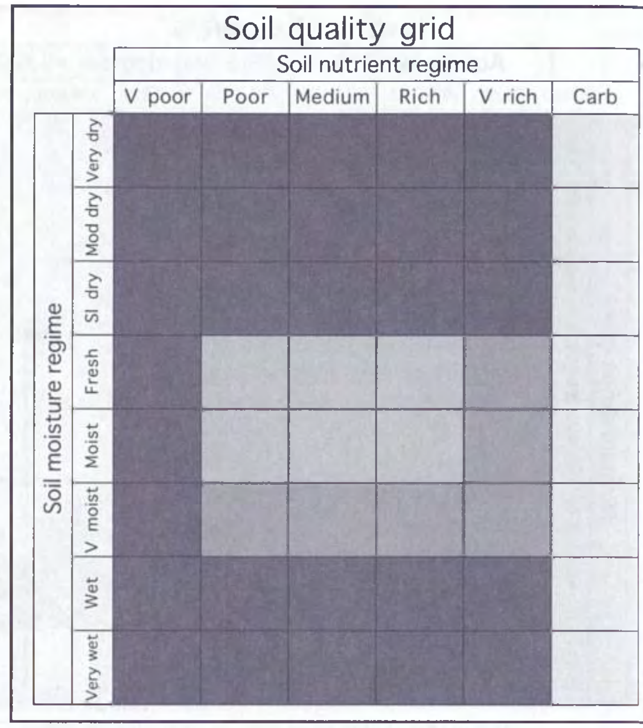


Figure 33 Grand fir





GYC: 18 - 20 in optimal climates and soil qualities, 12 - 18 in suitable climates and soil qualities.

Rather intolerant of ericaceous vegetation. To avoid drought crack do not plant on slopes facing between SE, SW and NW.

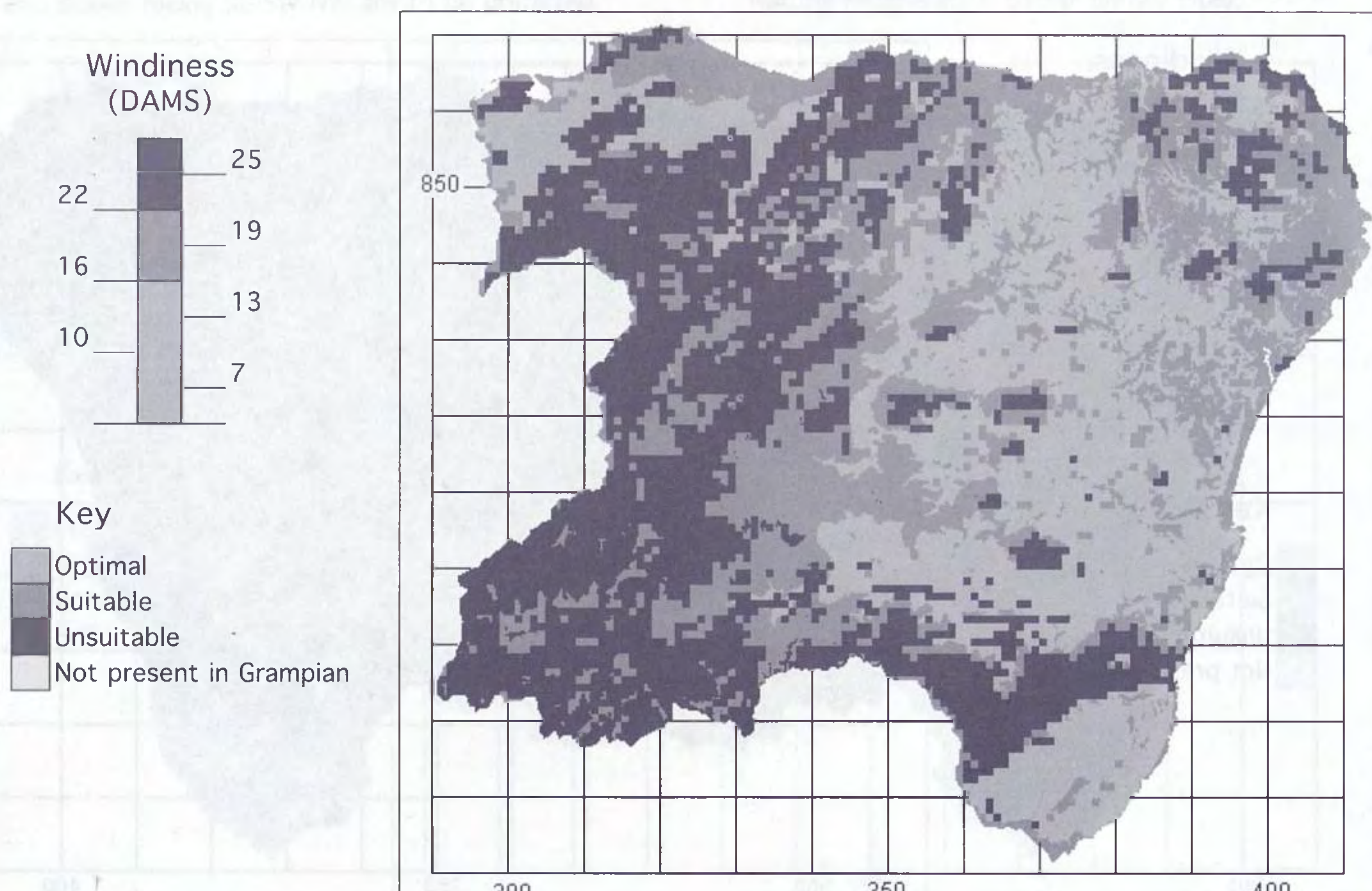
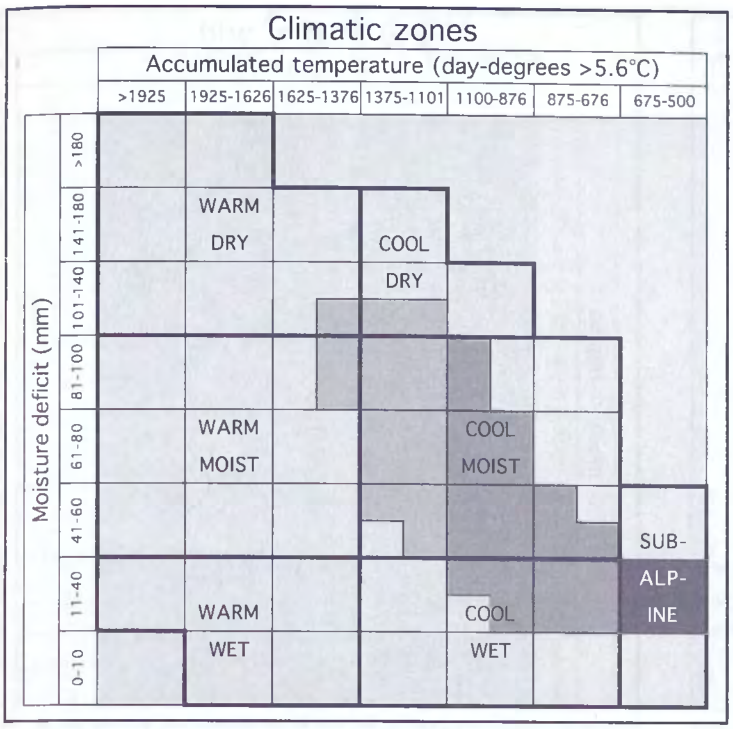
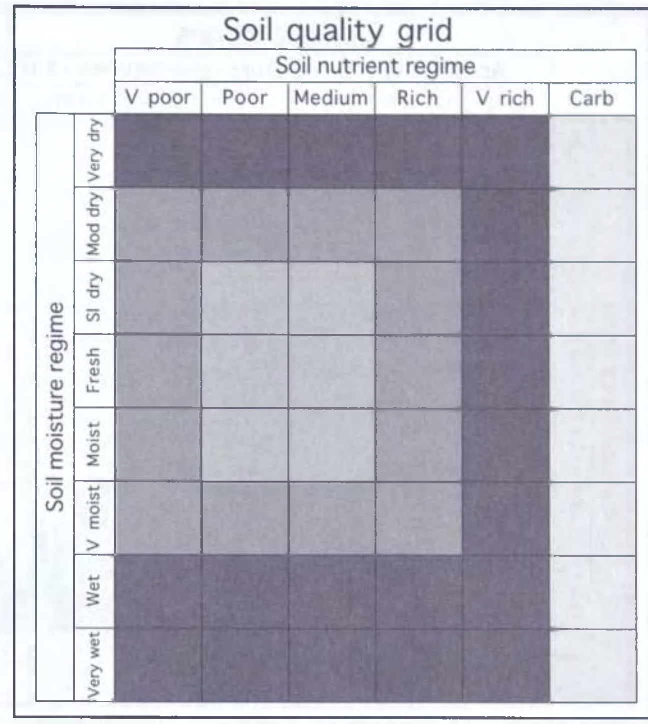


Figure 34 Noble fir



Suffers defoliation in drying winds.
Frost tender when young.
GYC: 16 - 18 in optimal climates and soil qualities,
12 - 16 in suitable climates or soil qualities.



Rather intolerant of ericaceous vegetation.
Ideal conditions Fresh/Poor. Not recommended for Rich soils because of poor stem form and susceptibility to butt-rot.

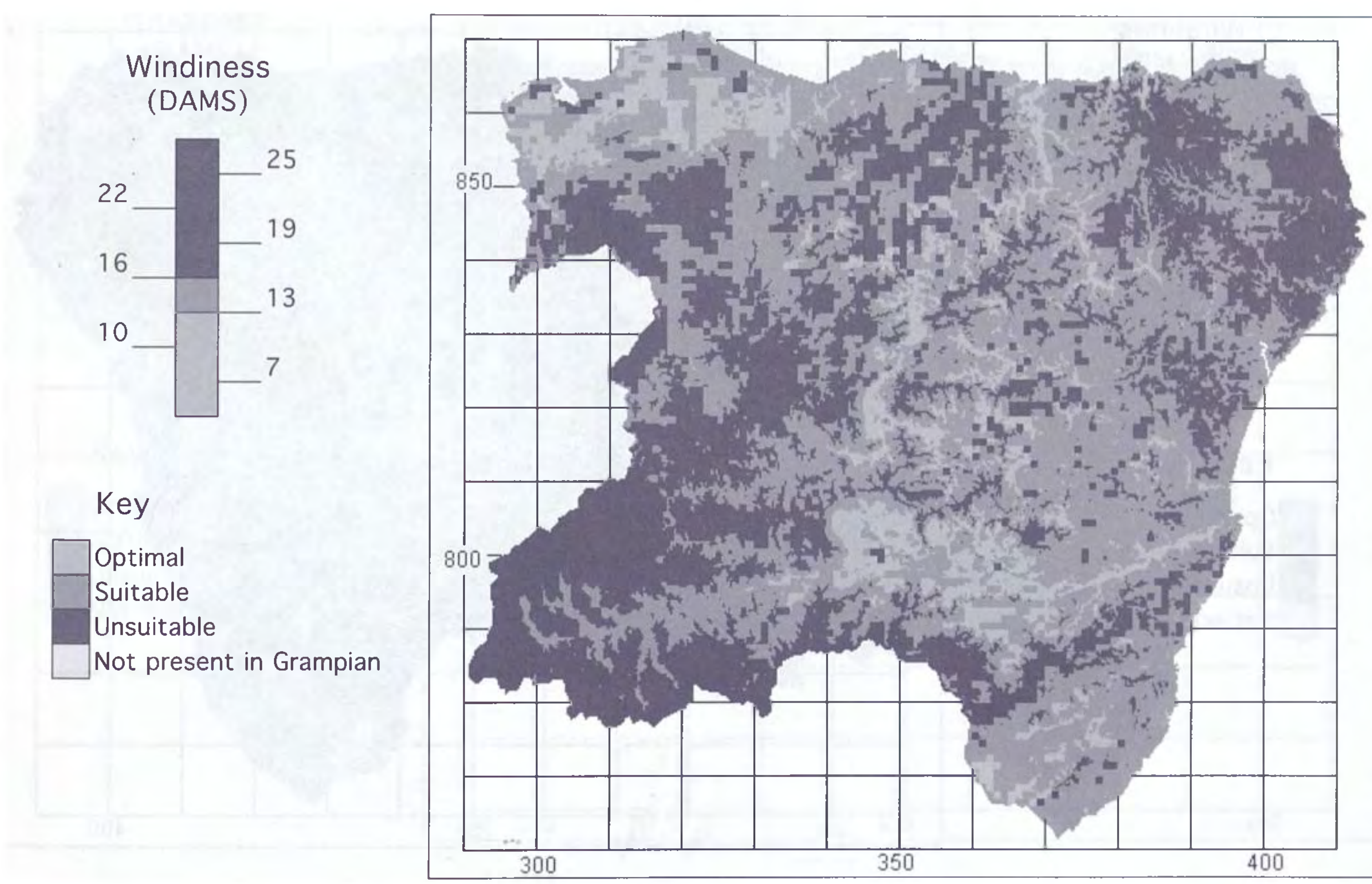
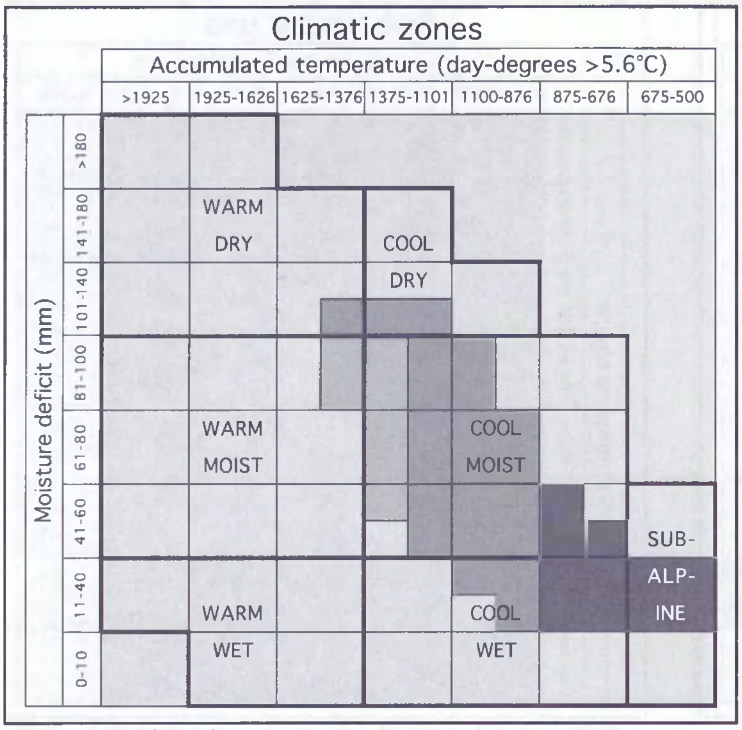
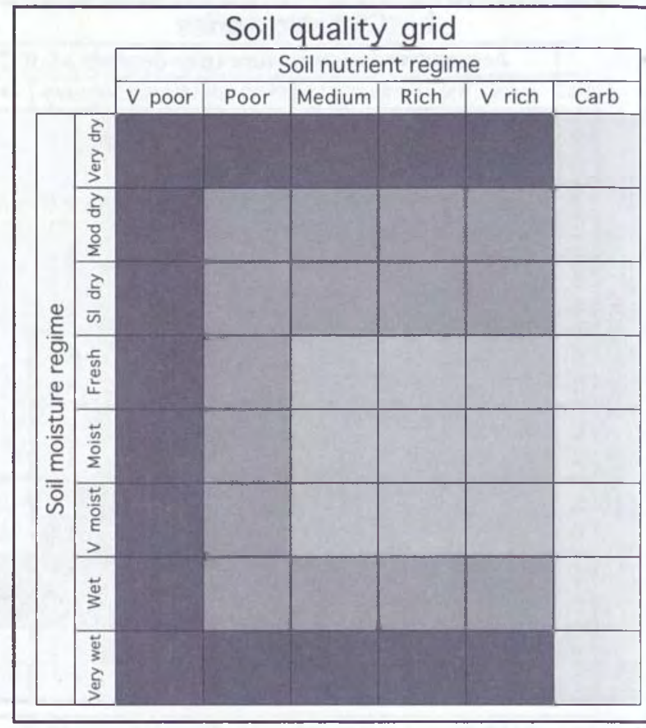


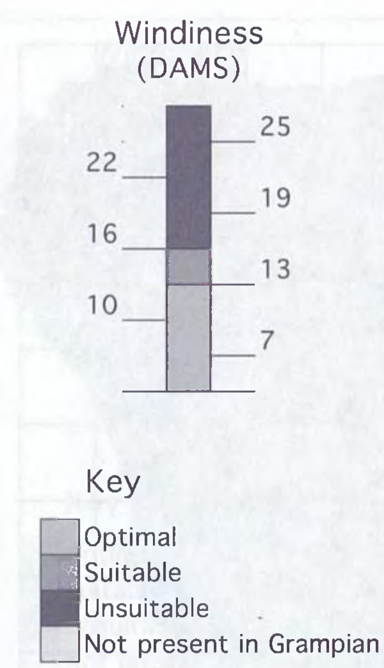
Figure 35 Western hemlock



Frost tender when young.
GYC: 14 - 18 in optimal climates and soil qualities, 12 - 14 in suitable climates or soil qualities.



Rather intolerant of ericaceous vegetation.
Litterfall is high in calcium.
Very palatable to browsers.
Very susceptible to butt-rot.



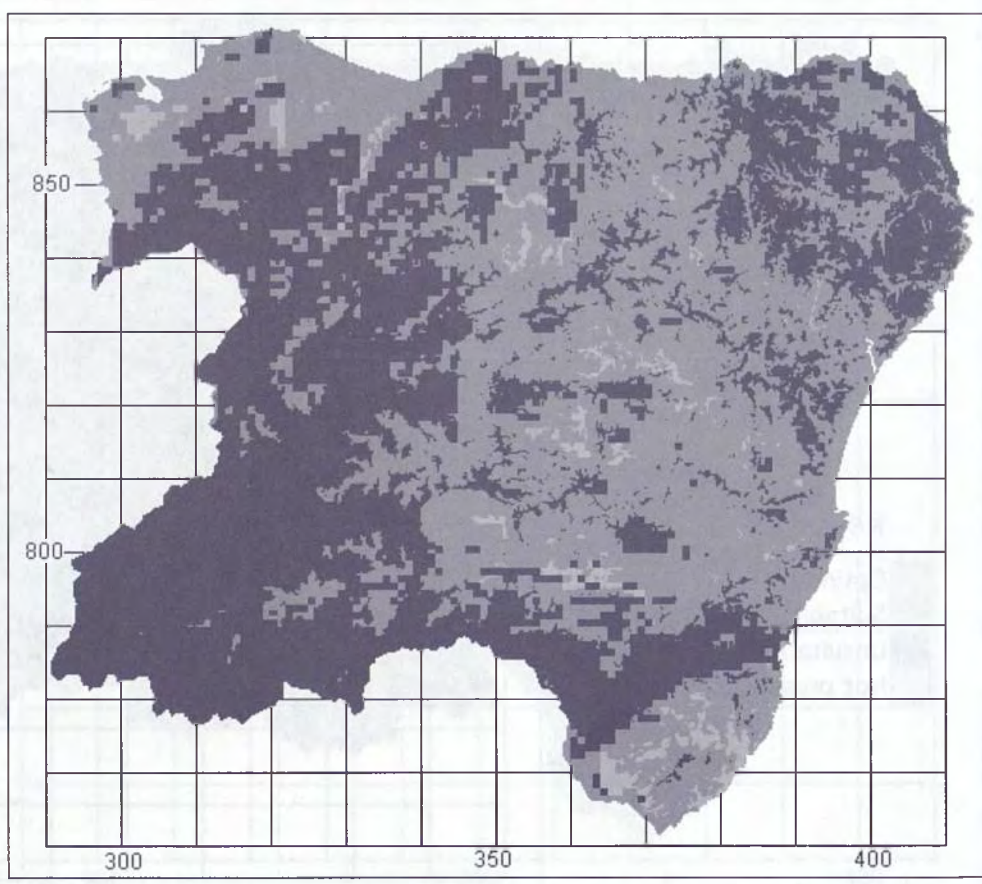
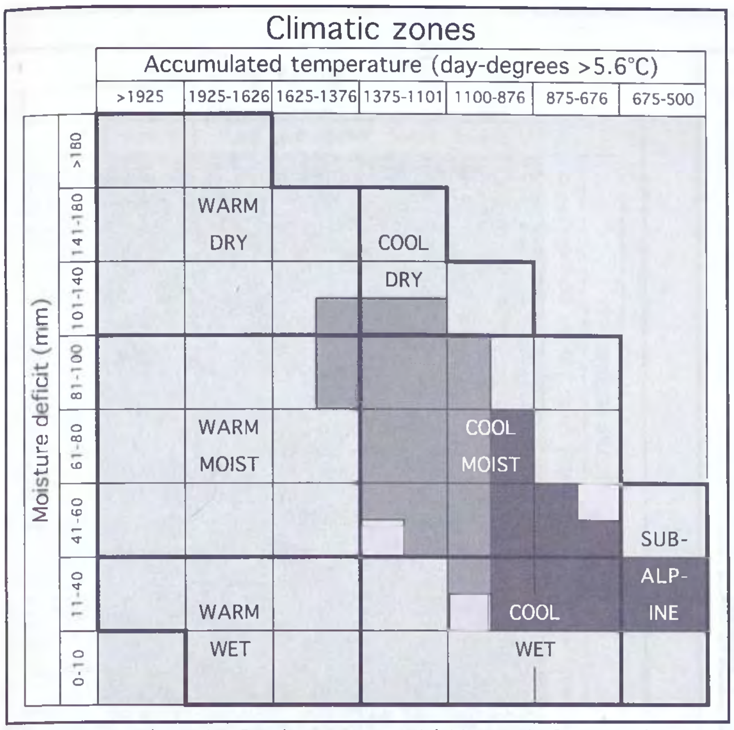
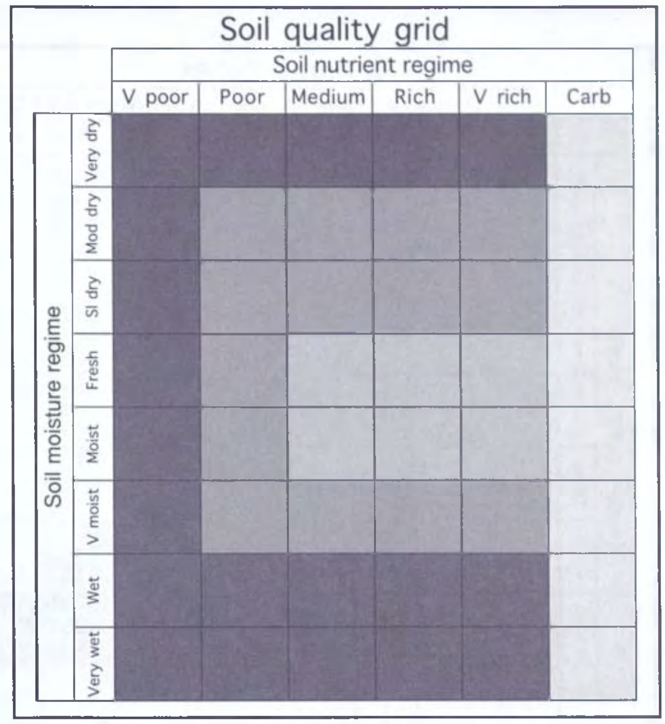


Figure 36 Western red cedar



Frost tender. In Cool zones avoid N or NE-facing slopes.
GYC: 4 in suitable climates and soil qualities.



Rather intolerant of ericaceous vegetation.
Ideal conditions: Fresh and Rich.

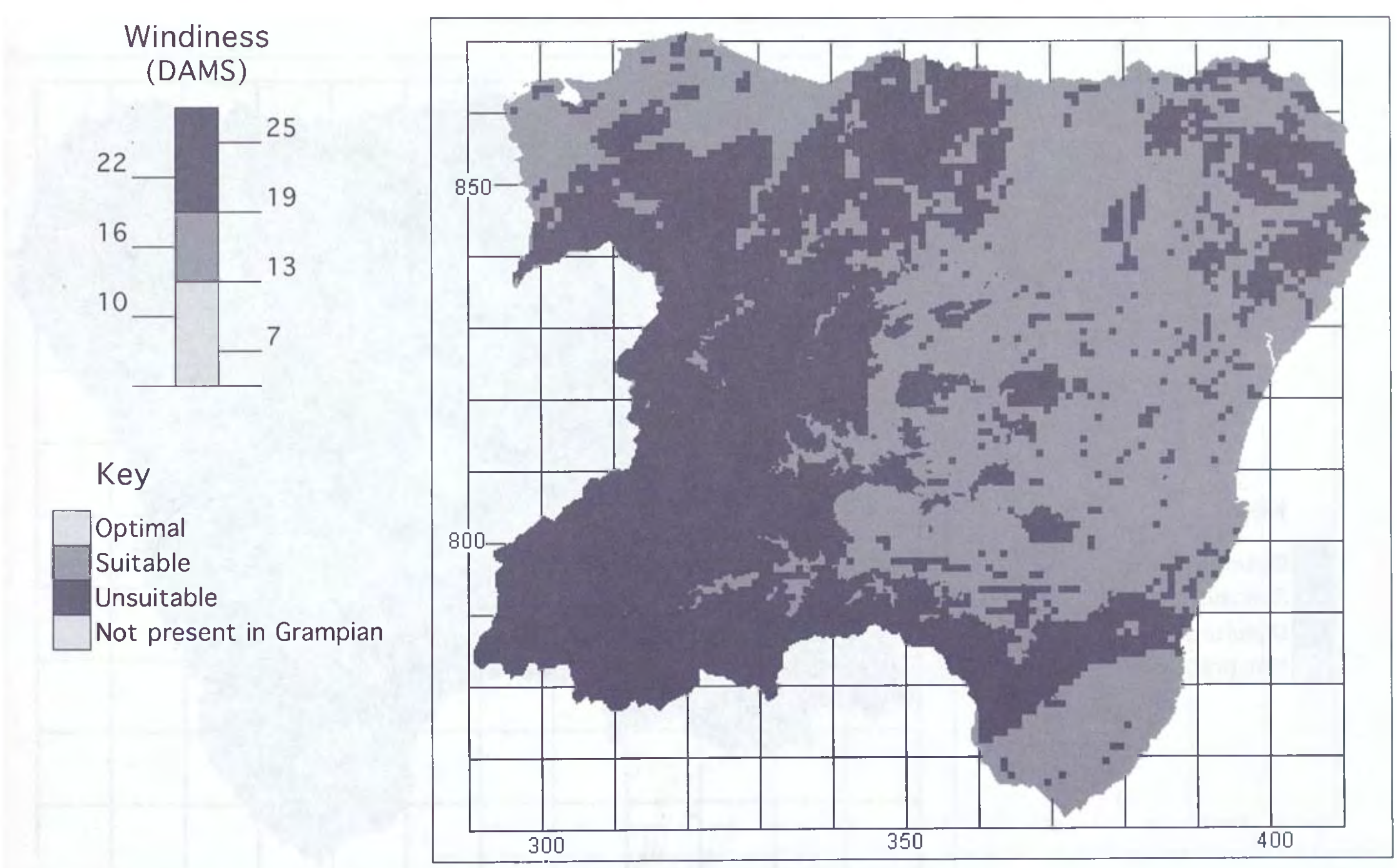
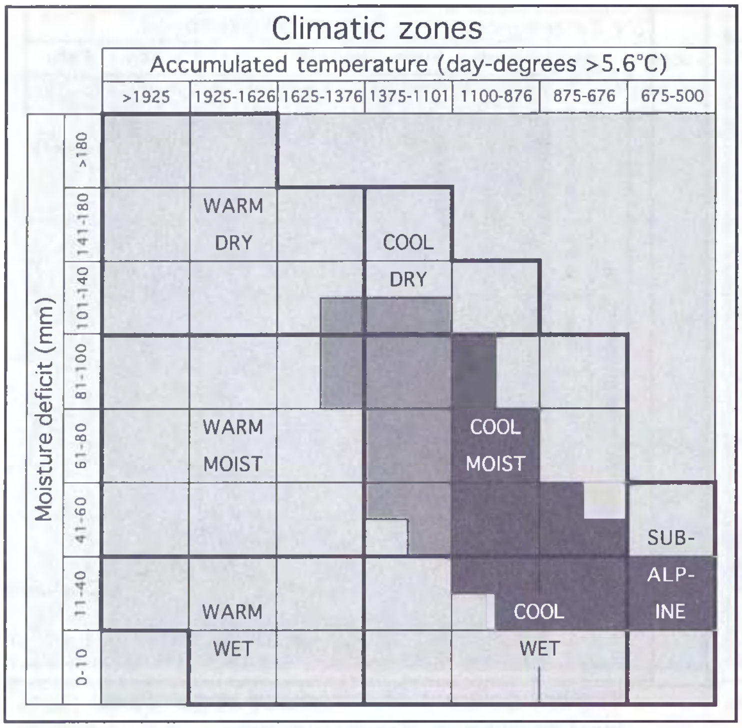
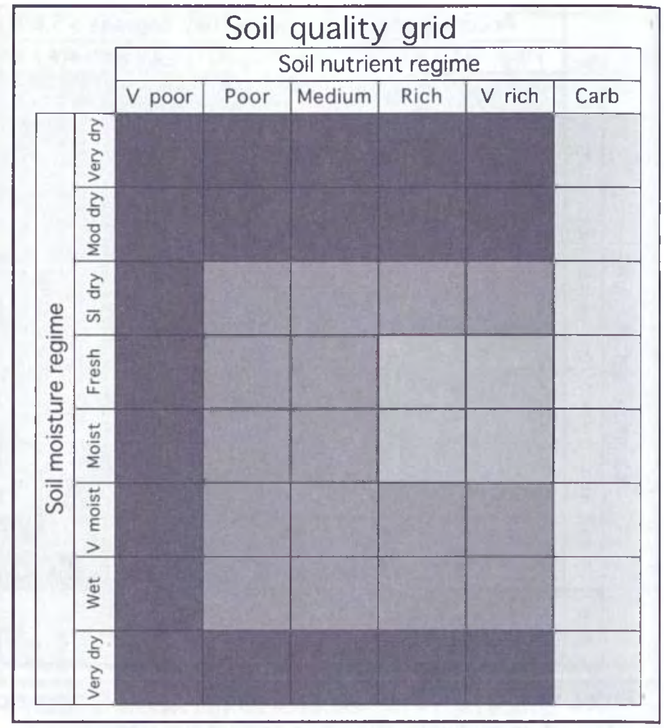


Figure 37 Sessile oak



Frost tender. In Cool zones avoid N or NE-facing slopes.
GYC: 4 in suitable climates and soil qualities.



Intolerant of ericaceous vegetation.
Ideal conditions: Moist and Rich.

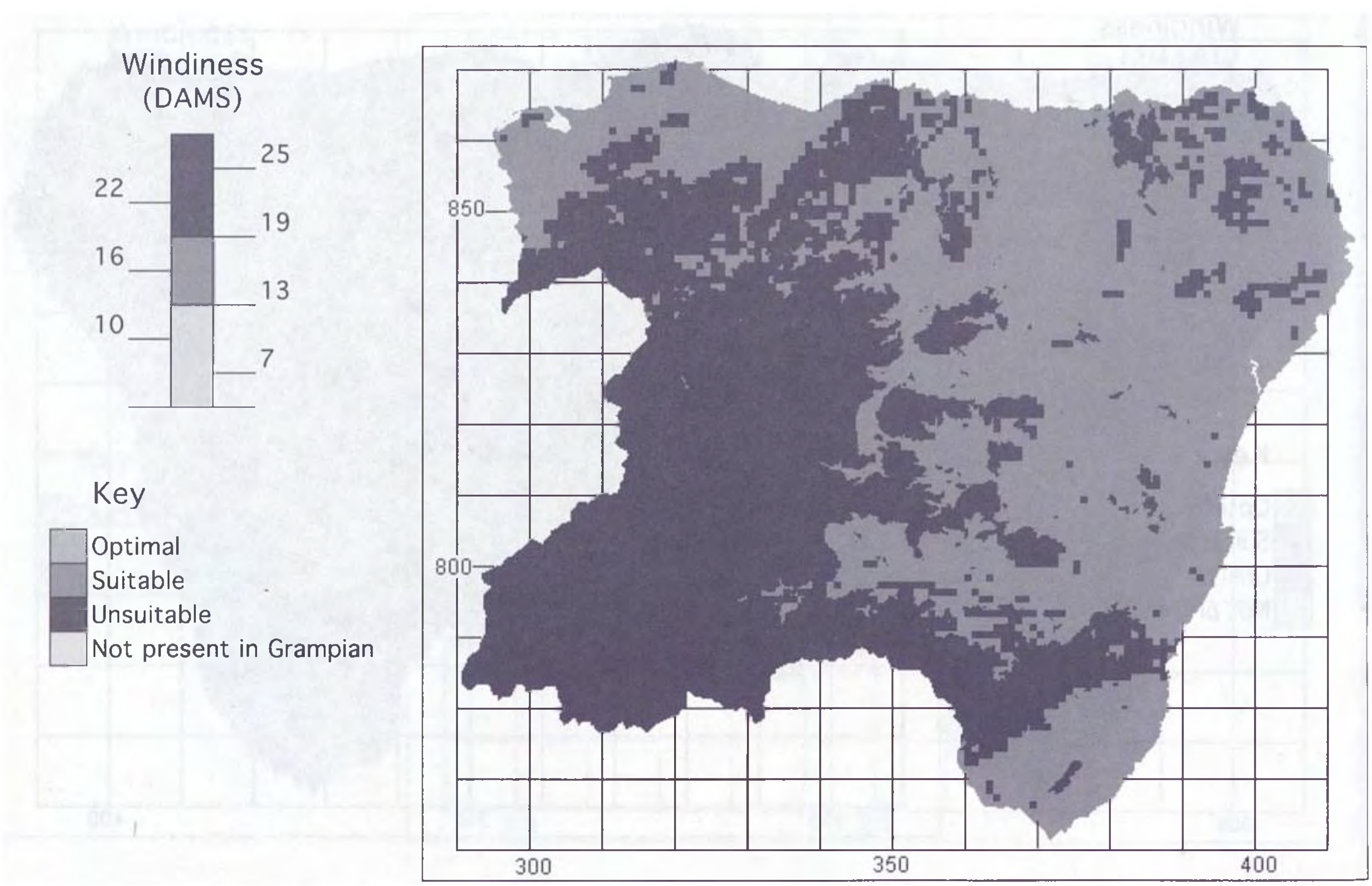
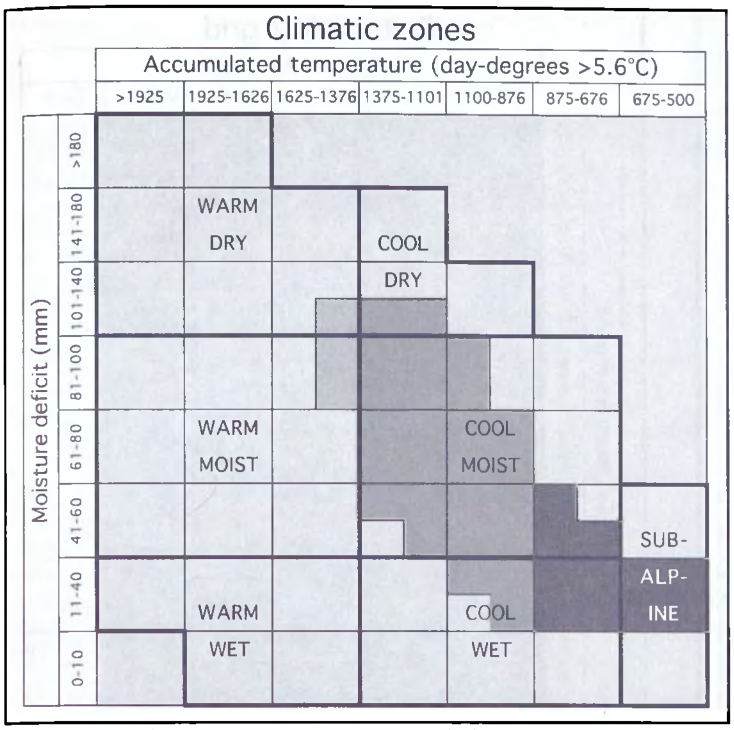
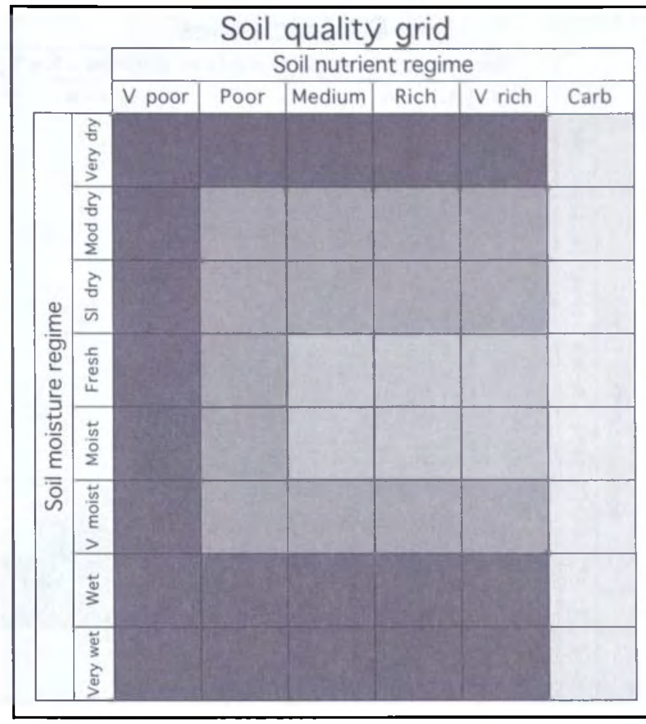


Figure 38 Pedunculate oak





Frost tender. In Warm zones avoid dry S or SW-facing slopes.
GYC: 6 - 8 in optimal climates and soil qualities,
4 - 6 in suitable climates or soil qualities.

Avoid soils with fluctuating water-table.
Ideal conditions Fresh and Rich.

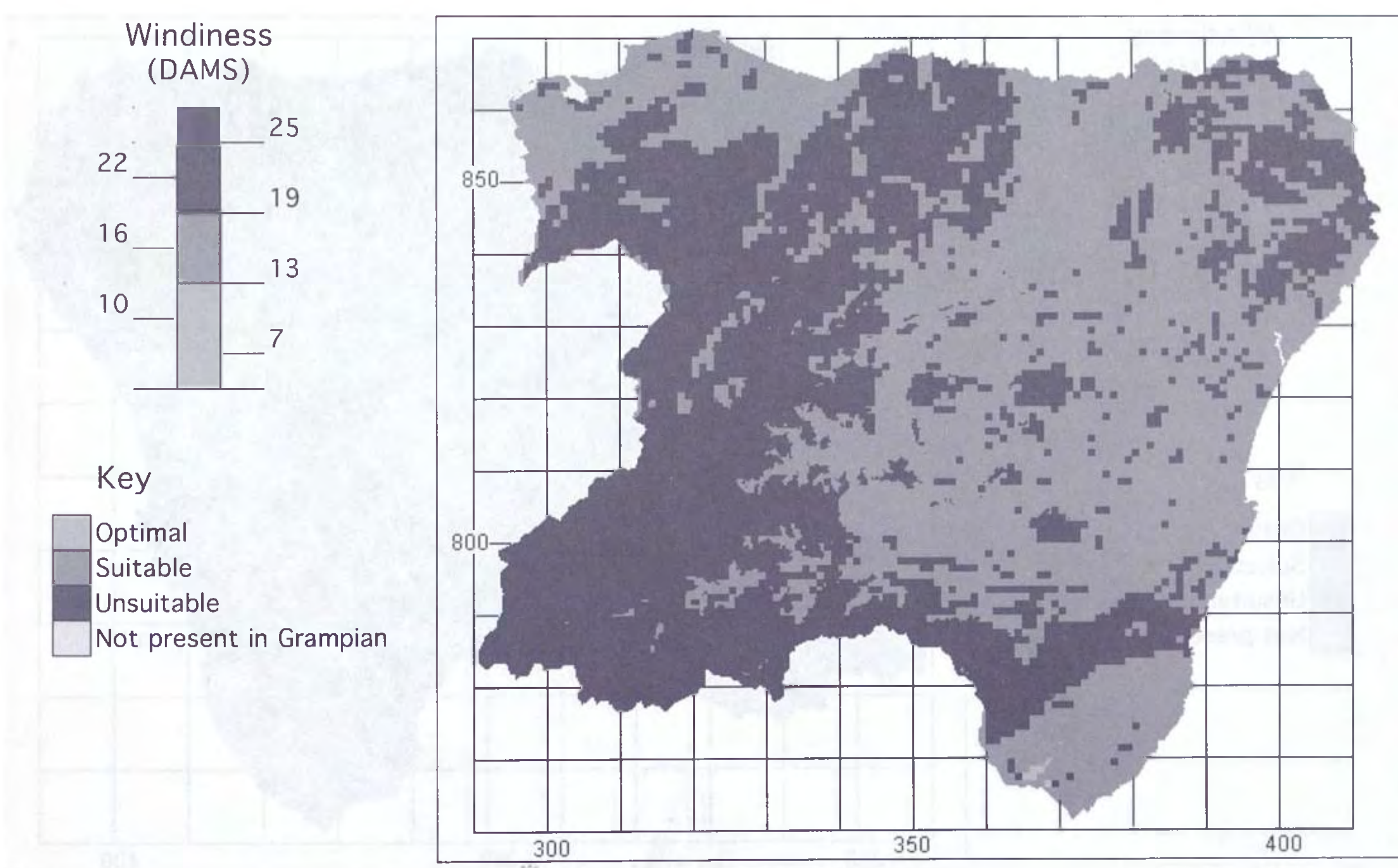
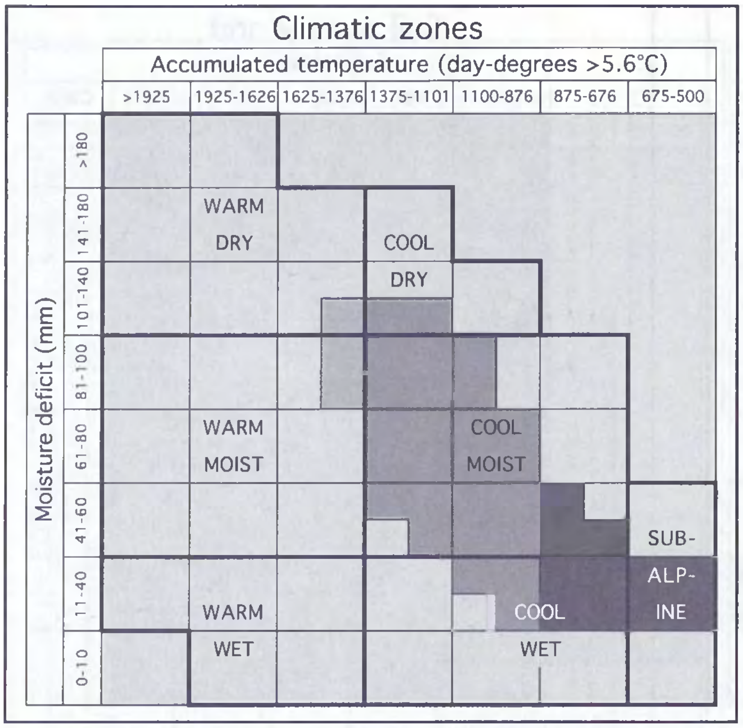
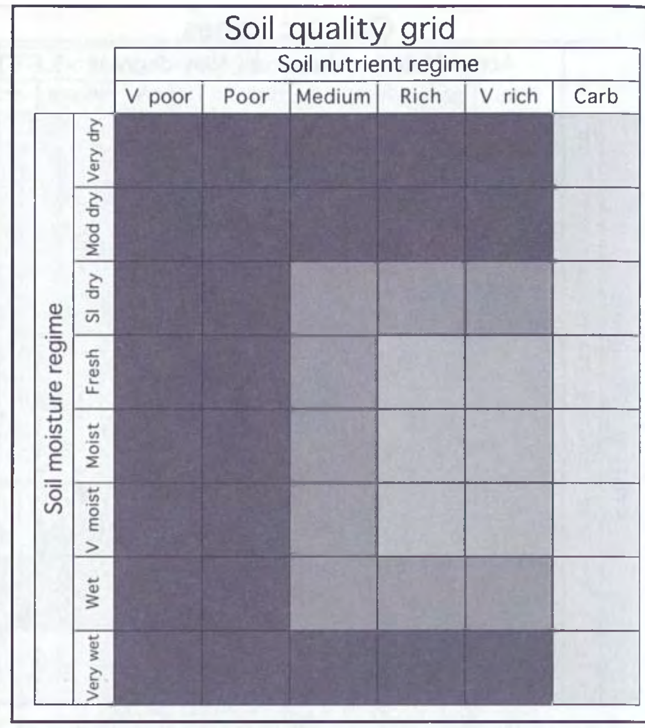


Figure 39 Beech



Frost tender.
GYC: 6 - 8 in optimal climates and soil qualities, 4 - 6 in suitable climates or soil qualities.



Intolerant of grass swards.
Ideal conditions: Moist and Very rich.

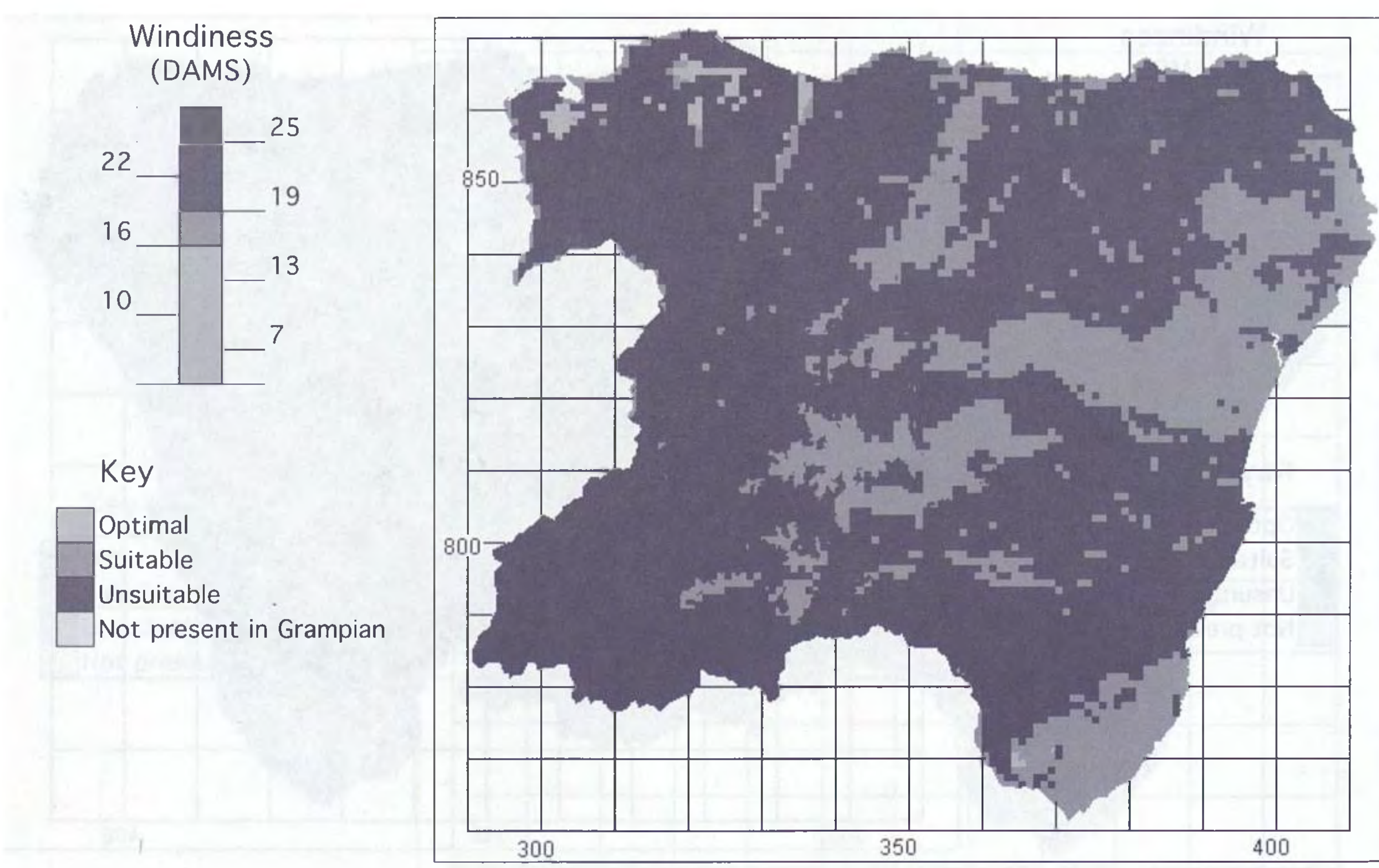
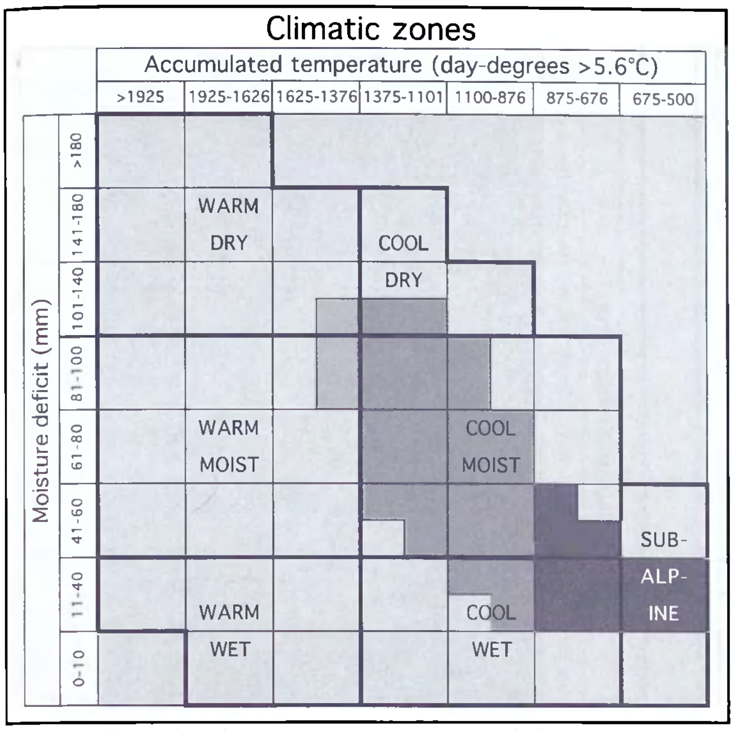
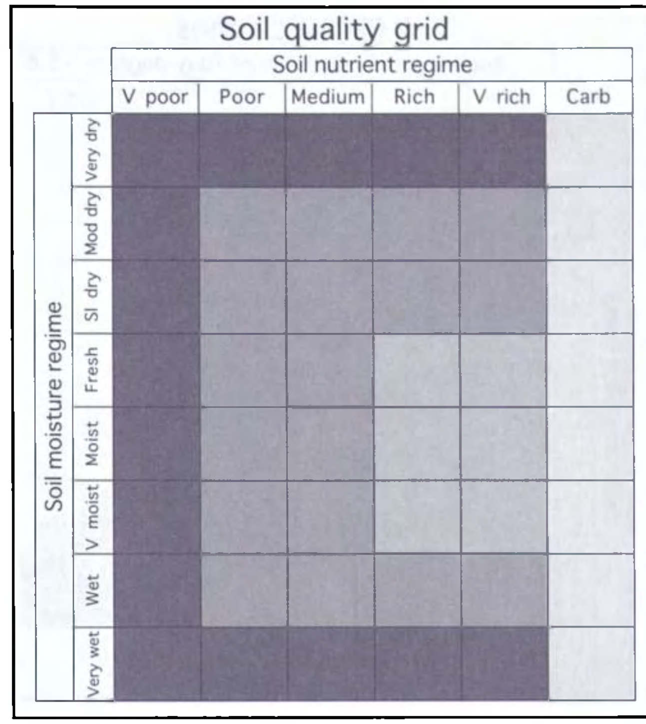


Figure 40 Ash



Fairly frost hardy. In Warm zones avoid dry S or SW-facing slopes.
GYC: 6 - 8 in optimal climates and soil qualities,
4 - 6 in suitable climates or soil qualities.



Ideal conditions: Moist and Rich.

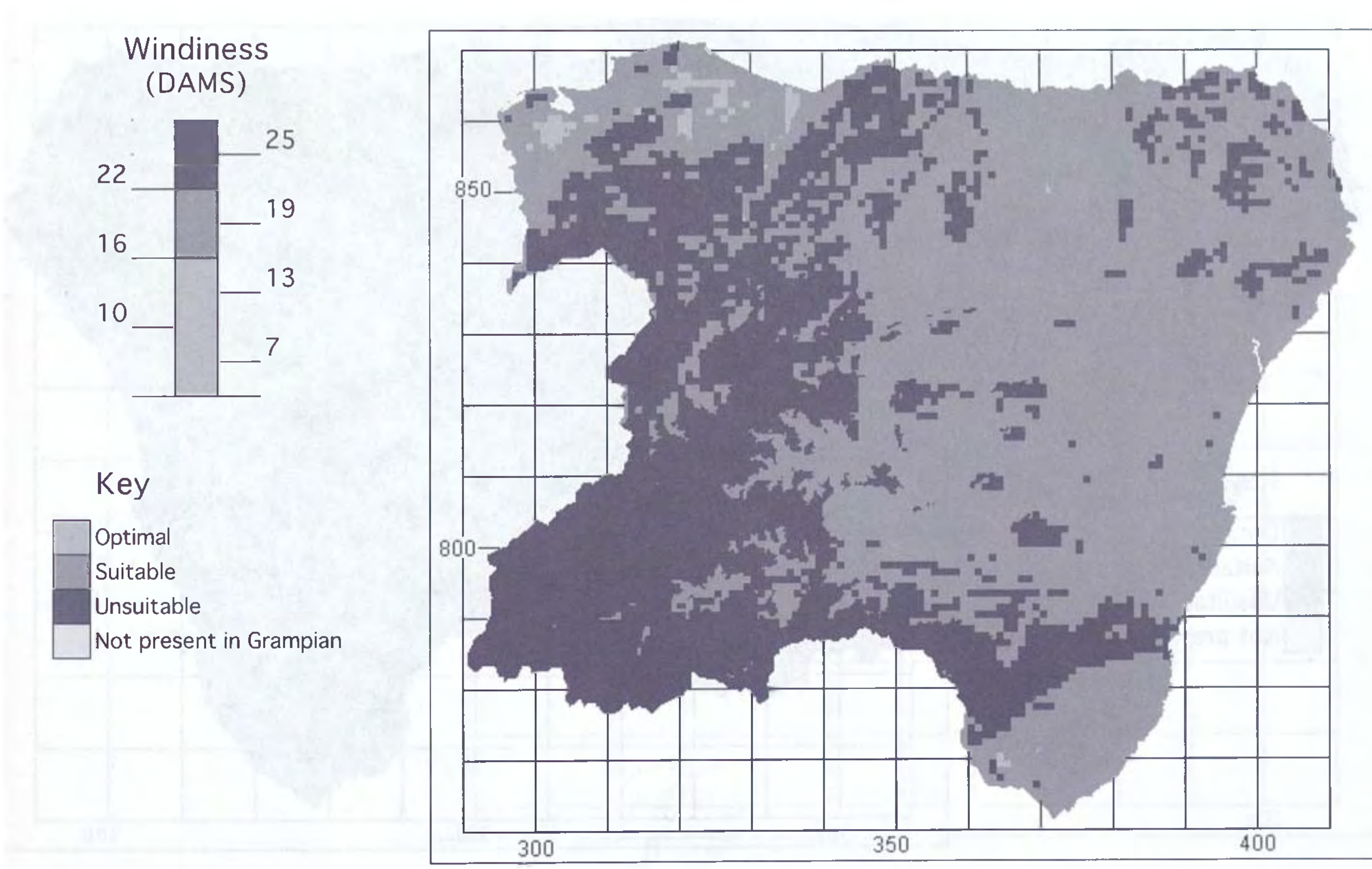
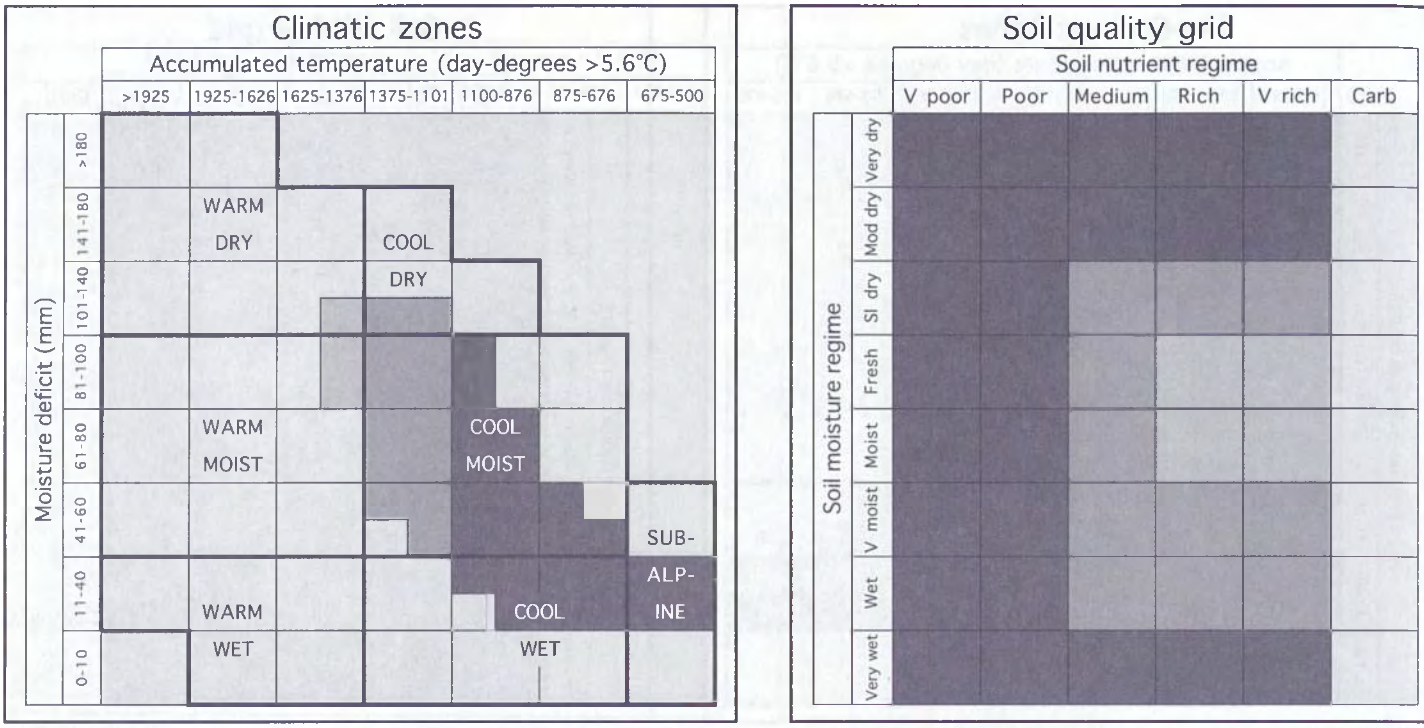


Figure 41 Sycamore



Planting not advised because of risk of Dutch elm disease. Frost hardy.

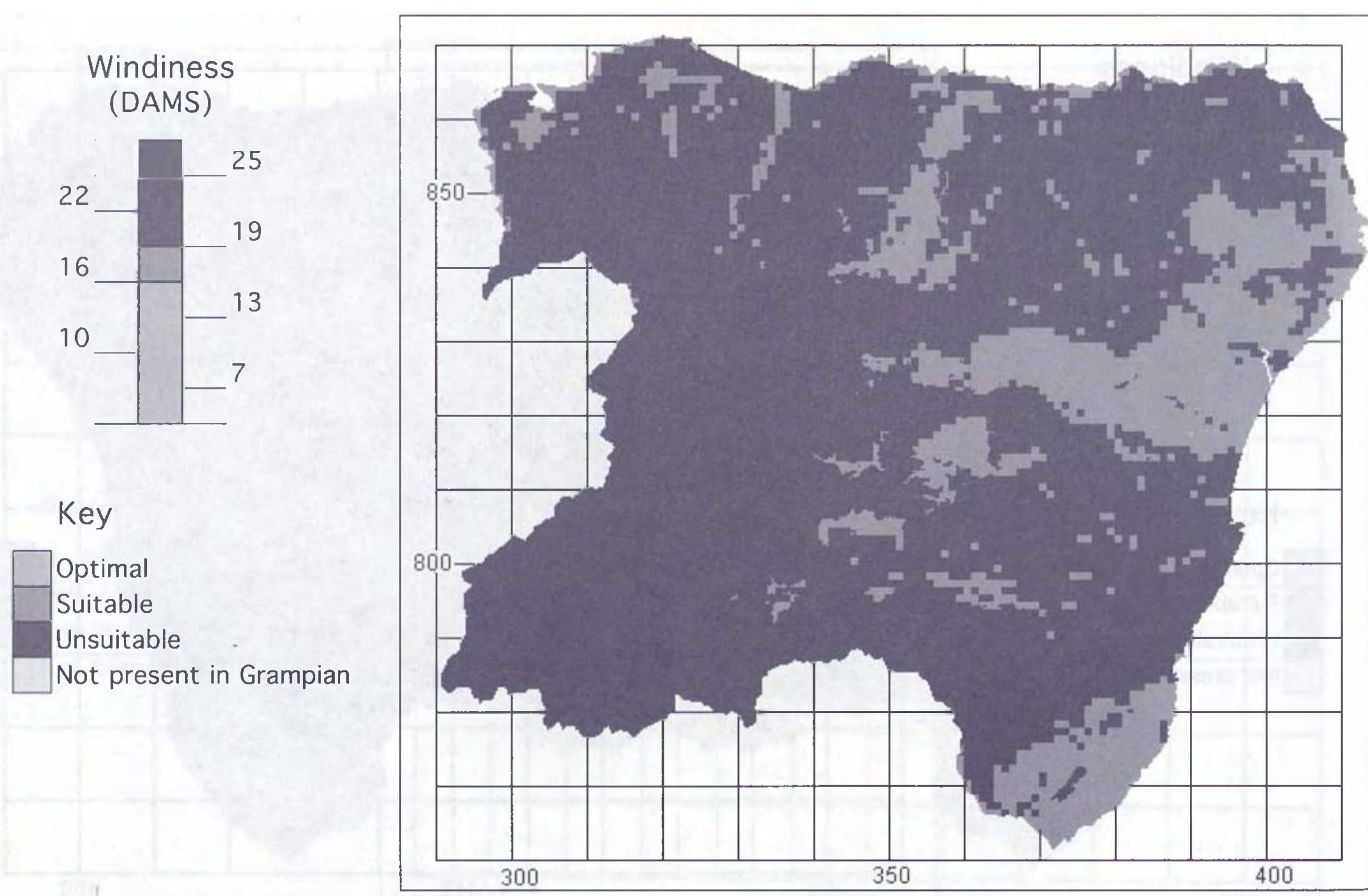
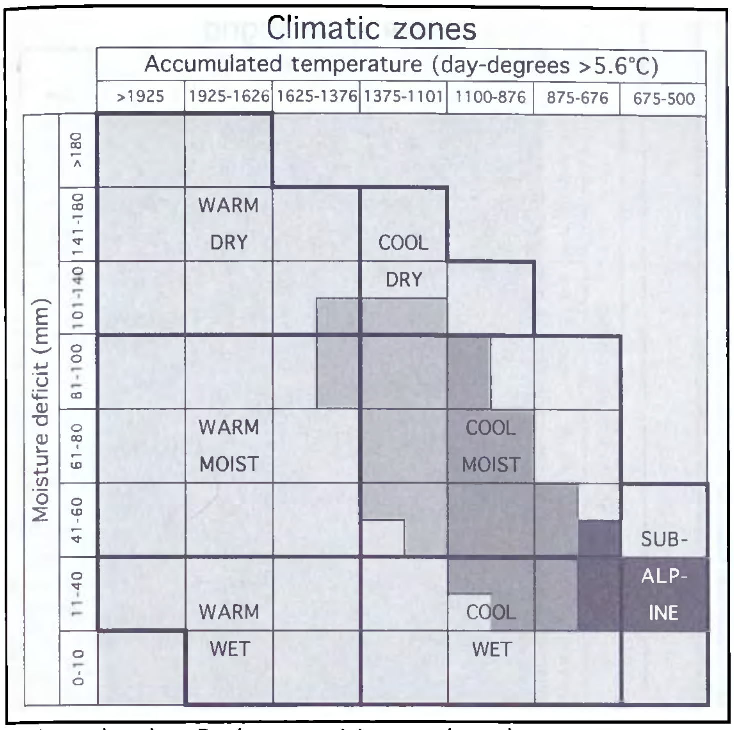
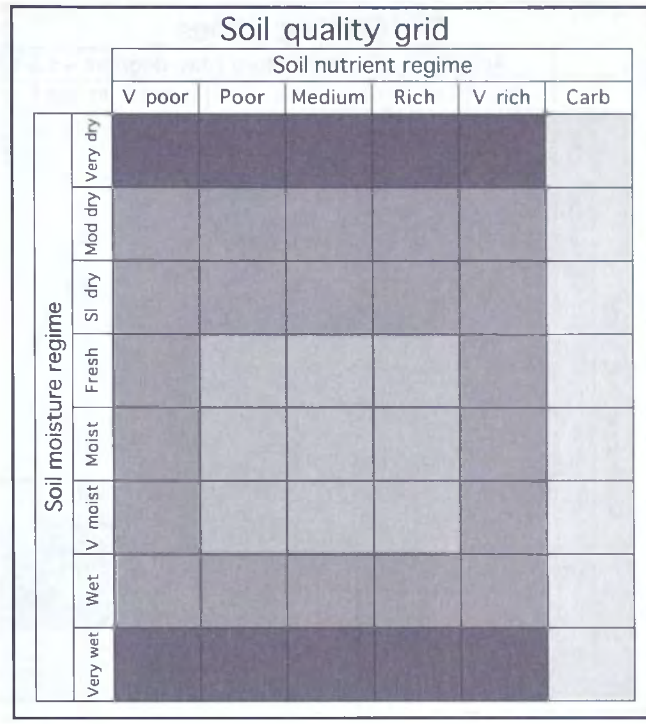


Figure 42 Wych elm



Frost hardy. Rather sensitive to drought.
GYC: 4 - 6 in optimal climates and soil qualities,
2 - 4 in suitable climates or soil qualities.



Fairly tolerant of ericaceous vegetation.

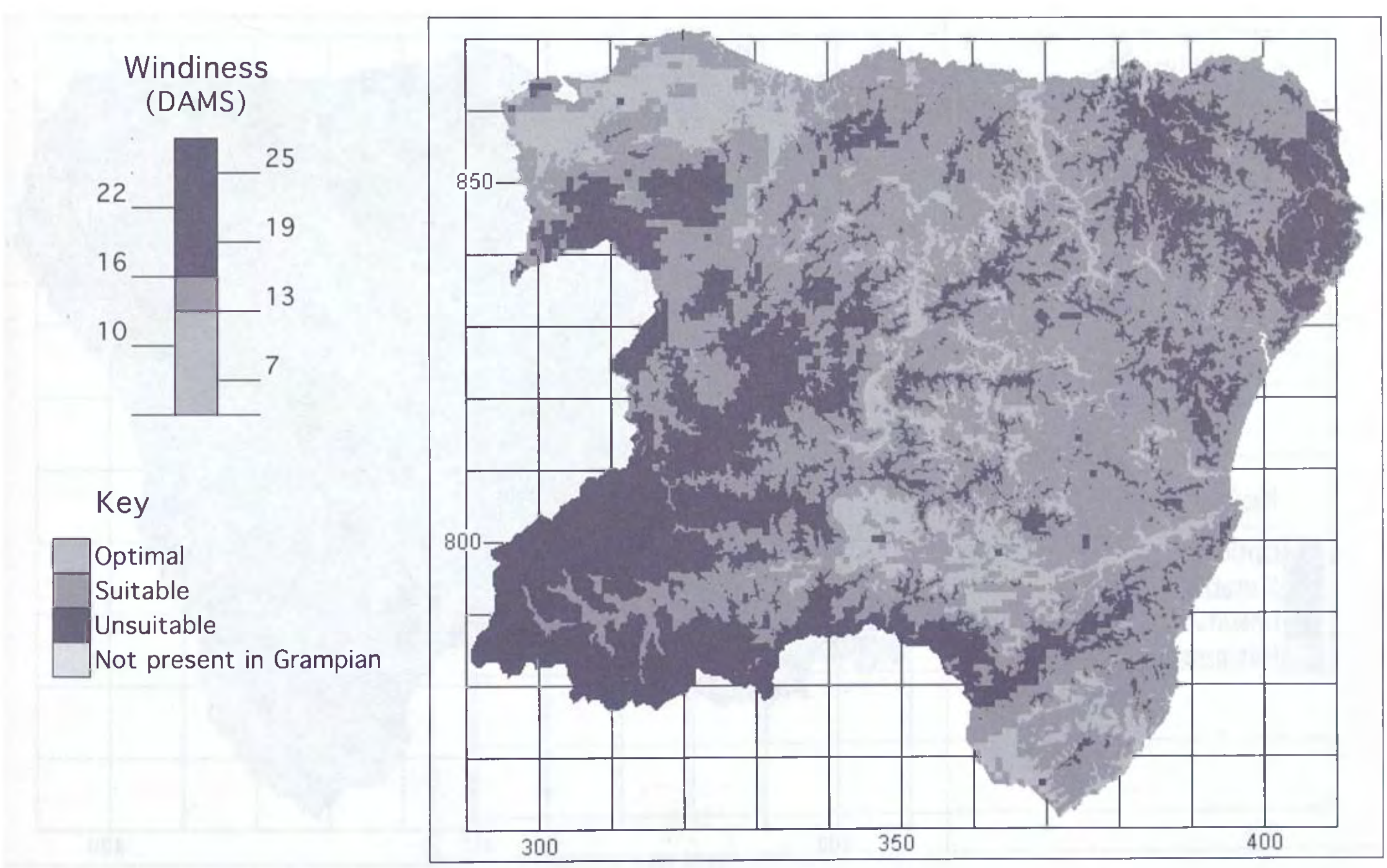
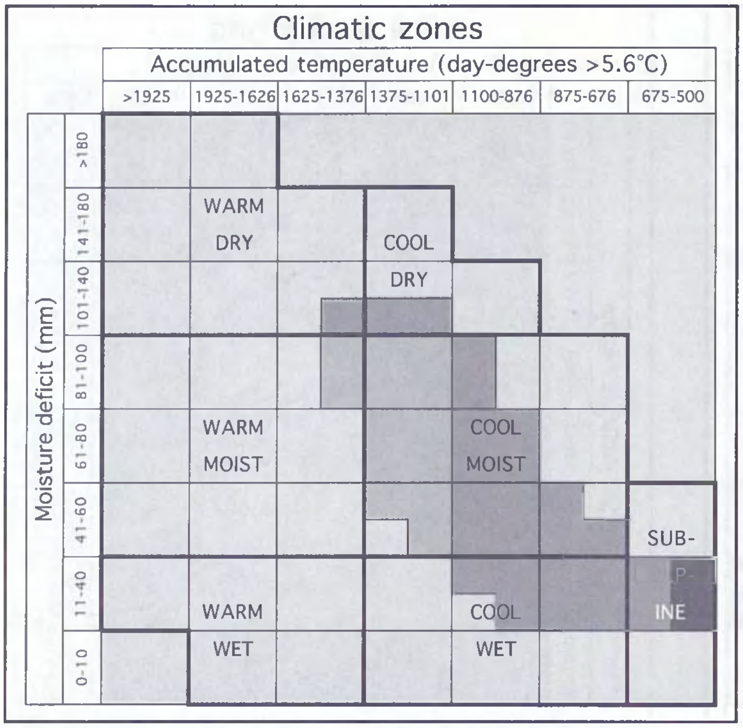
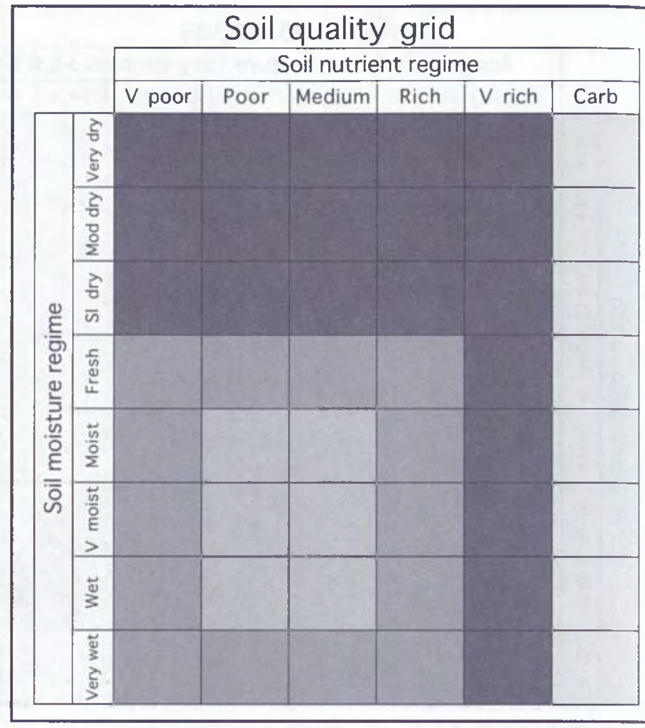


Figure 43 Silver birch





Frost hardy. Sensitive to drought.
Where AT <875 d-d subspecies tortuosa mainly occurs.

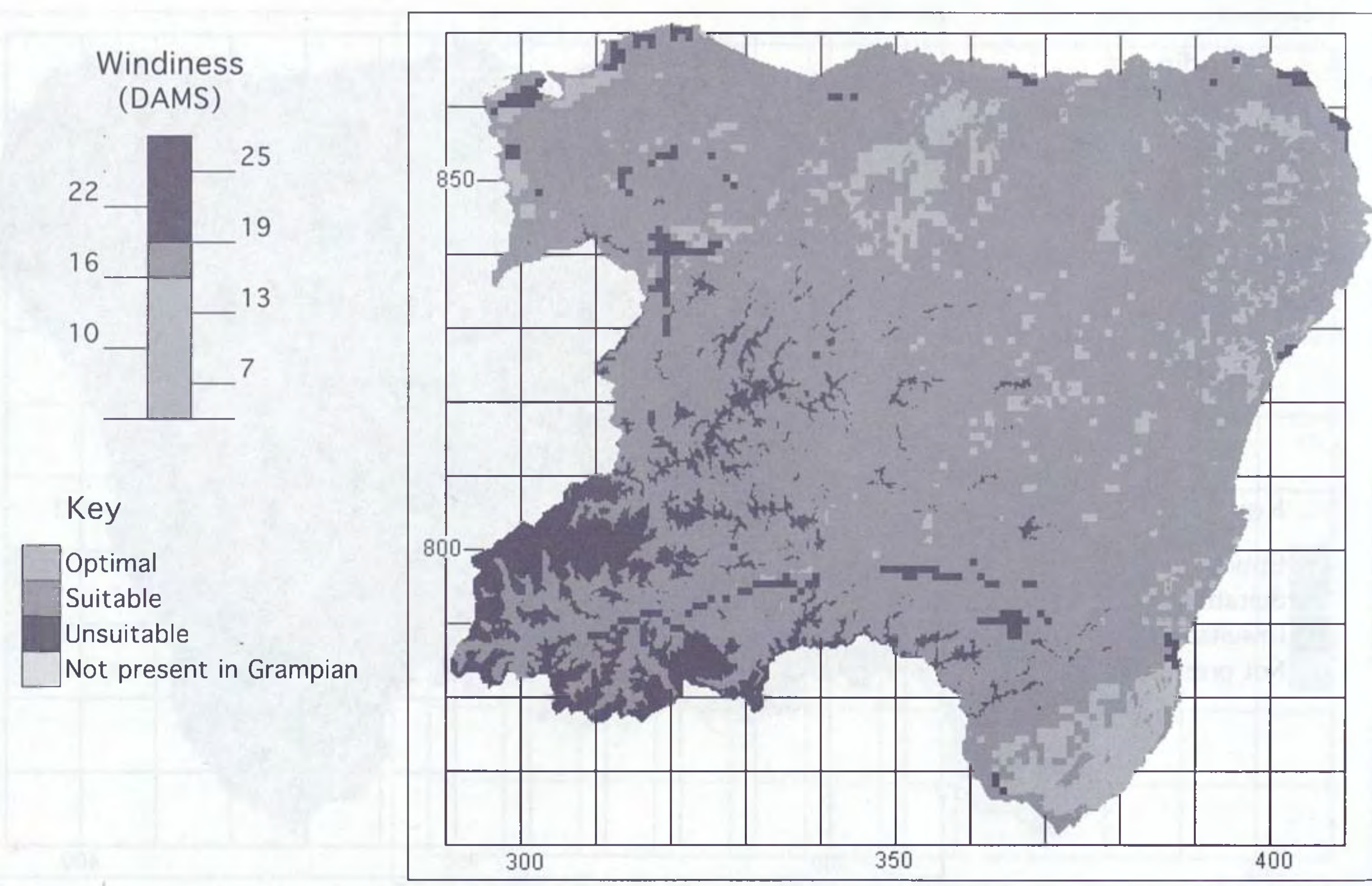
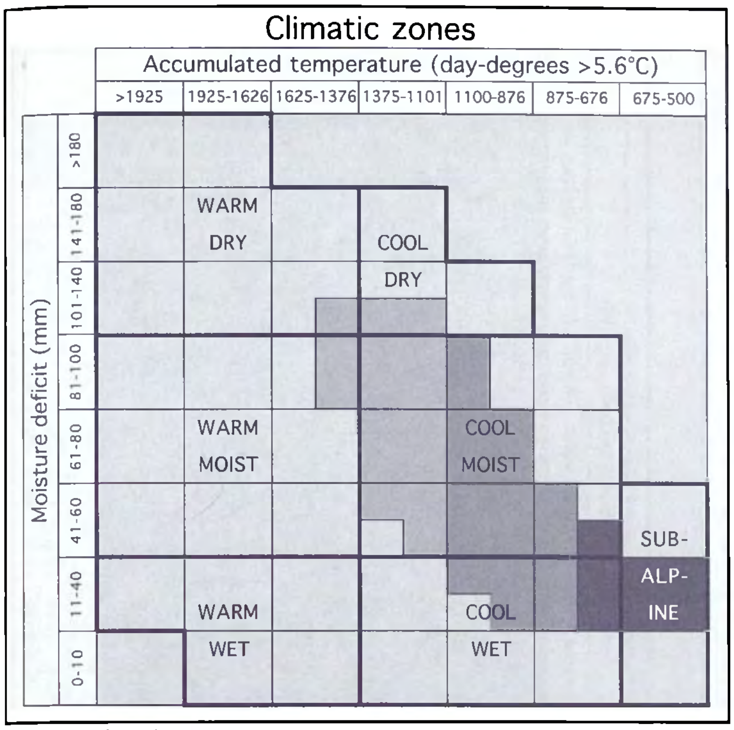
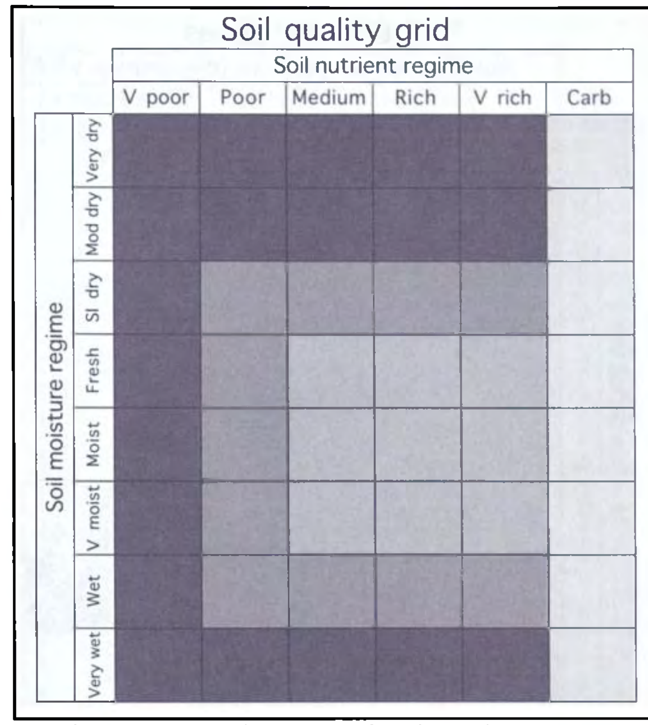


Figure 44 Downy birch



Frost hardy.



Tolerant of a wide range of soil conditions.

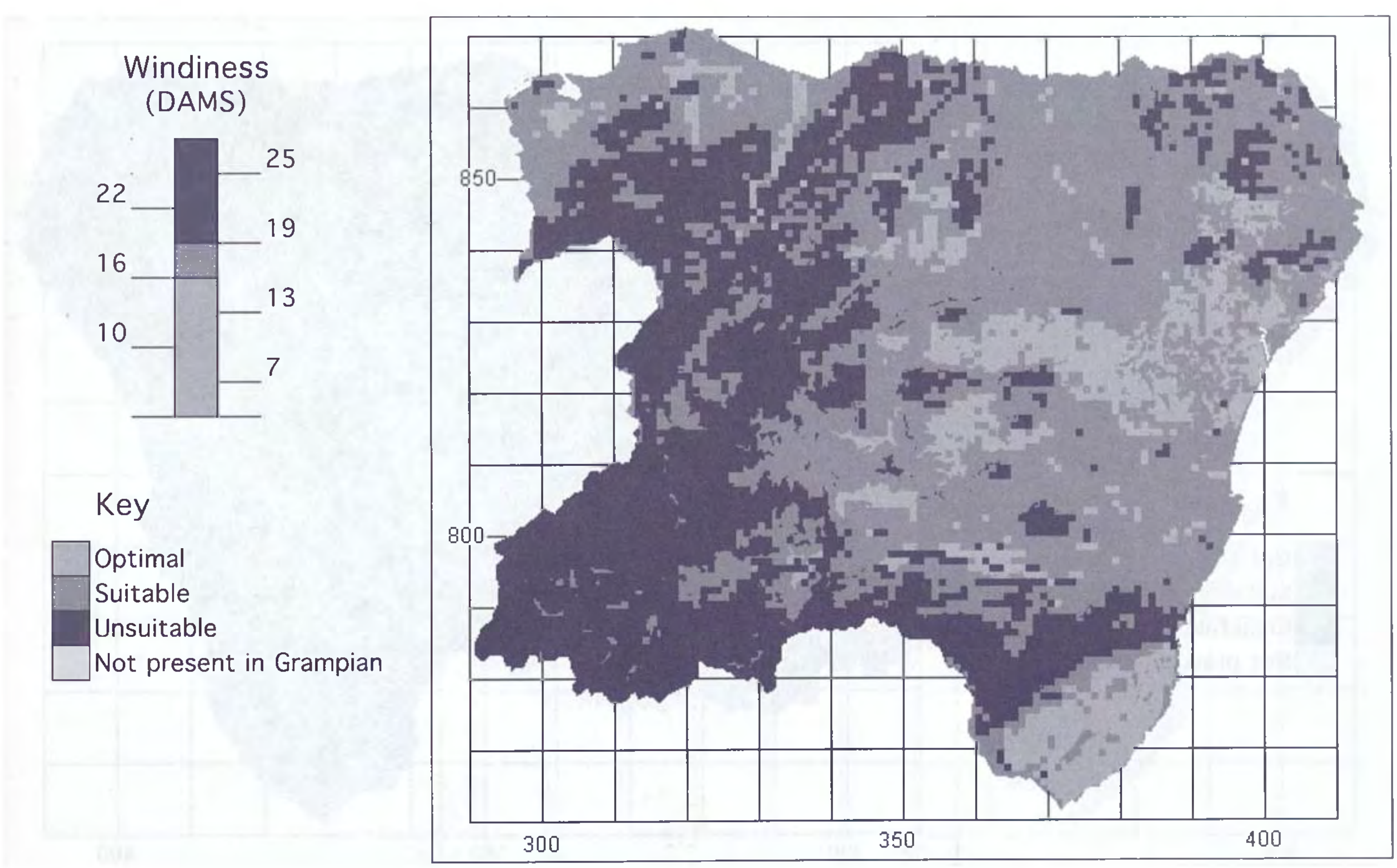
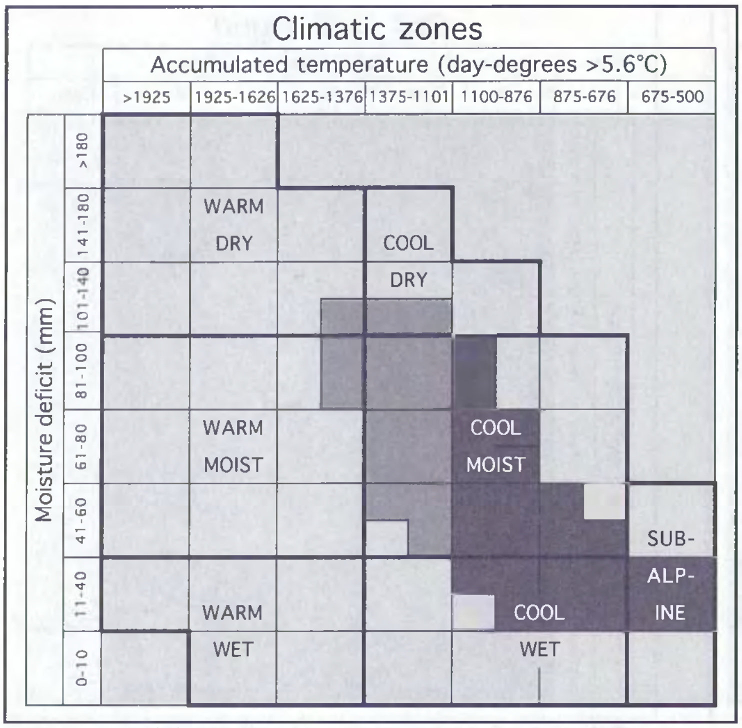
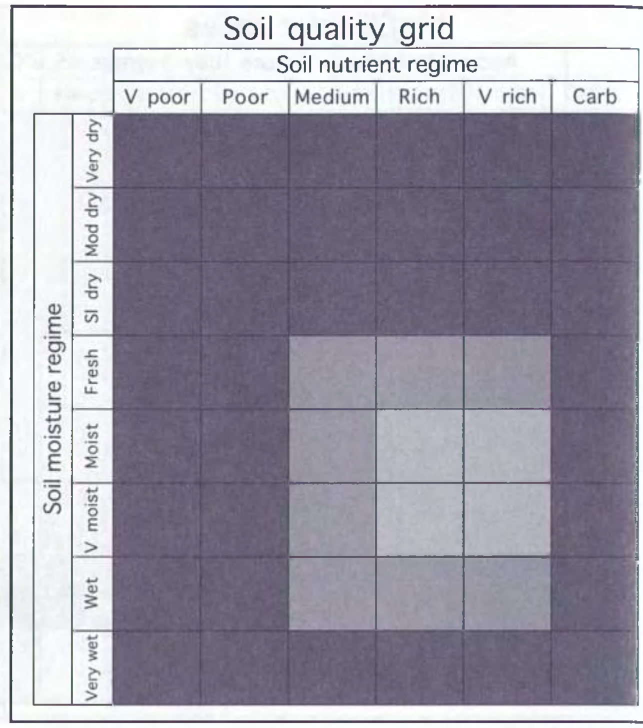


Figure 45 Aspen



Only *P. trichocarpa* known to be suited to Grampian.
Climatic suitability of DxT uncertain. DxN not suited.
GYC: Trich. 14 - 18, DxT 10 - 14, in suitable climates and soil qualities.



Intolerant of grass swards.
Ideal conditions: Very moist and Very rich.

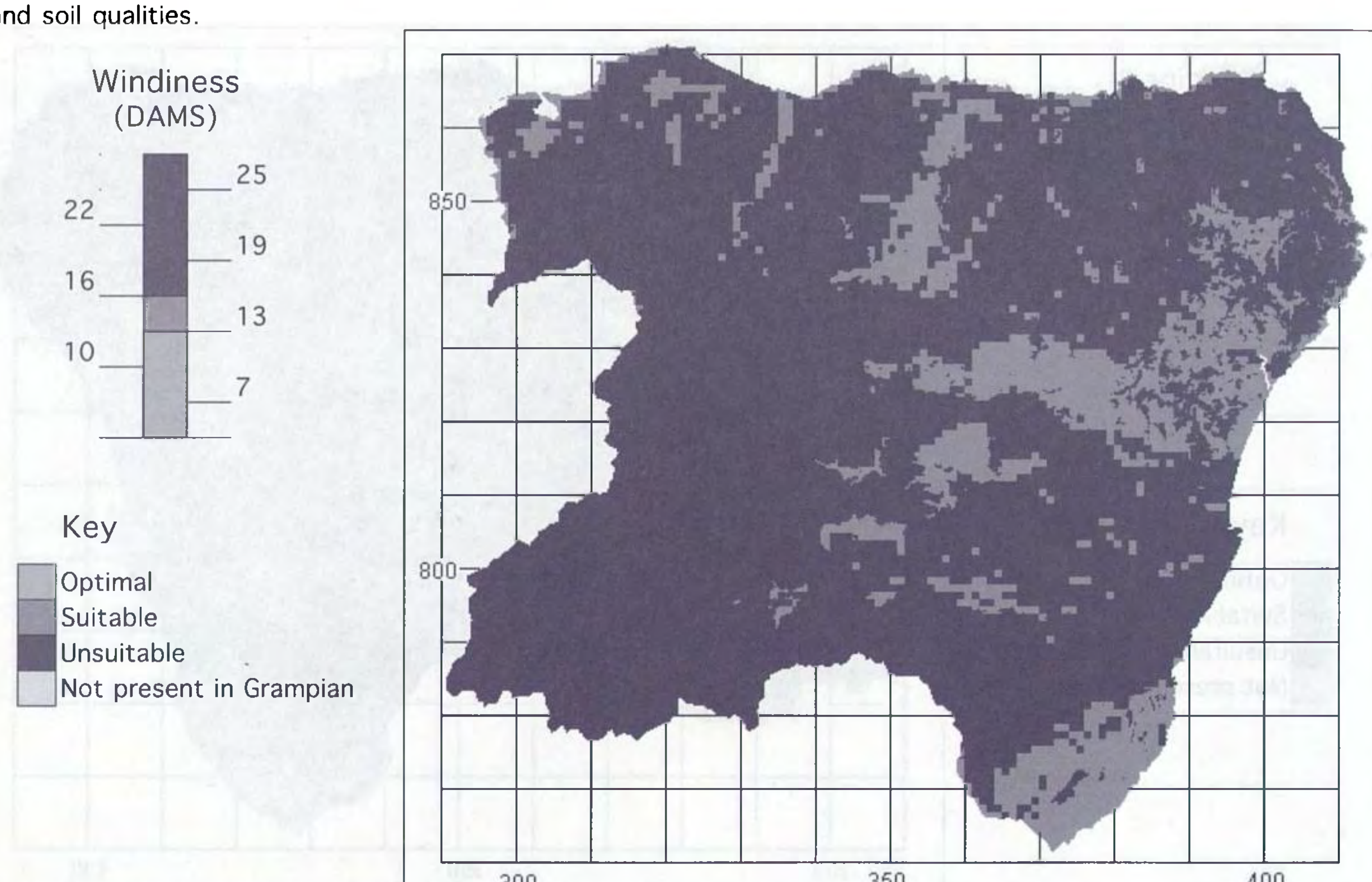
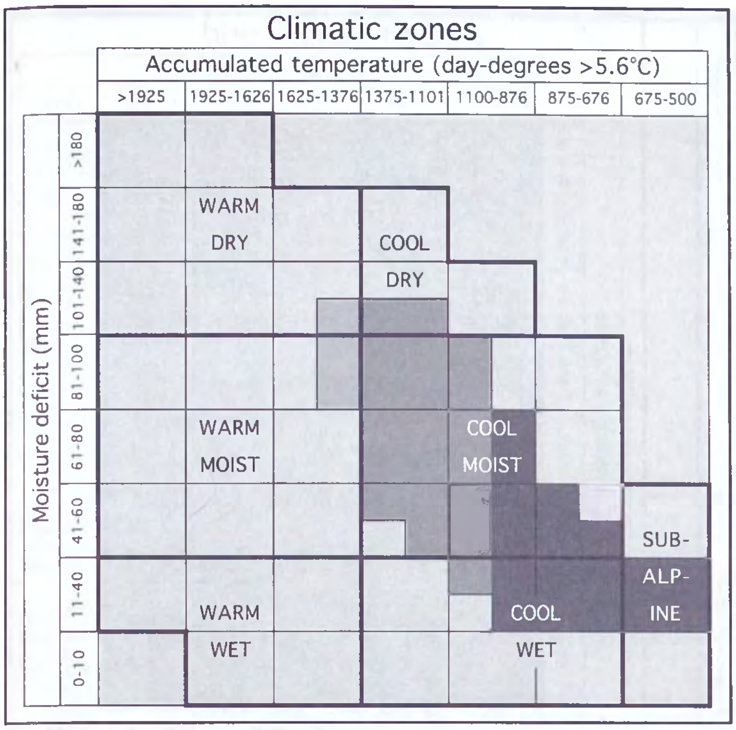
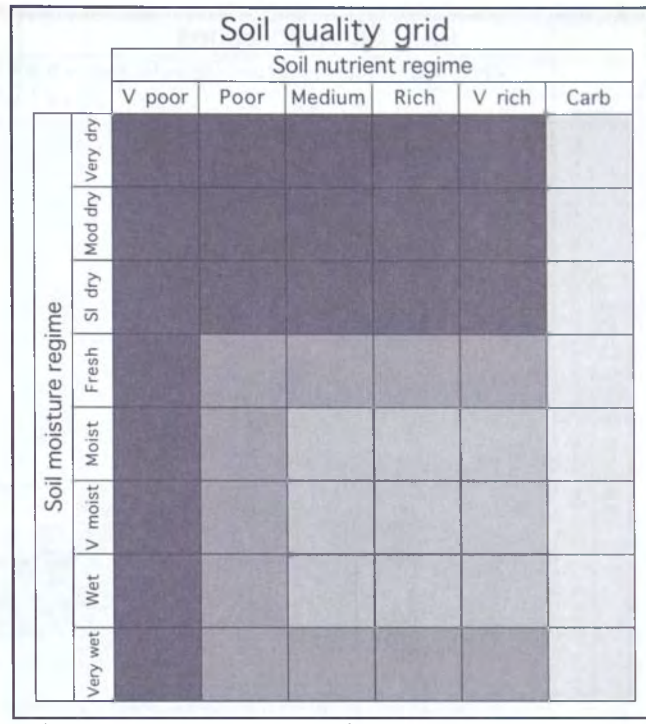


Figure 46 Poplar cultivars



Frost hardy.



Intolerant of grass swards.
Tolerant of flooding, but see *Forests & Water Guidelines* before planting along watercourses.

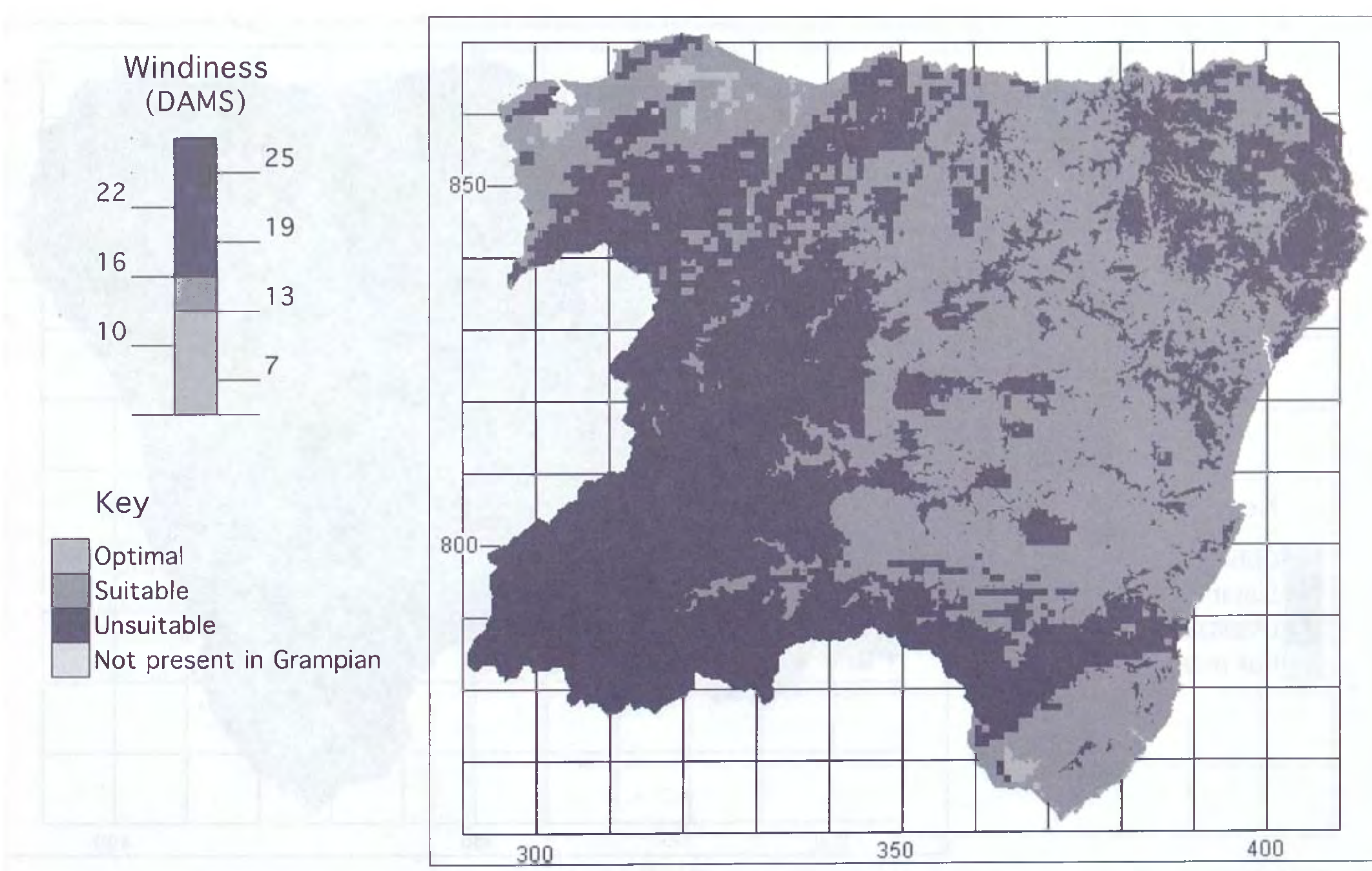
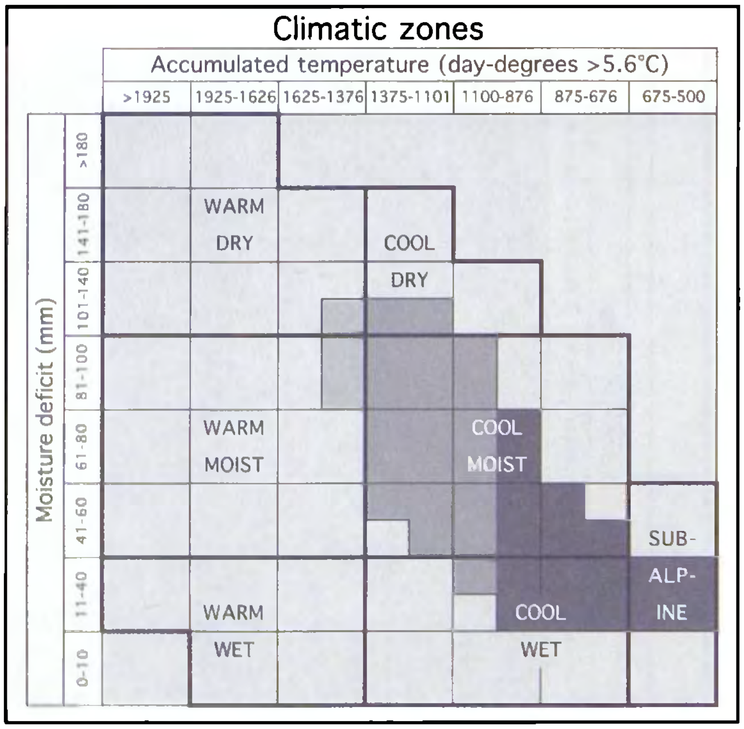
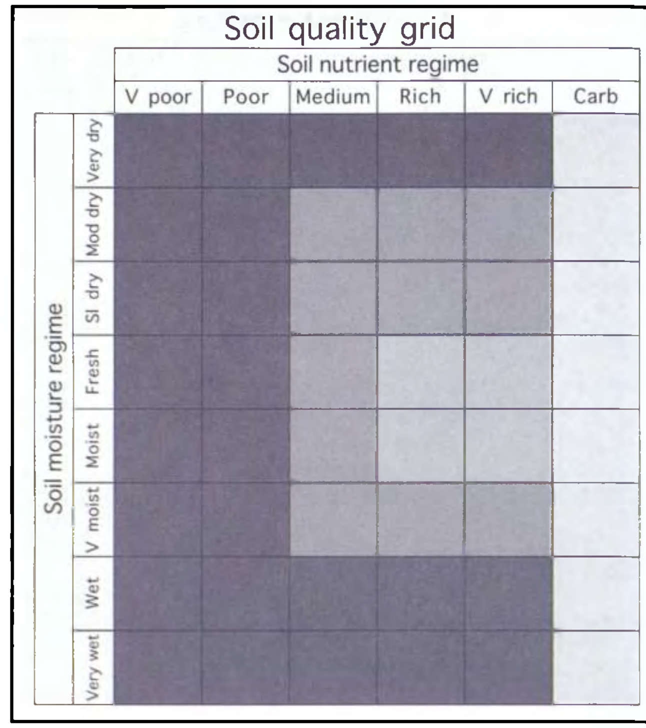


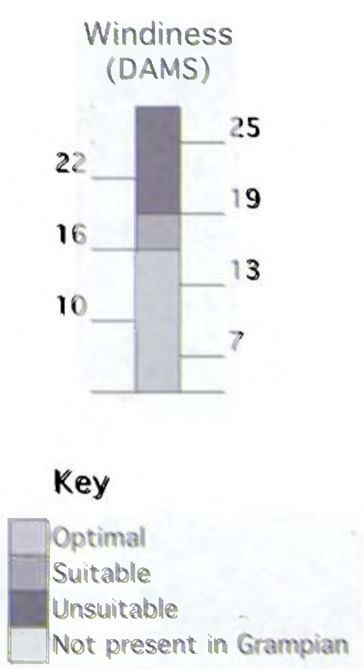
Figure 47 Common alder



Frost hardy.



Intolerant of grass swards.
Ideal conditions: Fresh/Moist and Very rich.



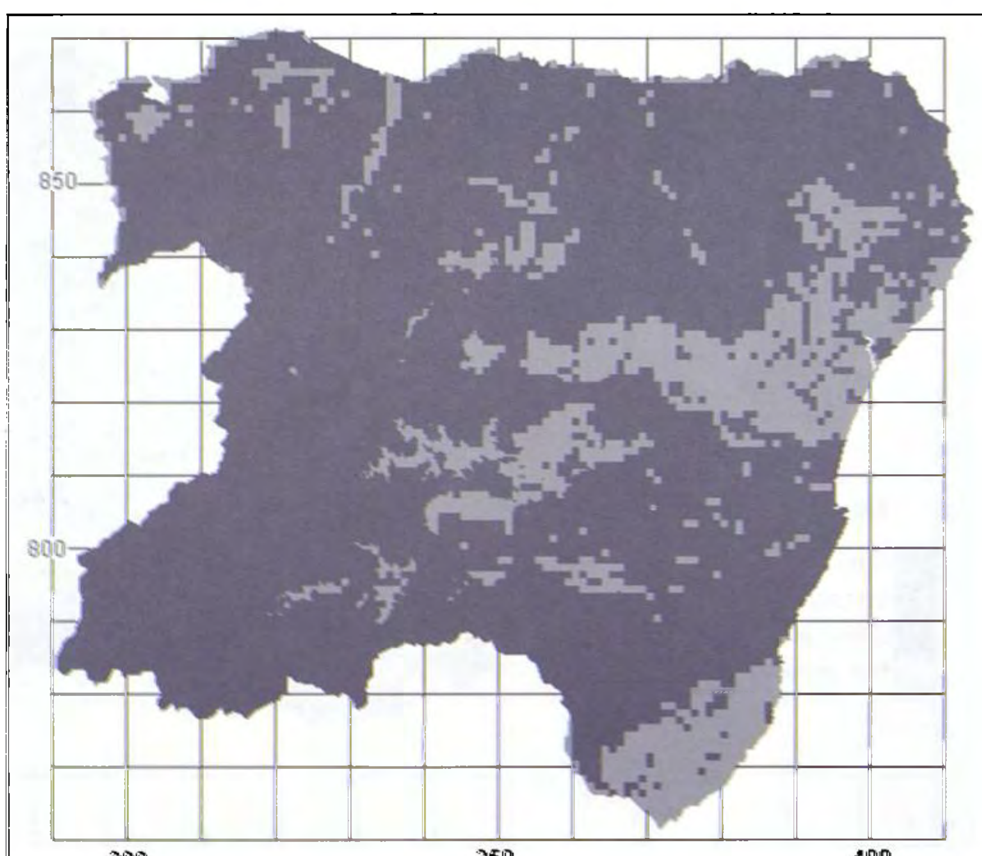
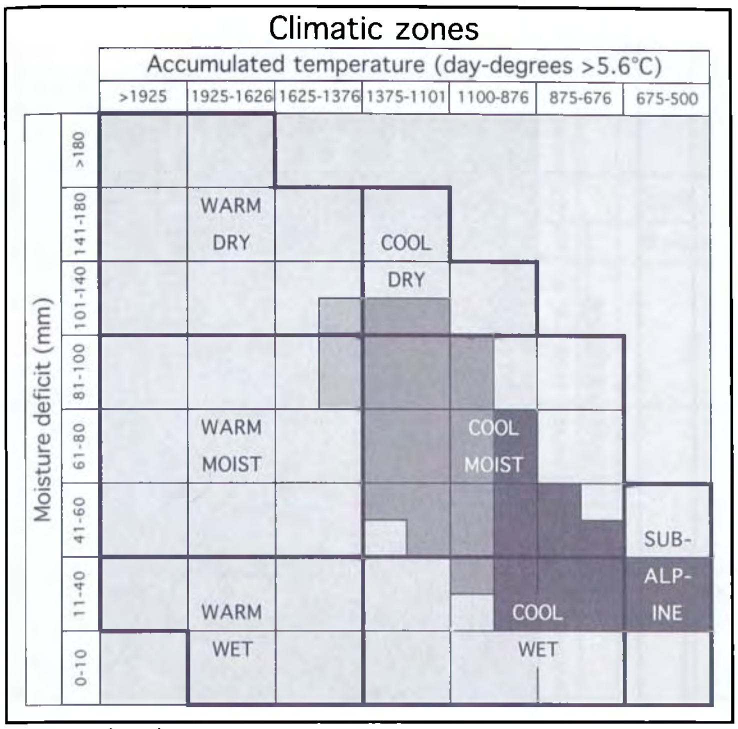
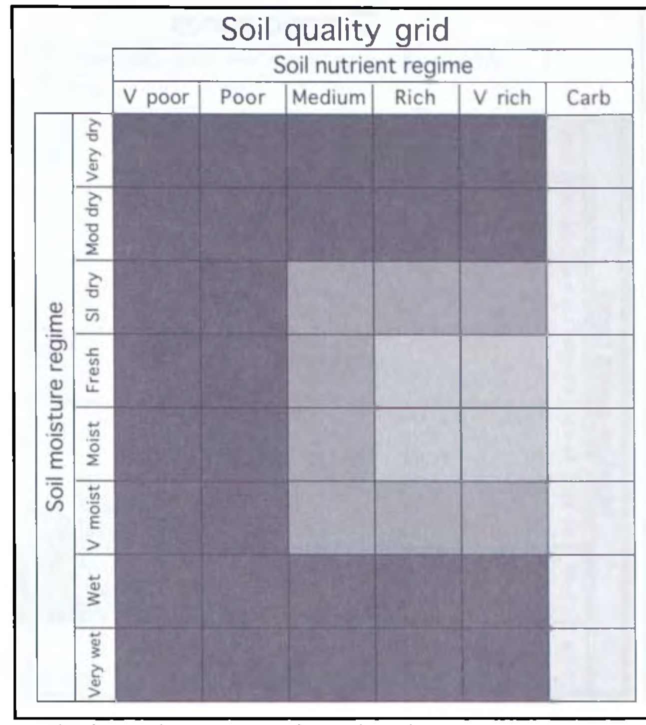


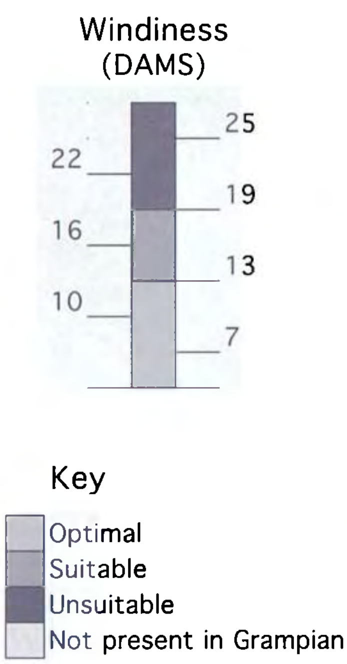
Figure 48 Norway maple



Frost hardy.



Ideal conditions: Fresh and Rich.



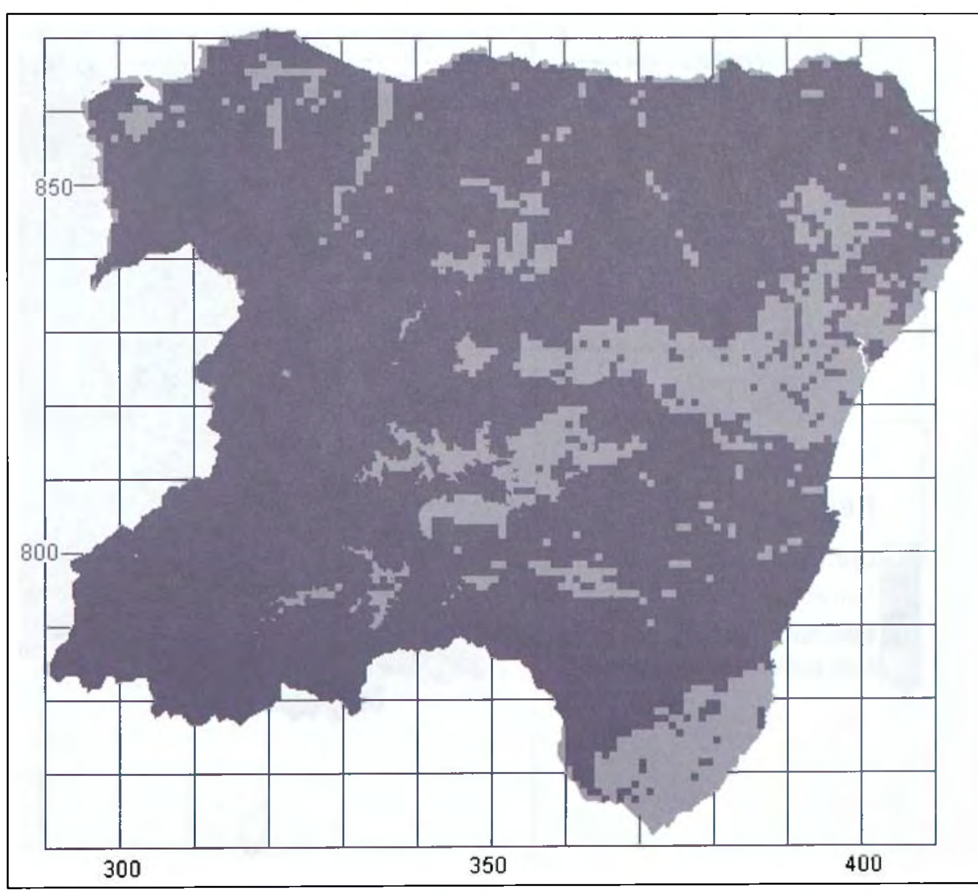


Figure 49 Gean / wild cherry

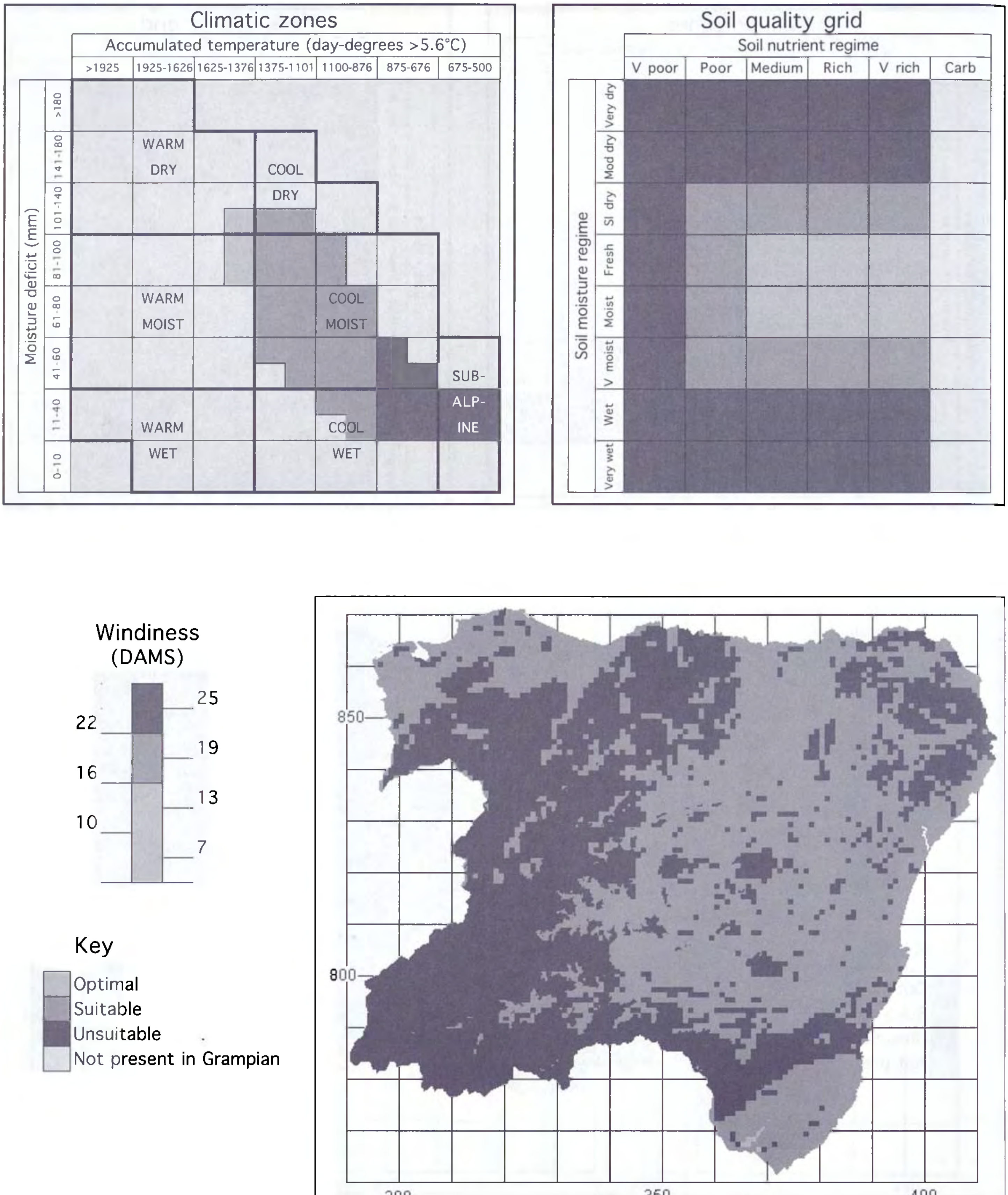


Figure 50 Swedish whitebeam

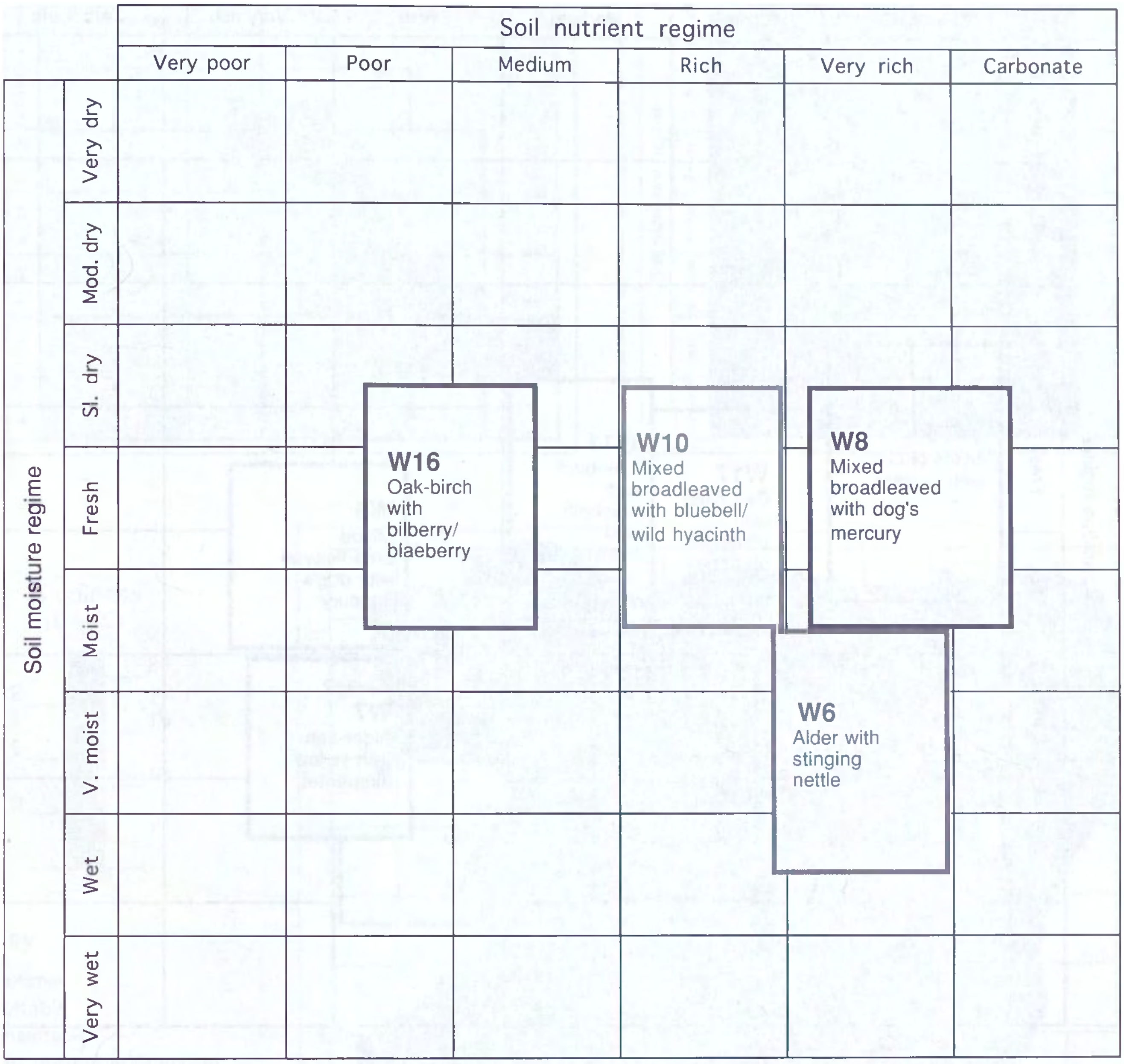


Figure 51 Optimal conditions for native (oak and alder) woodlands for climatic zones Warm dry and Warm moist (FC Bulletin 112 'Lowland zone')

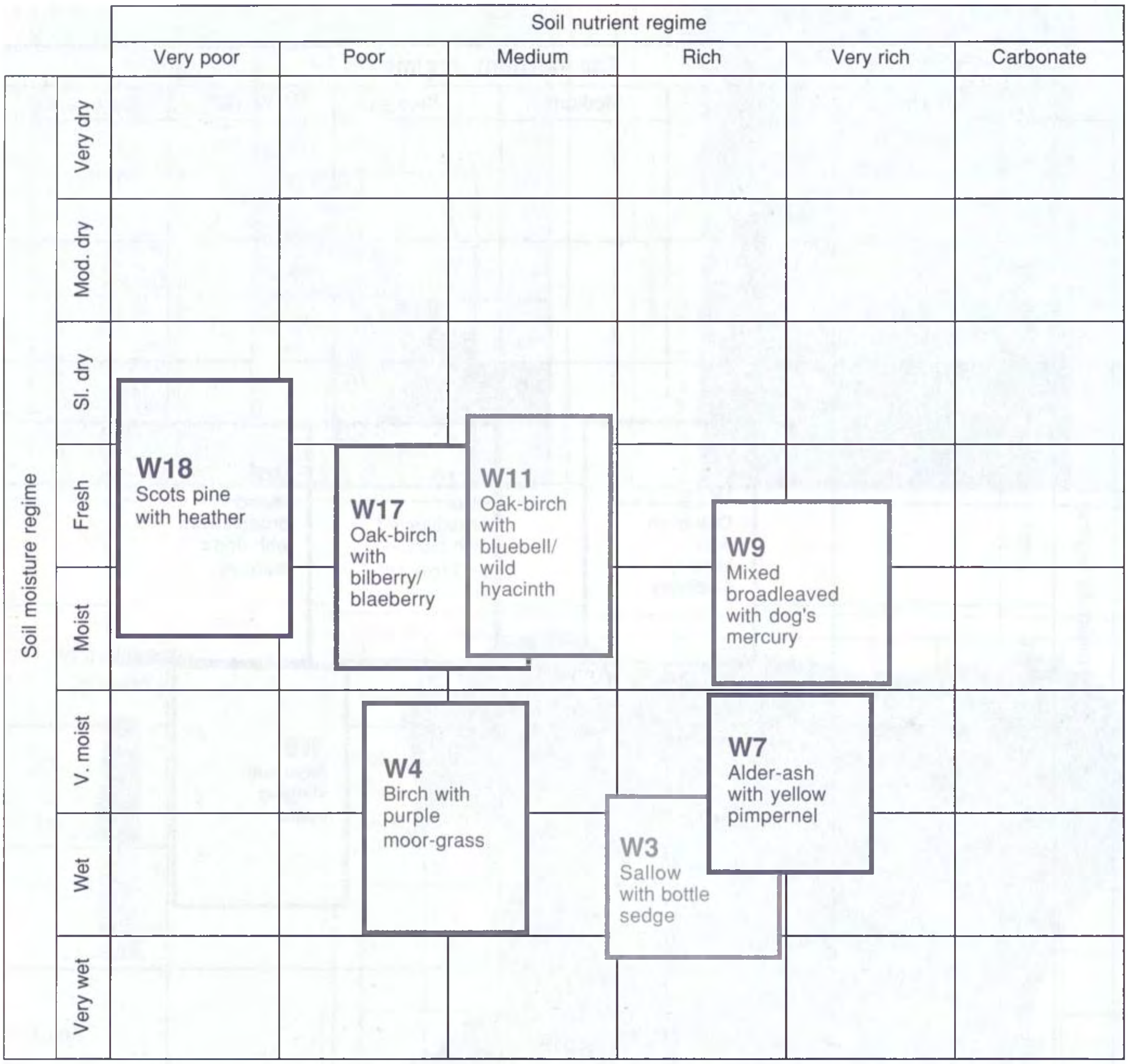


Figure 52 Optimal conditions for native woodlands for climatic zones Cool moist and Cool wet (FC Bulletin 112 'Upland zone')

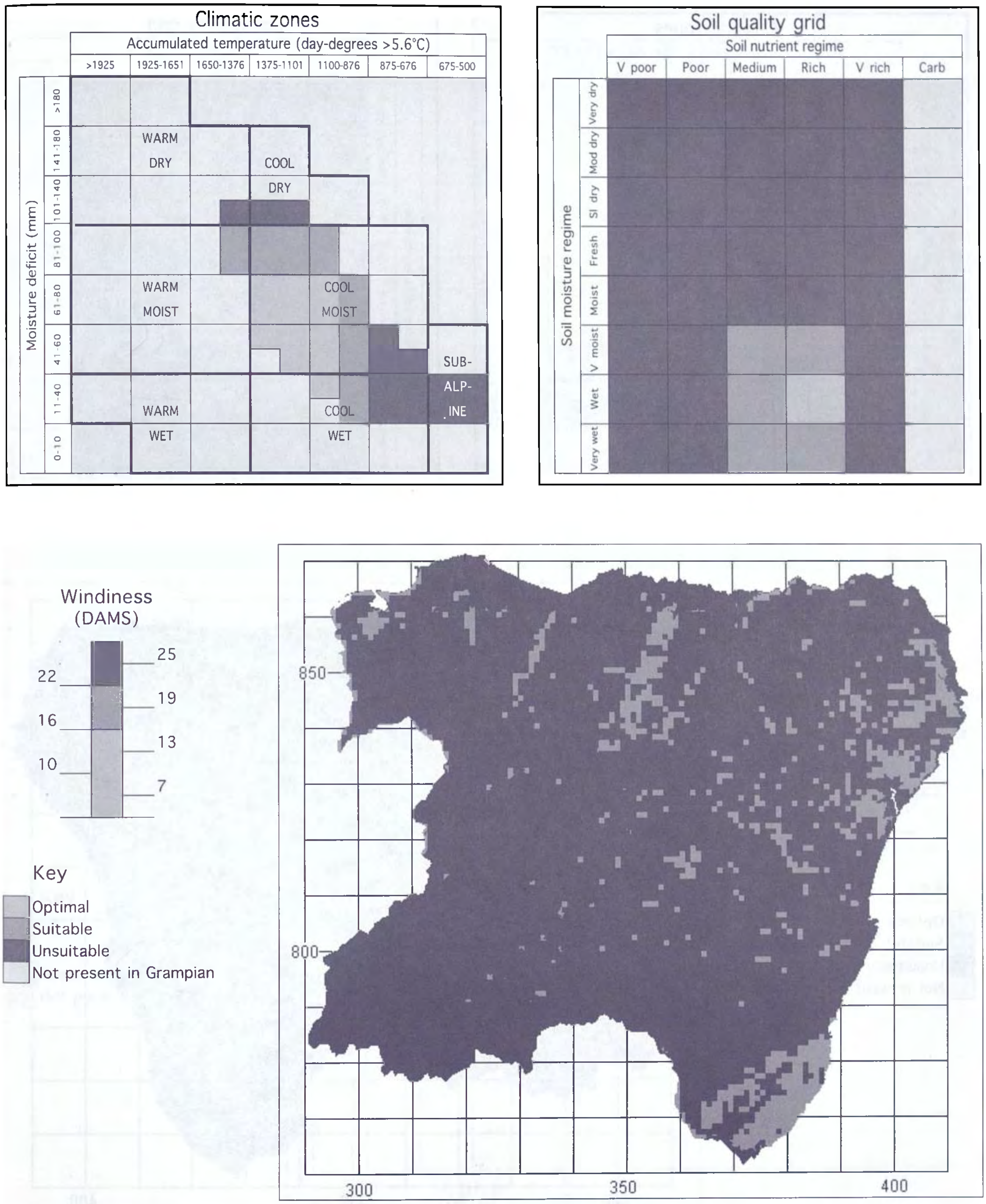
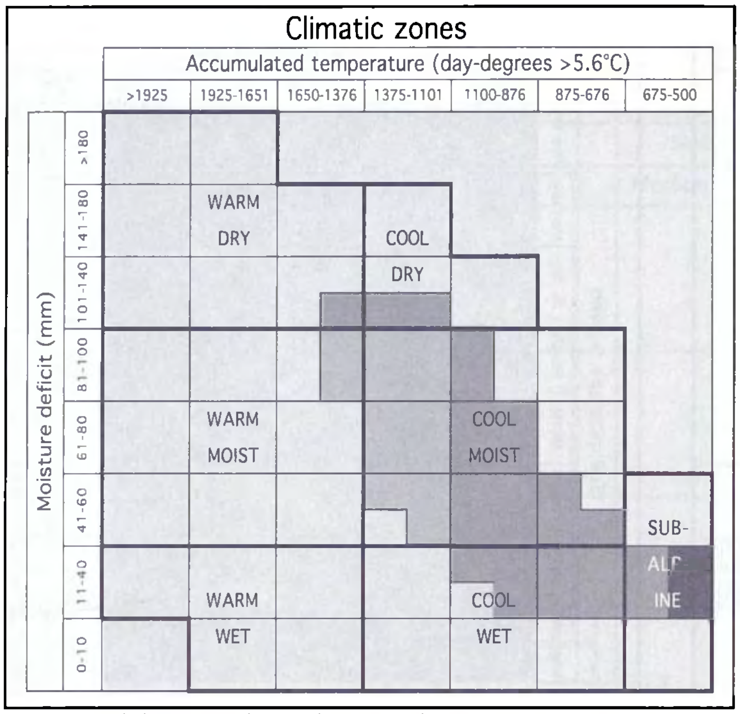
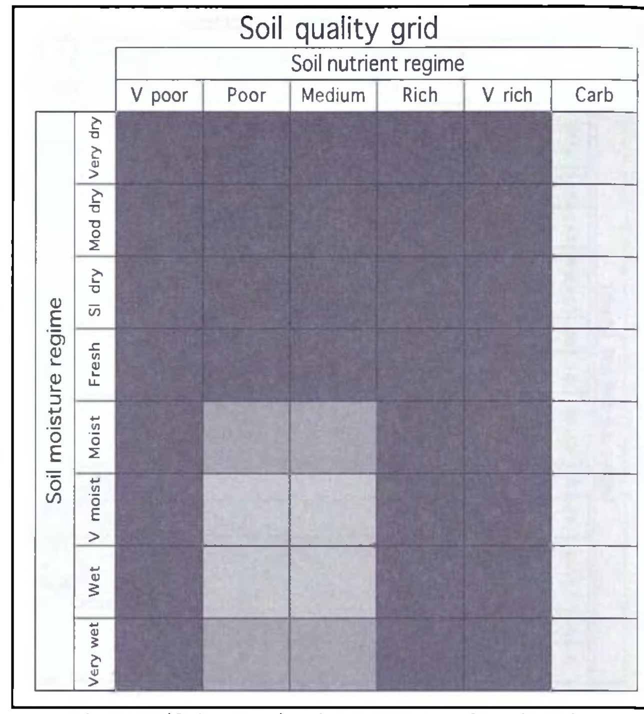


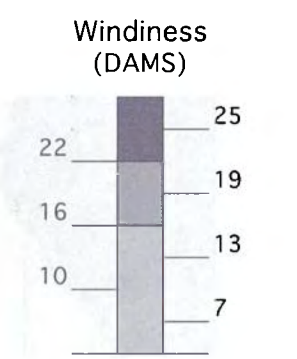
Figure 53 W3 Sallow woodland with bottle sedge



Trees will be severely wind-swept where DAMS >19. Most common on cool, wet north-facing slopes.



Mainly W4c (Sphagnum) sub-community, found at the poor end of the range of SNR and on wet SMR.



Key

Optimal
Suitable
Unsuitable
Not present in Grampian

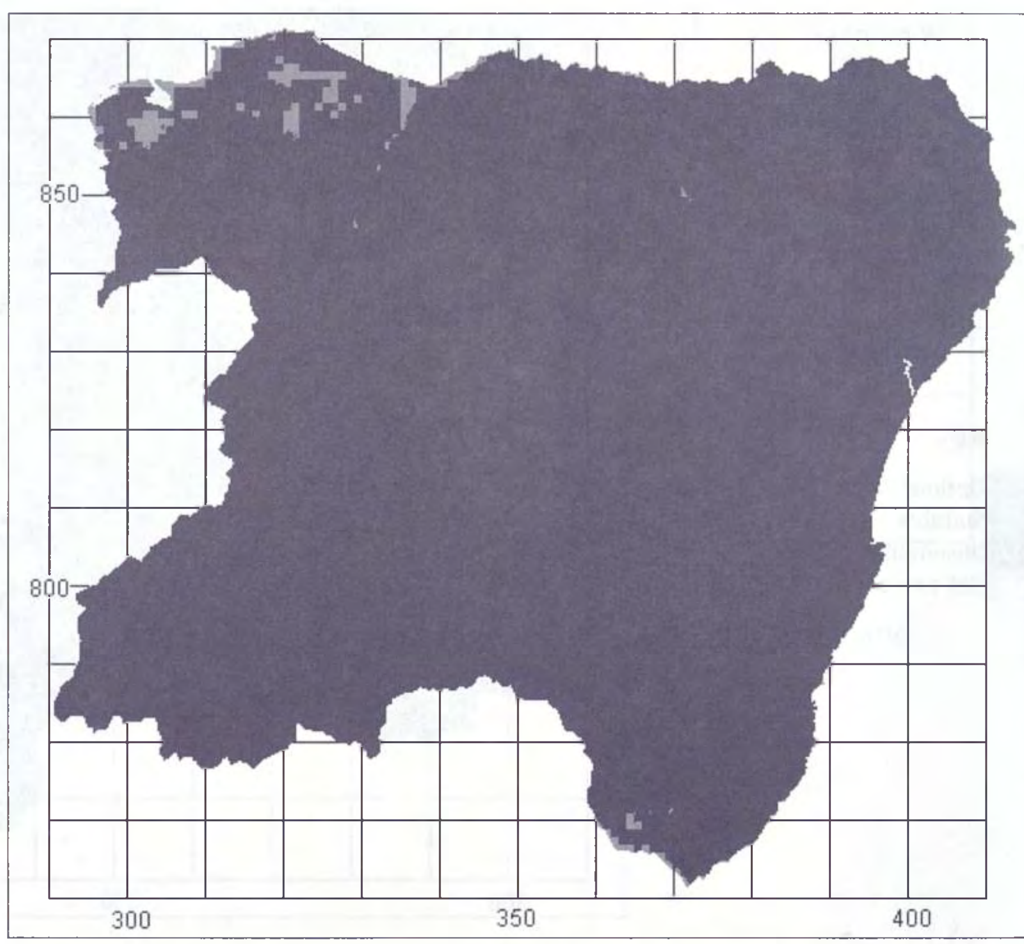
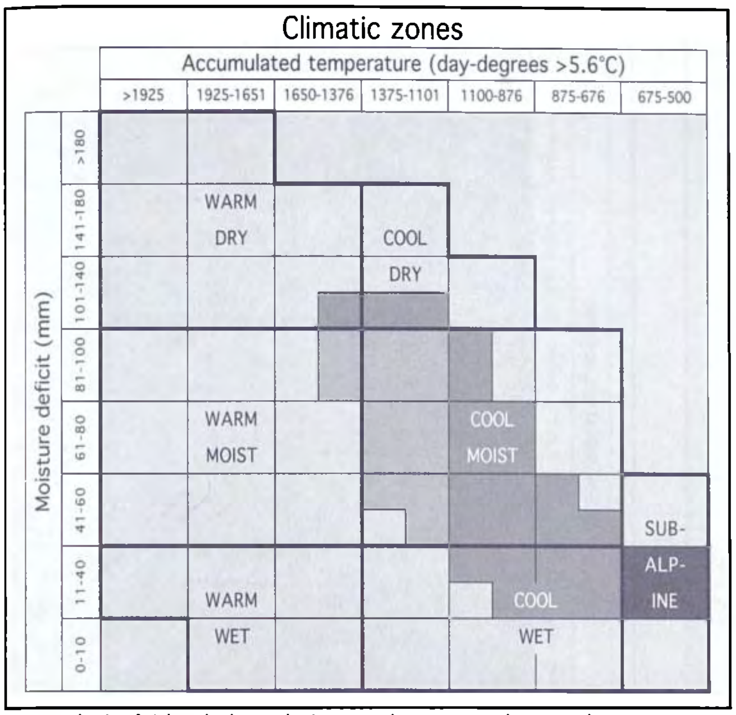
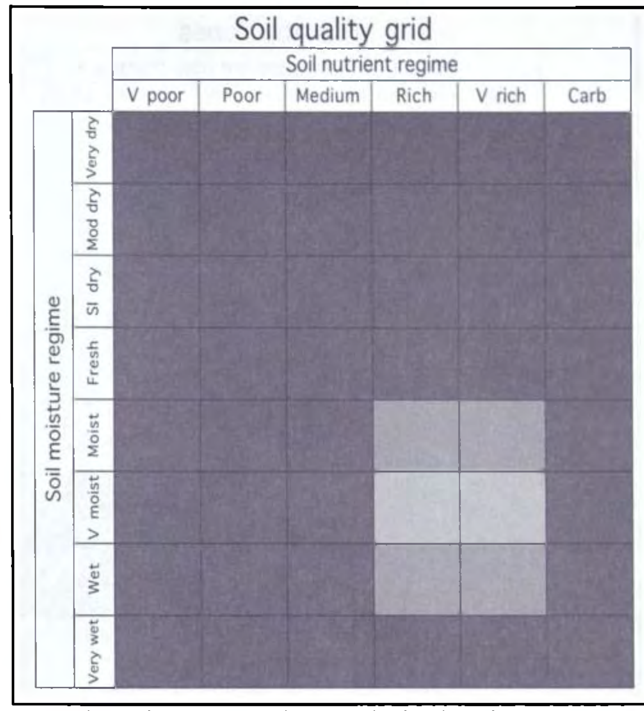


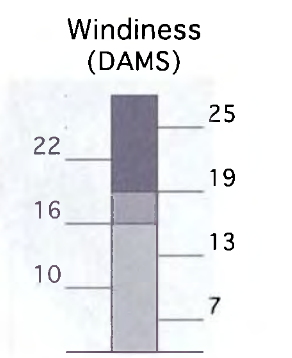
Figure 54 W4 Birch woodland with purple moor-grass



Mainly in fairly sheltered sites at low or moderate elevations.



Mainly W7b remote sedge-marsh thistle sub-community on strongly flushed sites.



Key

- Optimal
- Suitable
- Unsuitable
- Not present in Grampian

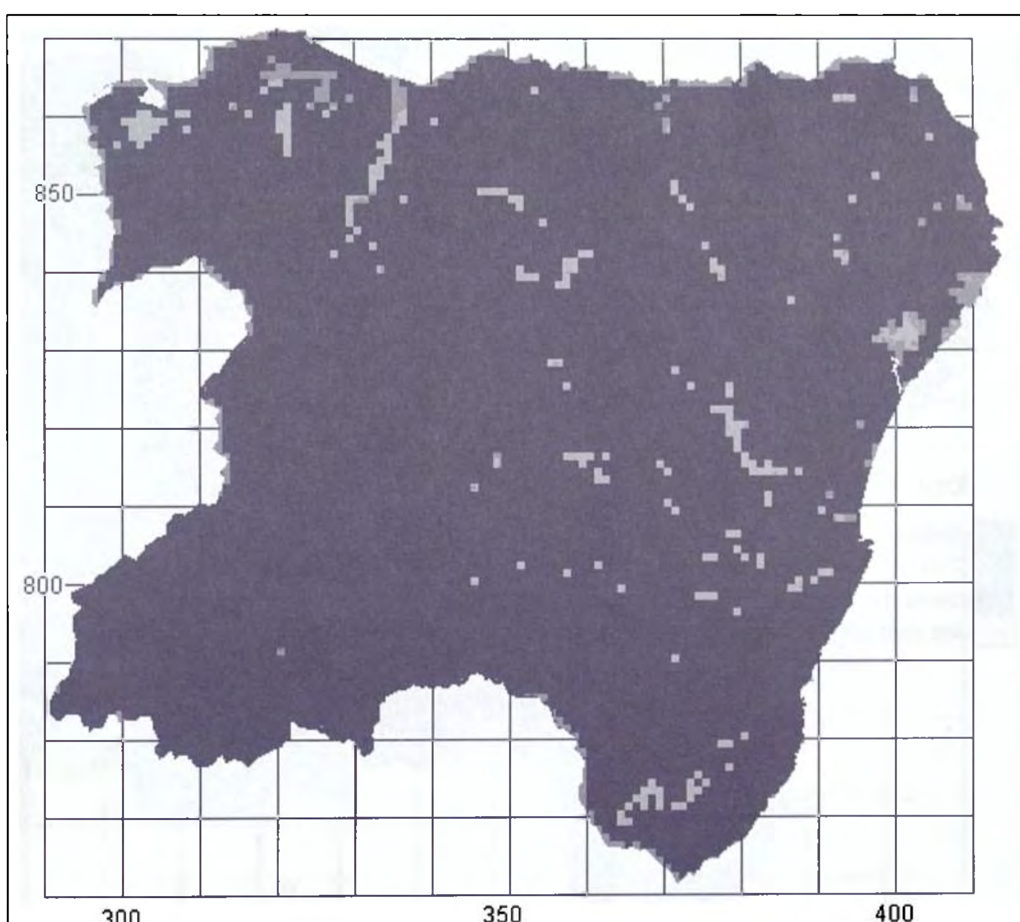
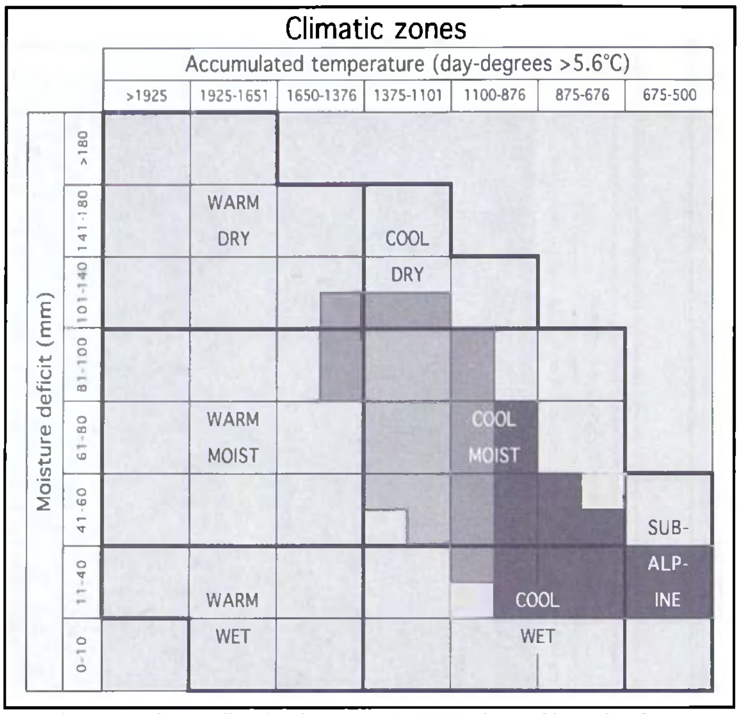
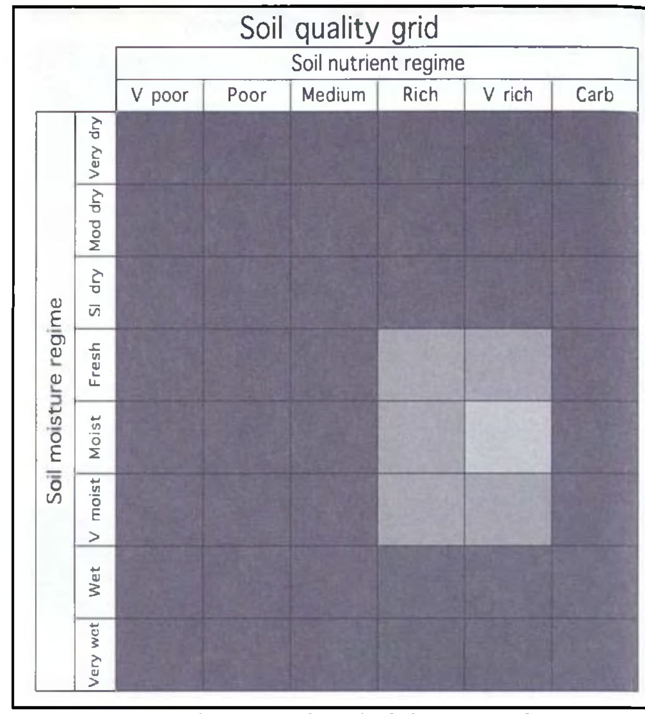


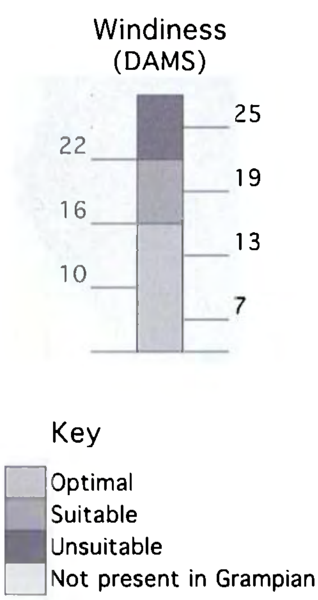
Figure 55 W7 Alder-ash woodland with yellow pimpernel



Includes NVC woodland sub-communities W9a, W9b and W8e.



W8e found at the very rich end of the range of SNR, W9b on rich SNR, W9a in the centre of the range.



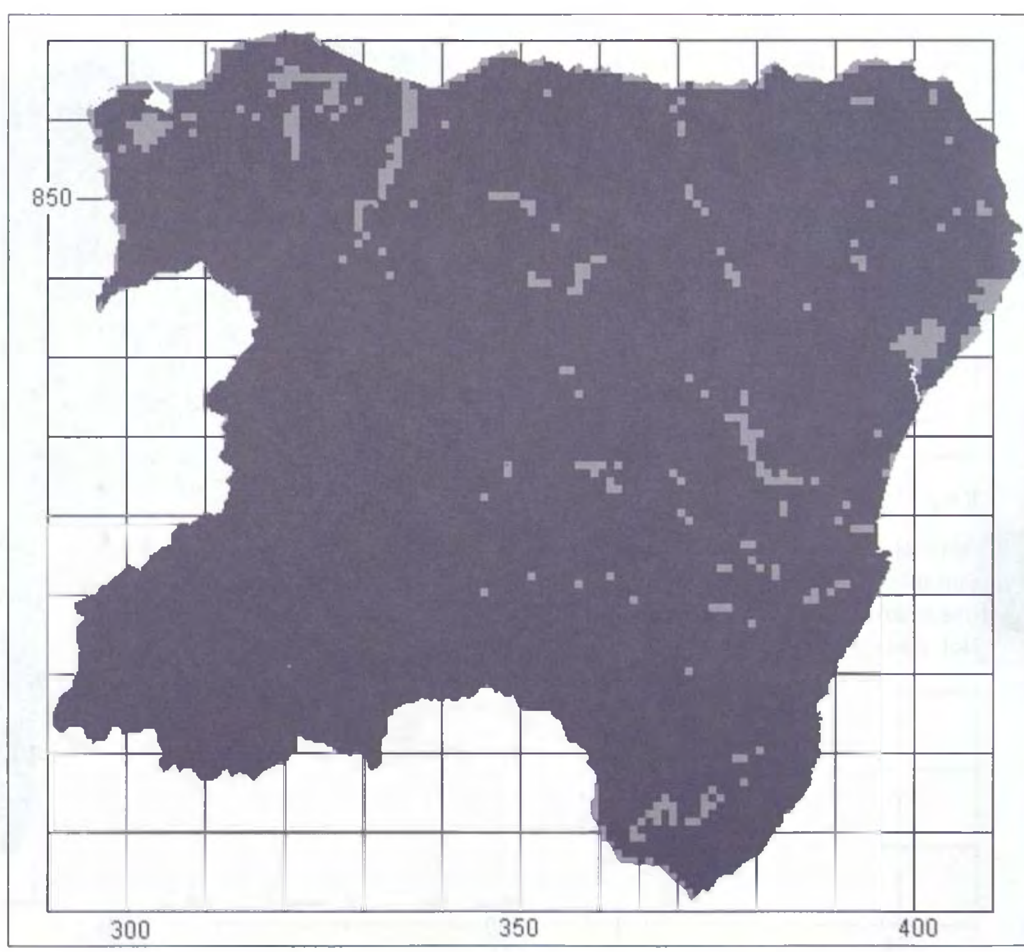
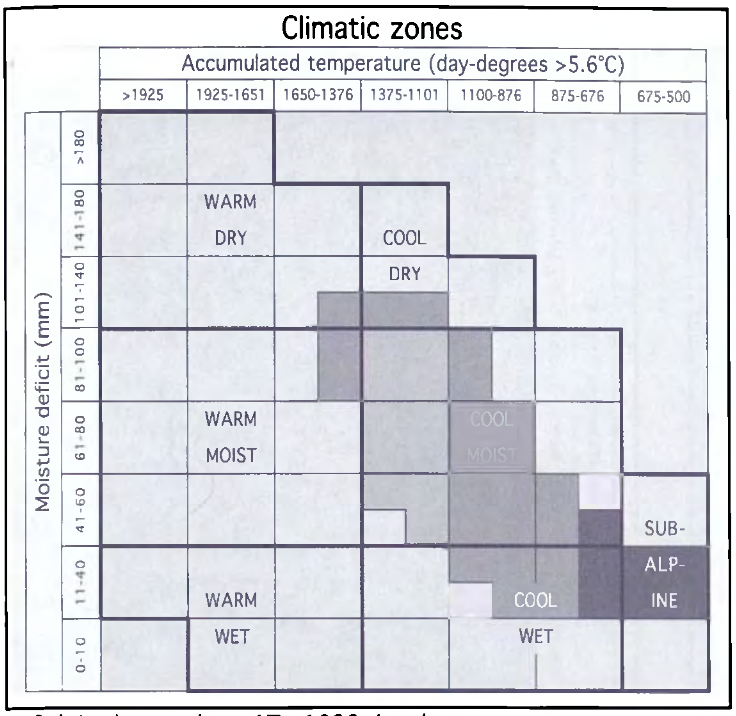
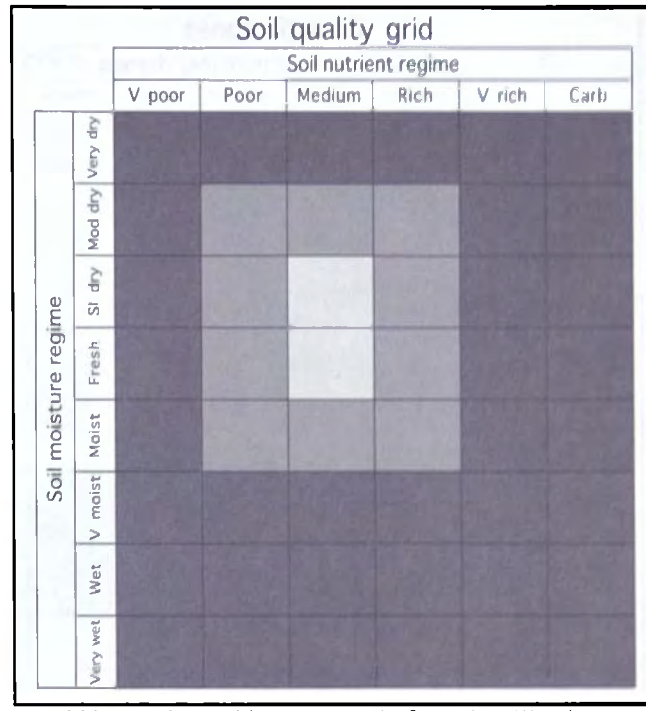


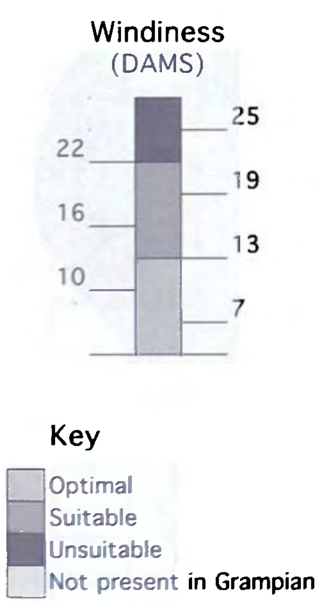
Figure 56 W8/W9 Upland mixed broadleaved woodland with dog's mercury



Oak is absent where AT <1000 day-degrees.
Trees will be severely wind-swept where DAMS >19.
Mainly W11c and d sub-communities in this rather continental climatic region.



Wild hyacinth is seldom present in Grampian. Wood sorrel and wood anemone are more typical members of the ground flora. W11c sub-community is found towards the poorer end of the range of SNR.



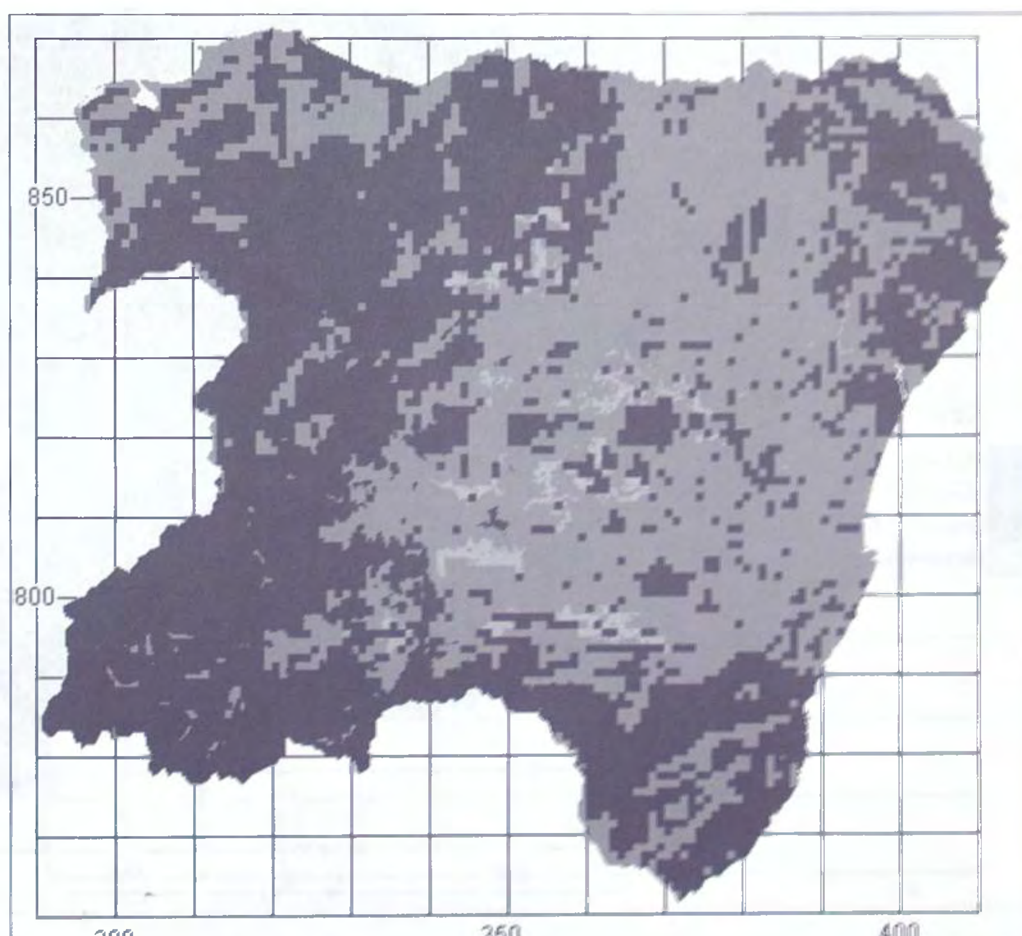


Figure 57 **W11 Upland oak-birch woodland with wild hyacinth**

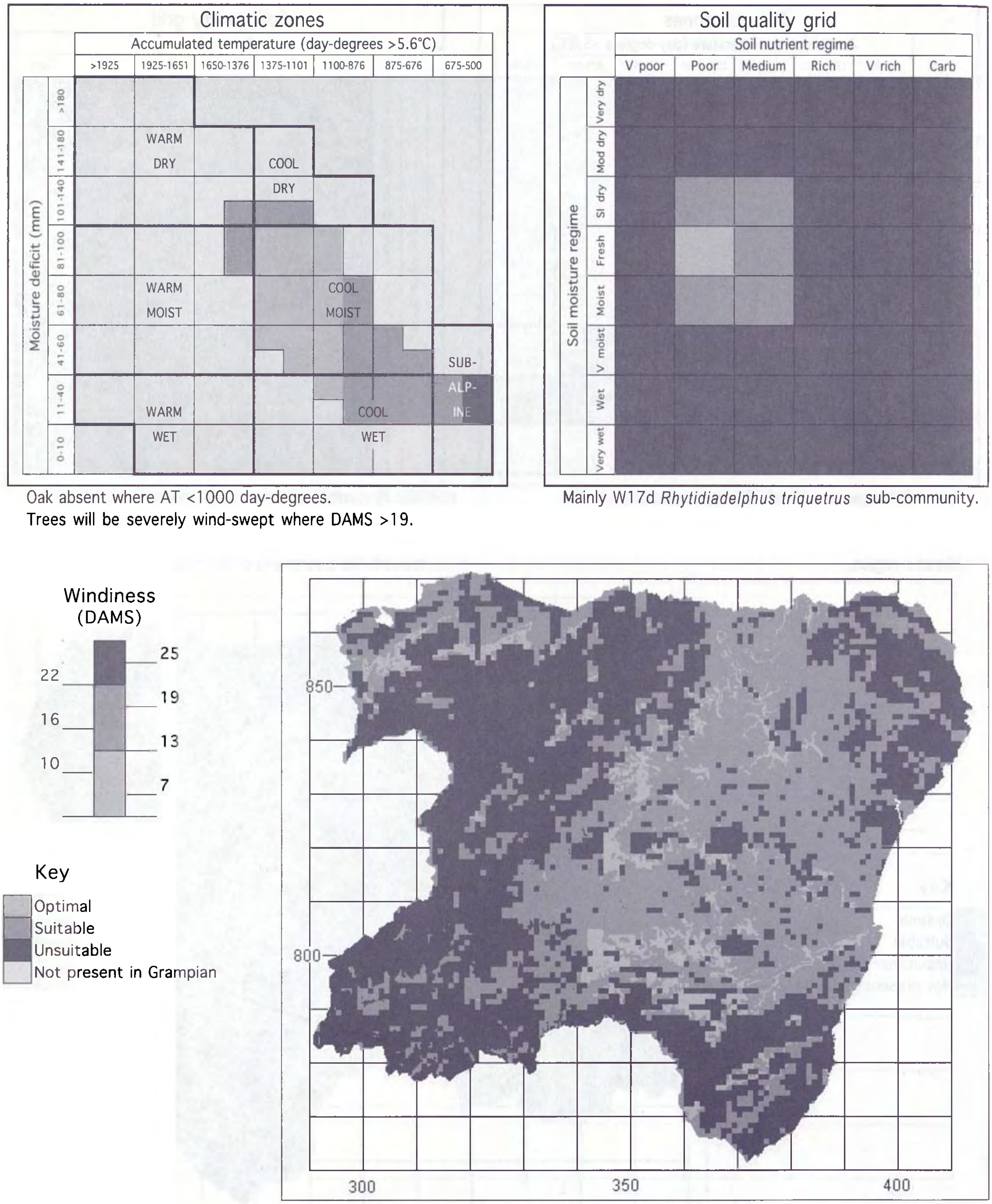
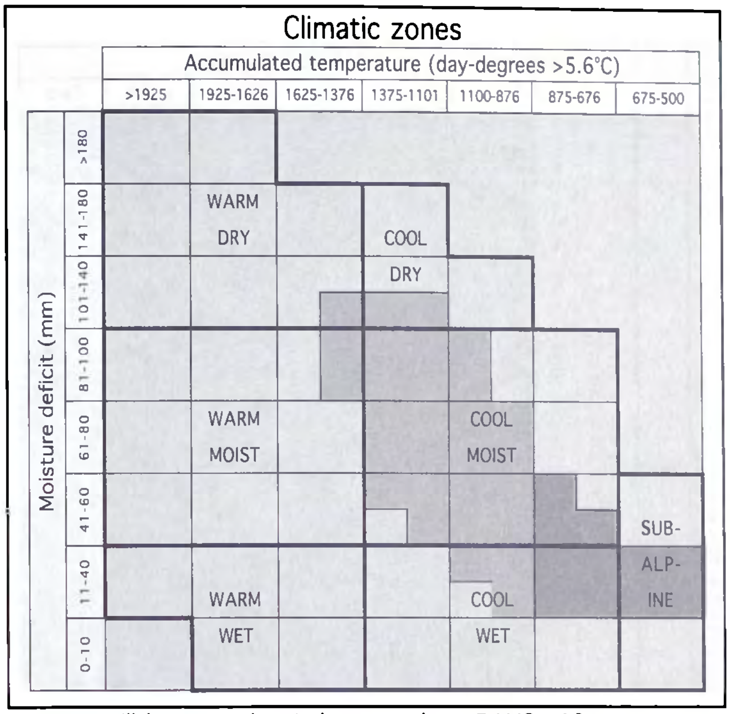
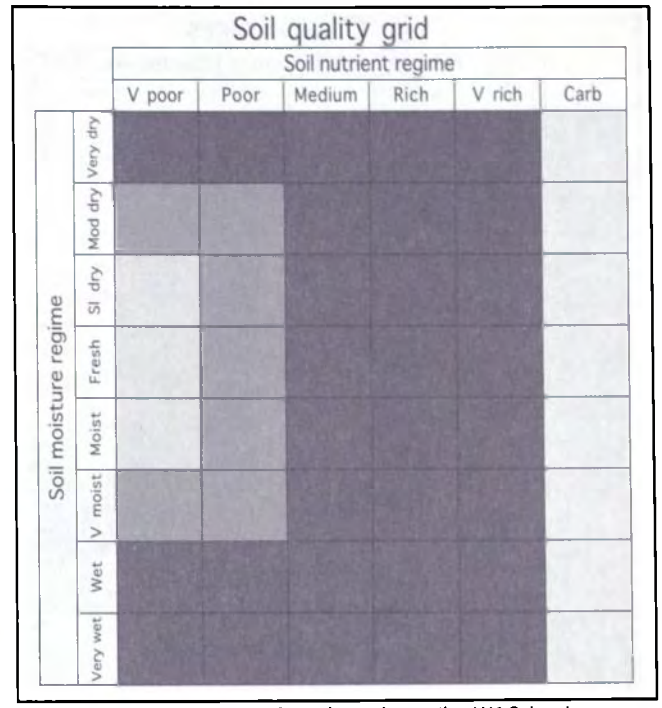


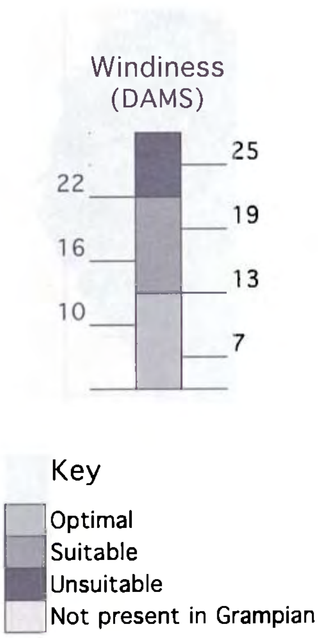
Figure 58 W17 Upland oak-birch woodland with blaeberry



Trees will be severely wind-swept where DAMS >19.
W18a sub-community is more typical of low elevations with larger moisture deficit.



W18a sub-community found on dry soils, W18d sub-community on very moist soils, W18c on poor SNR.



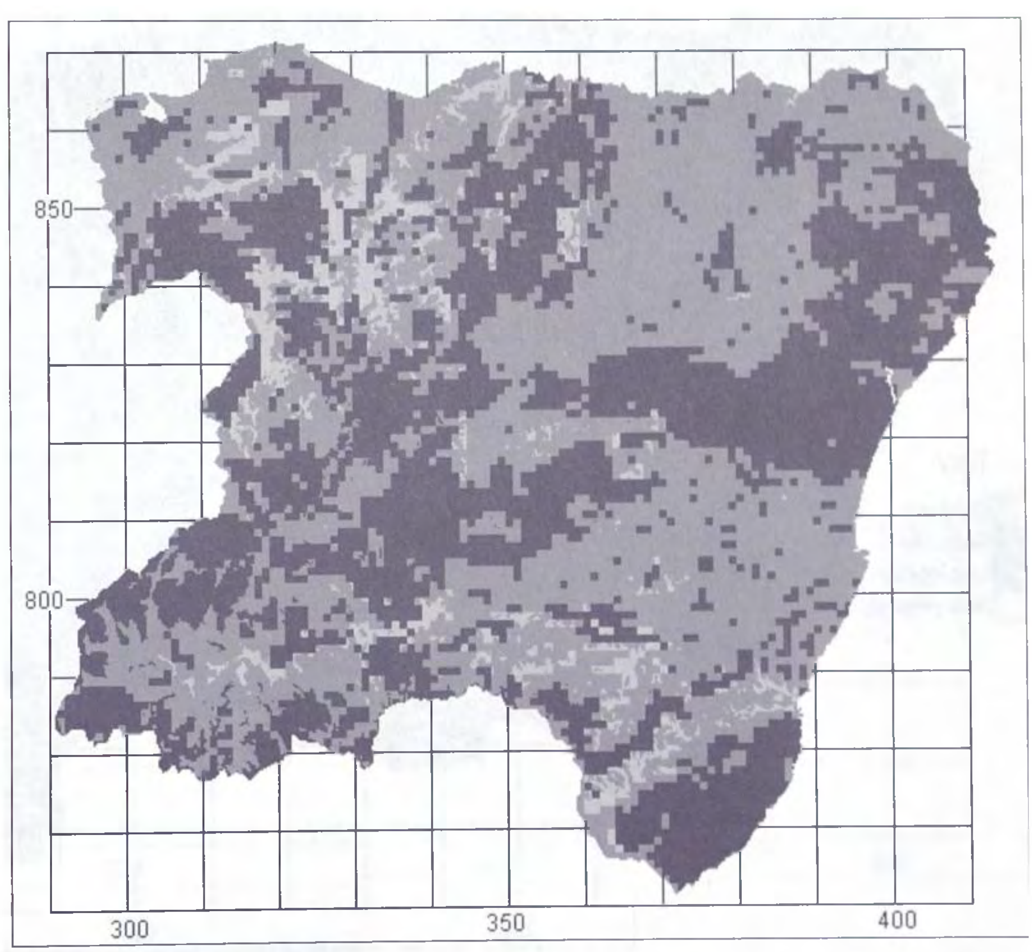


Figure 59 W18 Scots pine woodland with heather

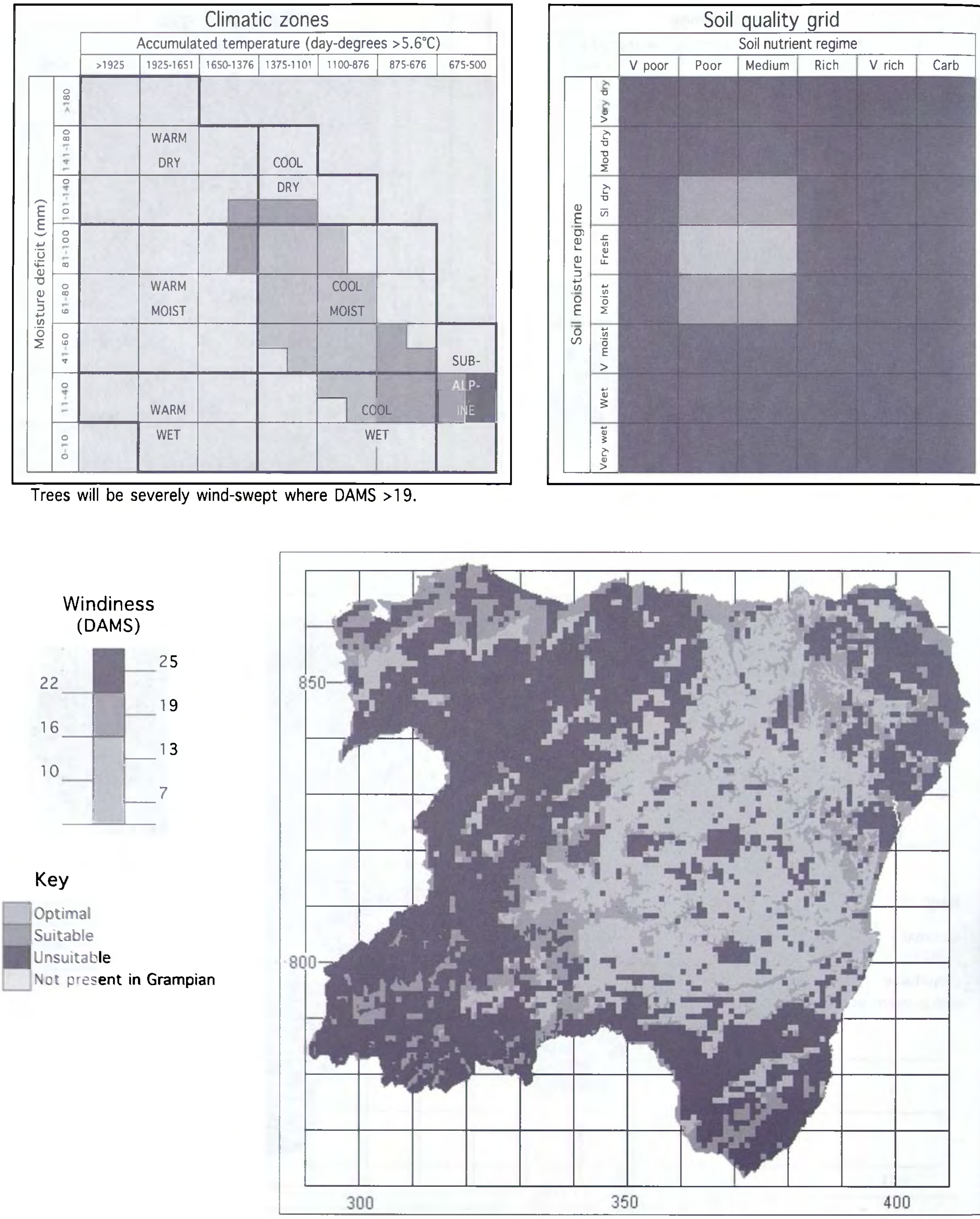
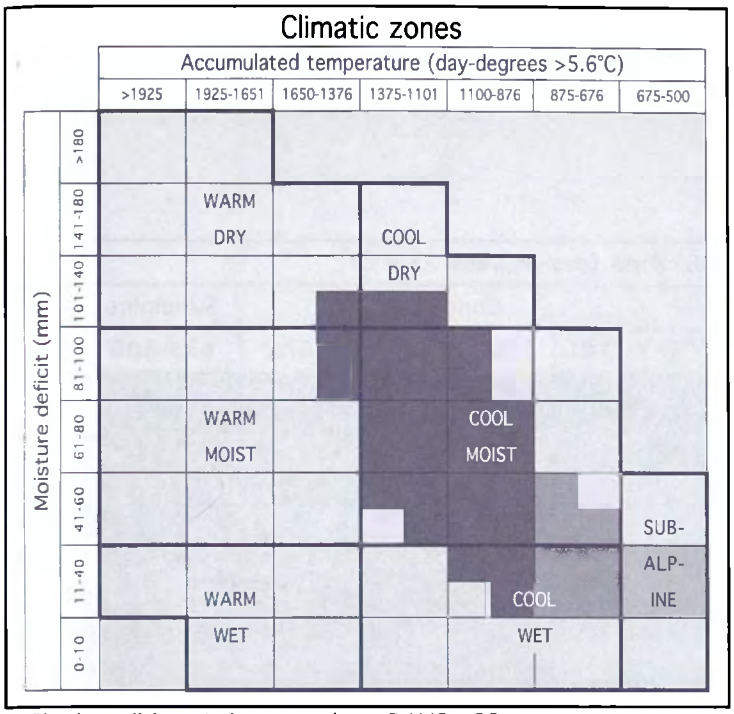
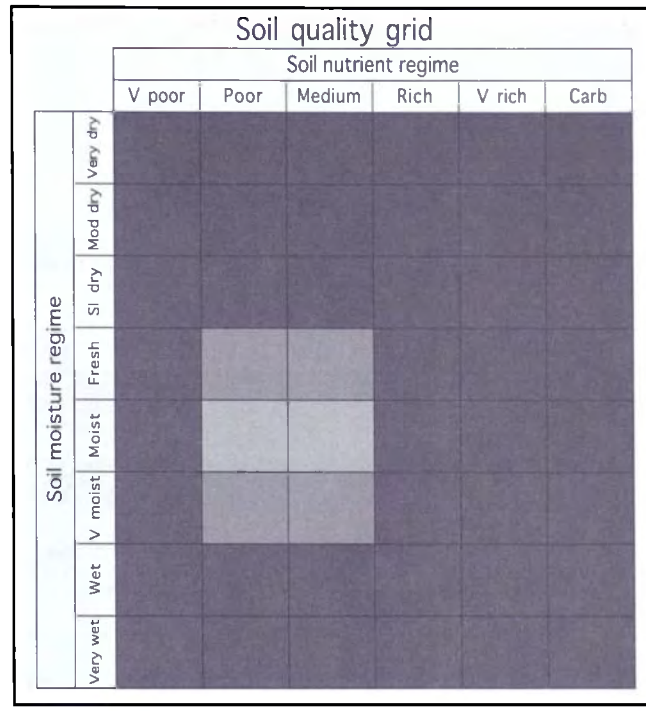
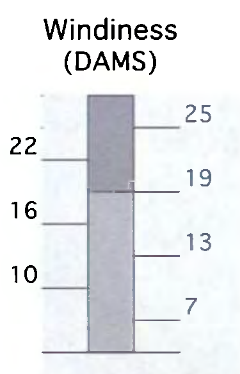


Figure 60 W19 Juniper woodland with wood sorrel



Shrubs will be wind-swept where DAMS >22.





Key
- Optimal
- Suitable
- Unsuitable
- Not present in Grampian

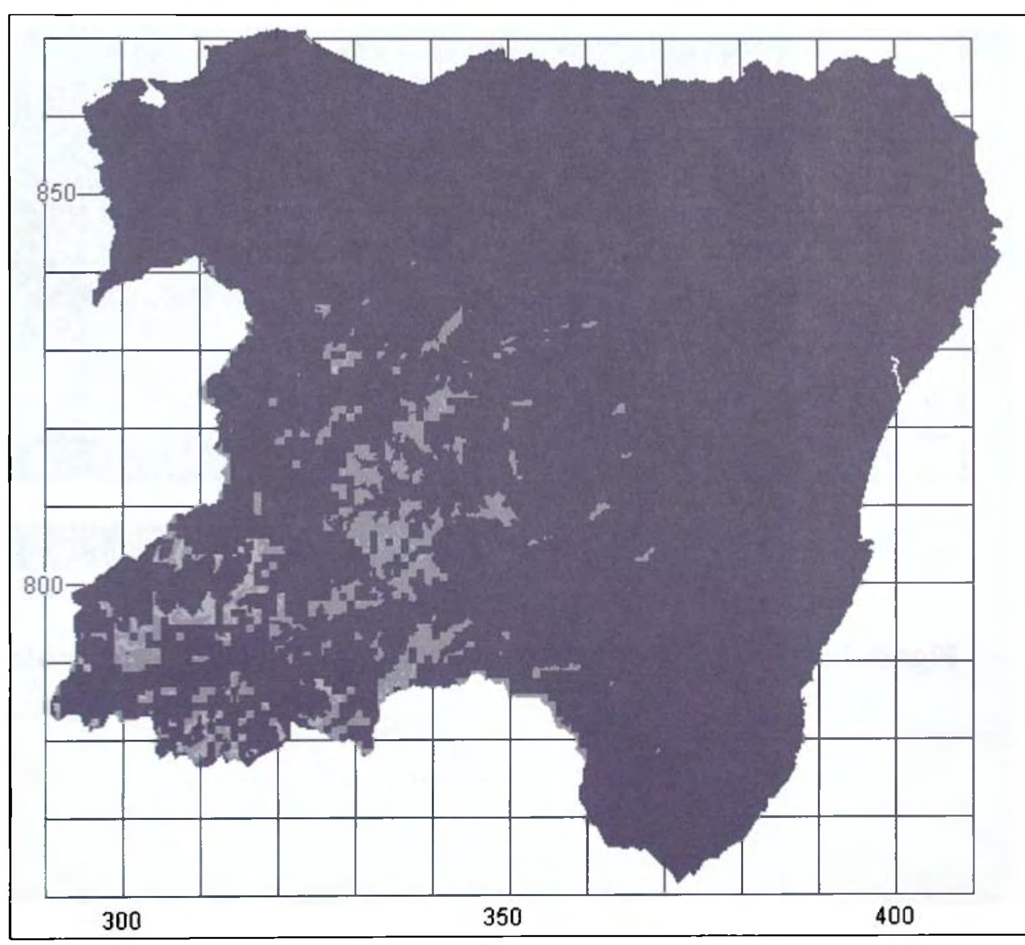


Figure 61 W20 *Salix lapponum-Luzula sylvatica* scrub

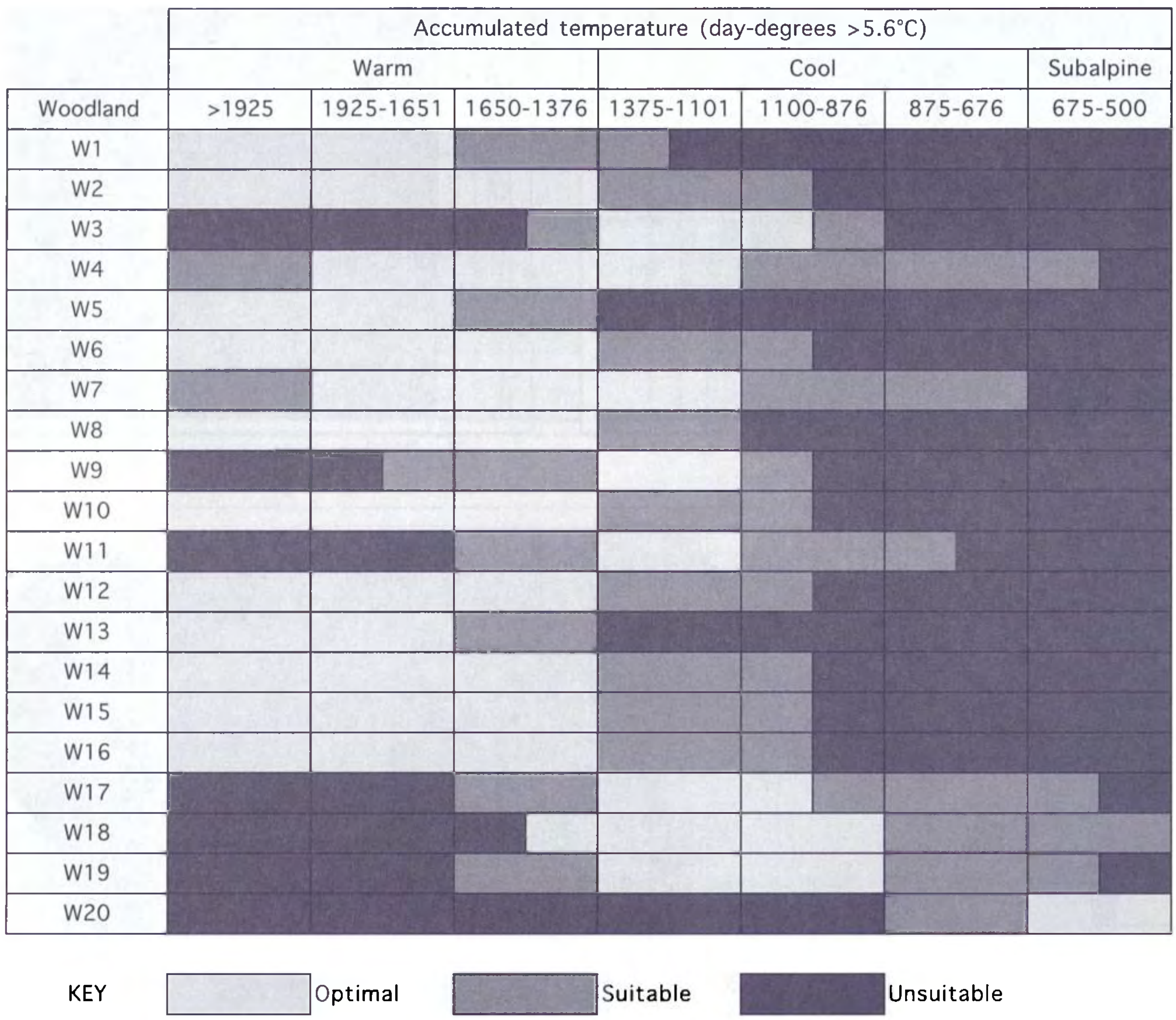


Figure 62 Suitability of native woodlands in Britain by accumulated temperature

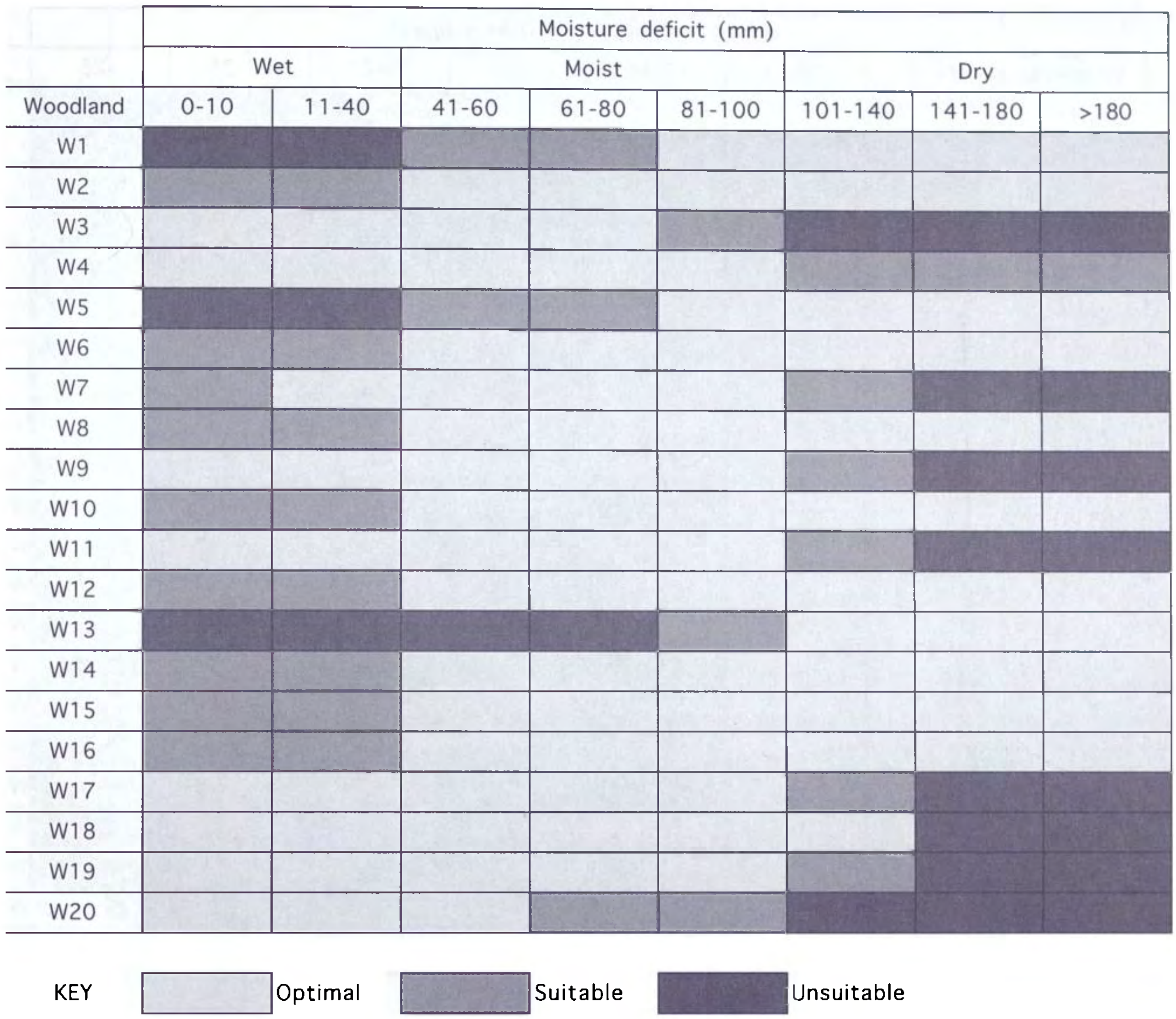


Figure 63 Suitability of native woodlands in Britain by moisture deficit

Mapping unit	Geology/Parent material	Soil types	FC type	SMR	SNR	Comments/main Soil Series	Area km2
631a	Carboniferous sandstone (Millstone Grit)	Podzols and humic rankers; rock outcrops & boulders prominent	3, 13p	SD-F	VP	Anglezarke & Revidge Series	137
631b,e,f,633	Permo-Triassic & Devonian sandstones	Podzols, reddish sand	3m	F	P		112
651b	Granite & other acid igneous	Ironpan & ferric stagnopodzols	4,4b	M	VP	Hexworthy & Rough Tor Series	72
654a	**Cam/Ord/Sil slate, mudstone, siltstone**	**Ferric & ironpan stagnopodzols, stagnohumic gleys**	**4b,4, 4p,6**	**M,W**	**P**	**Hafren, Hiraethog & Wilcocks Series**	**1374**
654b	**Devonian sandstone**	**Ferric & ironpan stagnopodzols**	**4b,4,4p**	**M**	**P**	**Lydcott Series**	**259**
654c	**Carboniferous (Pennant) sandstone**	**Ferric & ironpan stagnopodzols, stagnohumic gleys**	**4b,4, 4p,6**	**M,VM**	**P**	**Gelligaer & Rhondda Series**	**288**
711a,p,q	Ord/Sil/Carb slaty mudstone & siltstone	Stagnogleys, silty or loamy over clayey	7	VM	R	Pinder Series	356
711b,c,k,m,n,o, 712f	Permo-Triassic mudstone & till	Stagnogleys, silty or loamy over clayey	7	VM	VR	Salop Series	1656
711f,g,712a,b	Mesozoic clay	Stagnogleys, loamy over clayey, or clayey	7	VM	R		130
712d,e,h,l	Ord/Sil slaty mudstone & siltstone	Stagnogleys, clayey	7	W	M	Hallsworth Series	601
713c	Devonian sandstone & siltstone	Stagnogleys, fine silty, reddish	7	W	M	Fforest Series	85
713b,d,e	**Cam/Ord/Sil slaty mudstone & siltstone**	**Stagnogleys, fine loamy**	**7**	**W**	**M**	**Cegin Series**	**1842**
713a,f,g	Carboniferous & Precambrian shale & sandstone	Stagnogleys, fine loamy	7	W	M	Precambrian in Anglesey	1042
721b,c	**Carboniferous or Ord/Sil shale & sandstone**	**Stagnohumic gleys, fine loamy**	**6**	**W**	**P**	**Wilcocks Series**	**940**
721d	**Cam/Ord/Sil slaty mudstone & siltstone**	**Stagnohumic gleys, fine loamy, and deep peats**	**6,6p,9**	**W**	**P**	**Wilcocks & Crowdy Series**	**485**
721e	**Devonian sandstone & siltstone**	**Stagnohumic gleys, fine loamy, reddish**	**6,6p**	**W**	**P**	**Wenallt Series**	**243**
811a,b,c	River alluvium, sometimes calcareous	Groundwater gleys, loamy or silty	5,5k	W	VR	Conway Series	369
811d,e, 812b,c	Marine alluvium, sometimes calcareous	Groundwater gleys, loamy or silty	5, 5k	VM	-	Tanvats & Wallasea Series	147
813a,b,d,e	River alluvium, sometimes calcareous	Groundwater gleys, clayey	5,5k	VM	VR		72
813f,814c	Marine alluvium, sometimes calcareous	Groundwater gleys, clayey	5,5k	VM	-	Newchurch Series	298
821a,b, 831a,c, 861a,b	Aeolian, river terrace or fluvioglacial sand or loam	Groundwater gleys, sandy, sometimes peaty	5,5p	W	R	Everingham Series	105
851a,b	Marine alluvium & fen peat	Groundwater gleys, peaty	5p	W	-		36
871a	Rhyolite, granite, other acid igneous	Groundwater gleys, peaty	5p	VW	M	Laployd Series	30
1011a,b, 1013a,b,1021	**Blanket, basin, and raised.bog peat**	**Deep amorphous or fibrous peat, eroded in places**	**9,10,11**	**W**	**P"**	**Crowdy Series**	**661**
1022a,1024a, 1024b	Fen peat	Deep peat, sometimes with earthy topsoil	8	W	R"	Adventurers' Series	71
lakes	Lakes and reservoirs						51
sea							942
u	Urban areas						1493

" Variable, only the most likely class is shown. * Variable depending on the quality of the restoration,

Total 33634

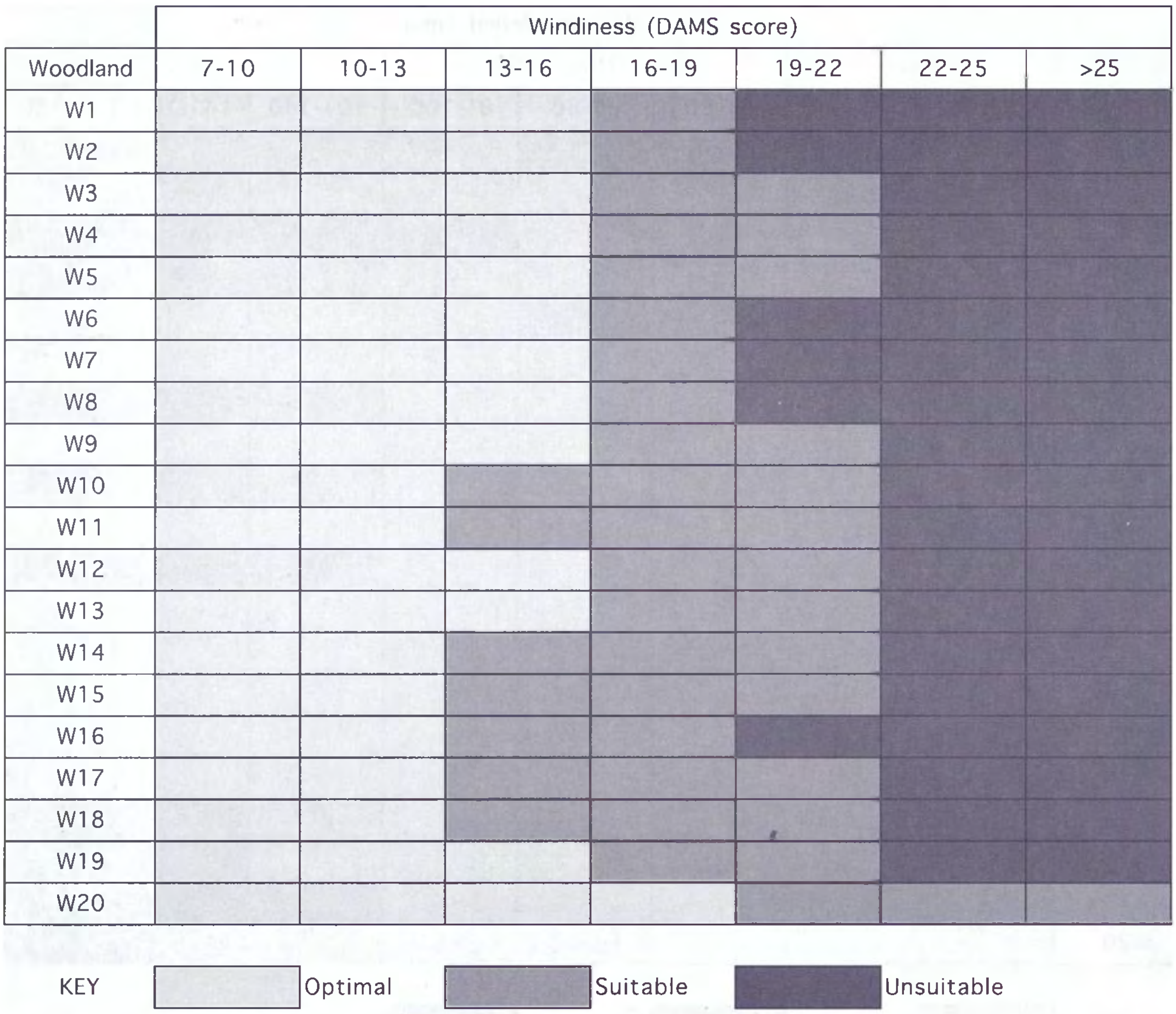


Figure 64 Suitability of native woodlands in Britain by windiness

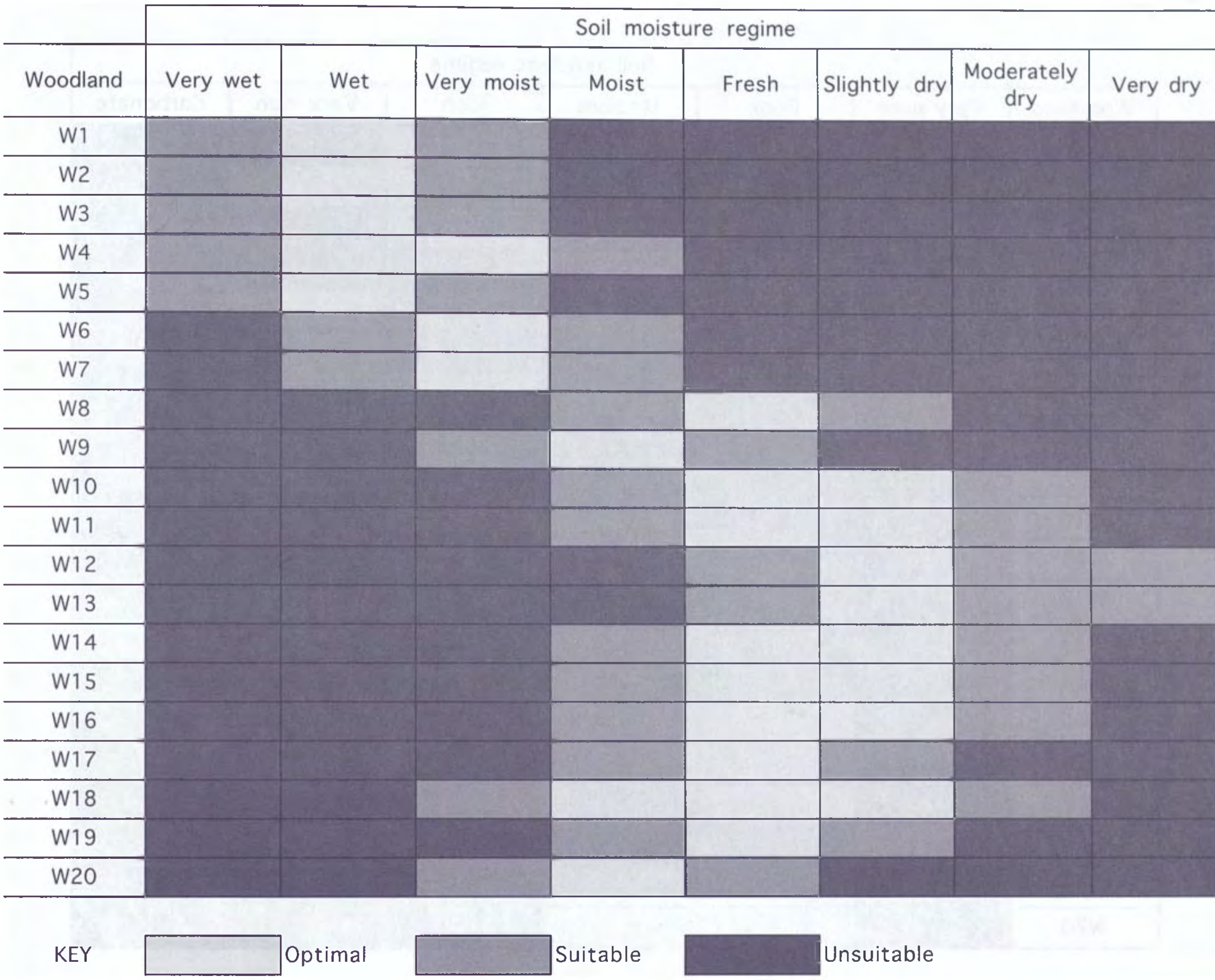


Figure 65 Suitability of native woodlands in Britain by soil moisture regime

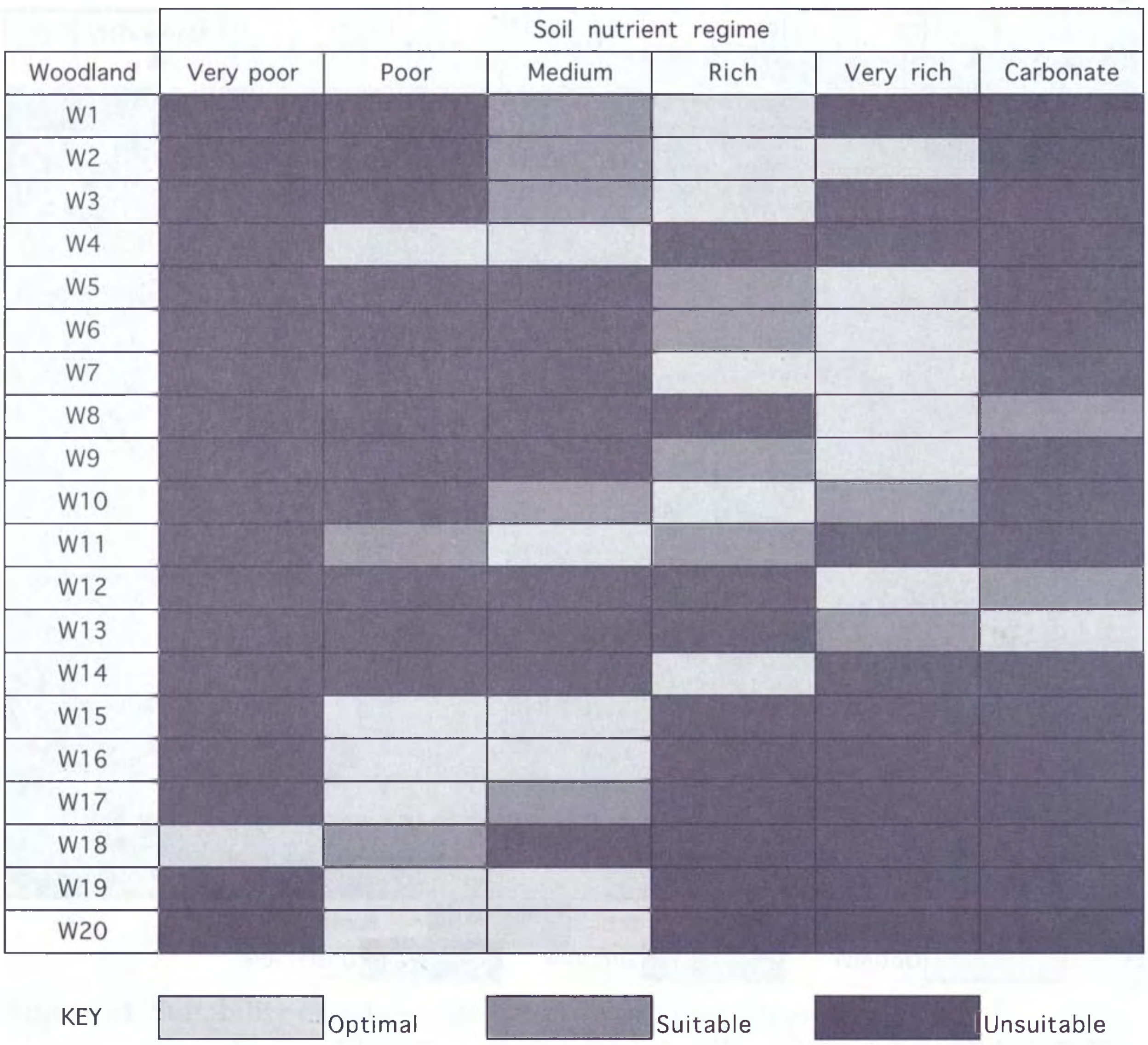
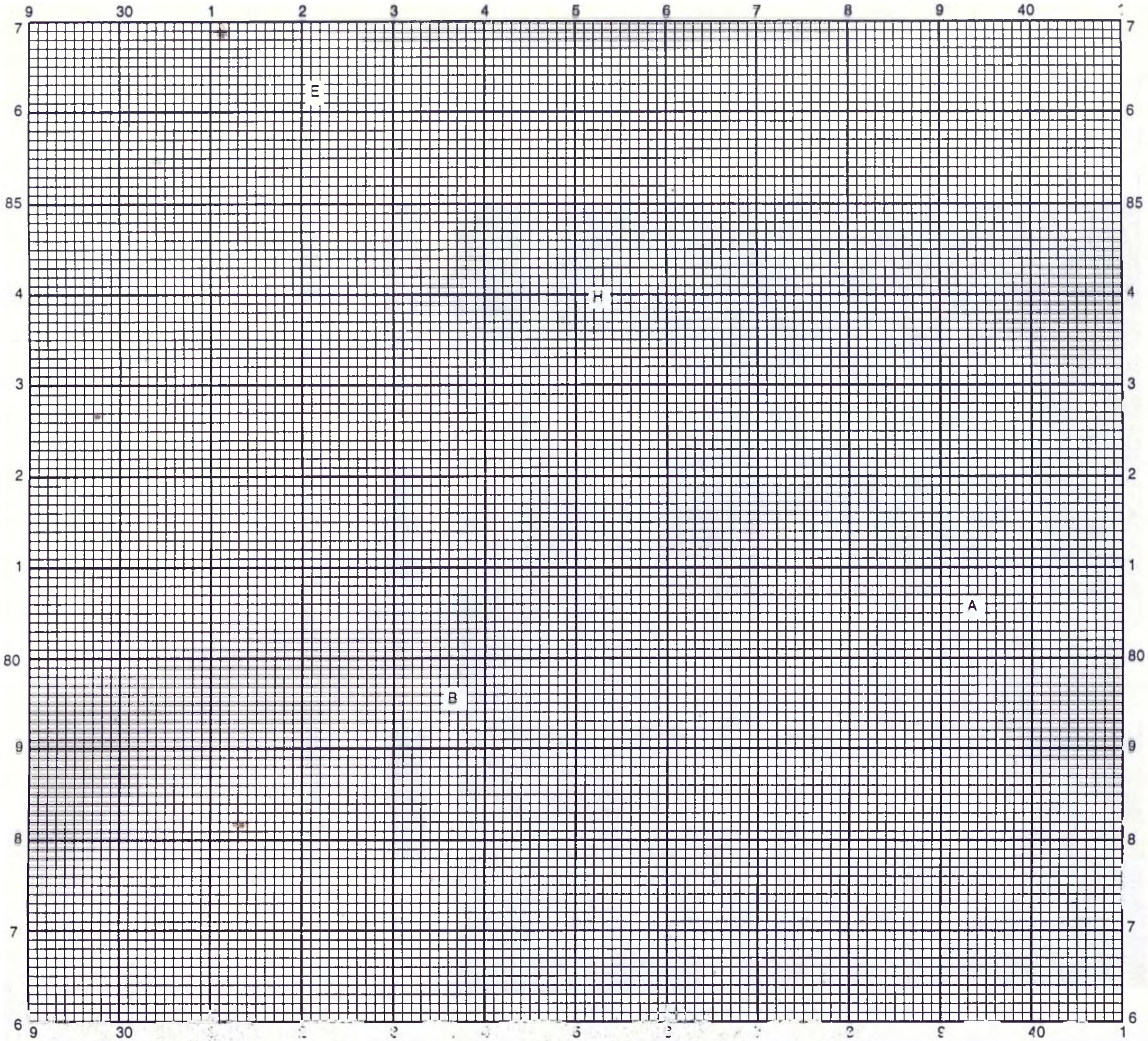


Figure 66 Suitability of native woodlands in Britain by soil nutrient regime



ECOLOGICAL

SITE

CLASSIFICATION

Grid to facilitate

location of sites

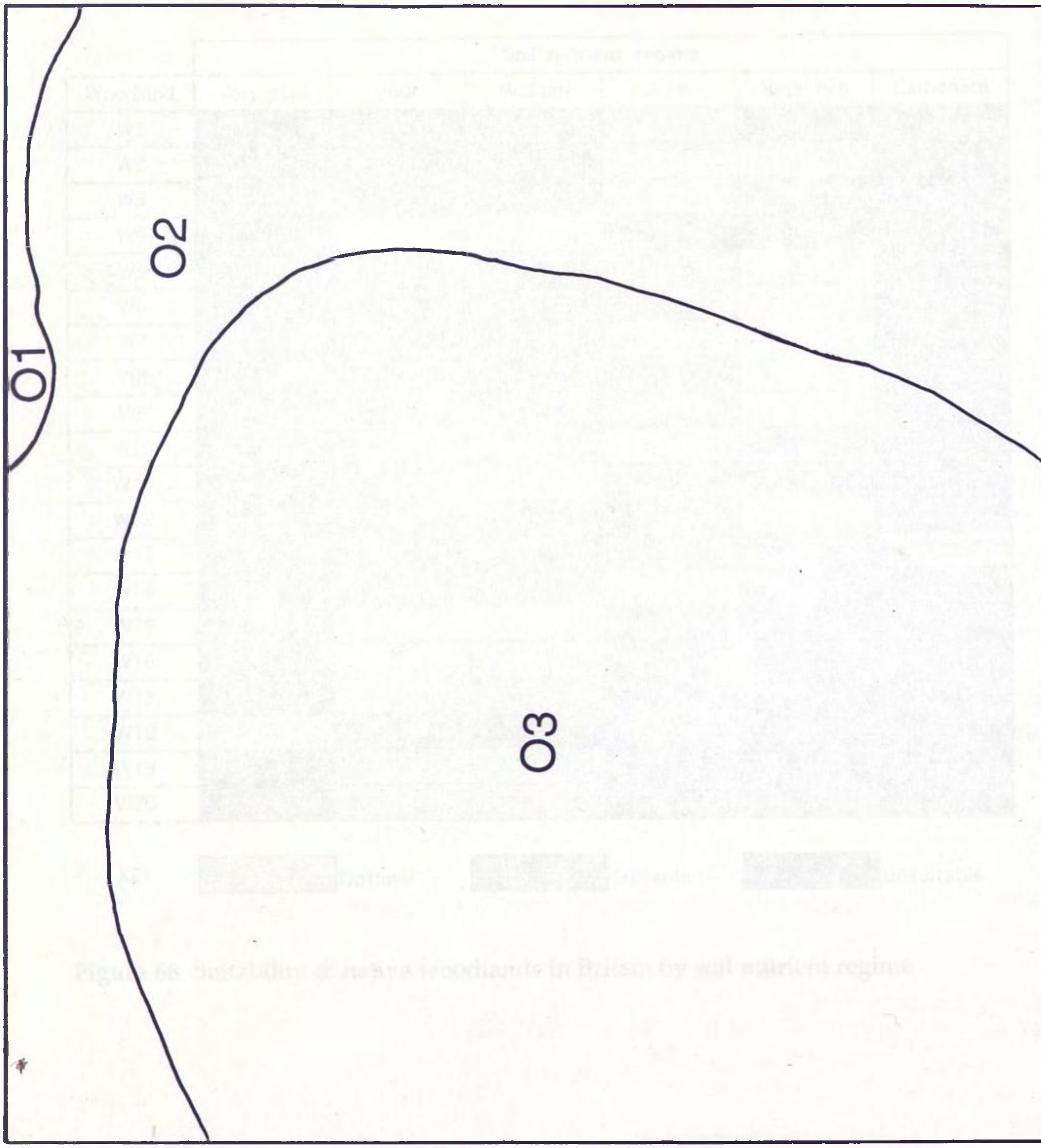
on maps of

Gramplan at a

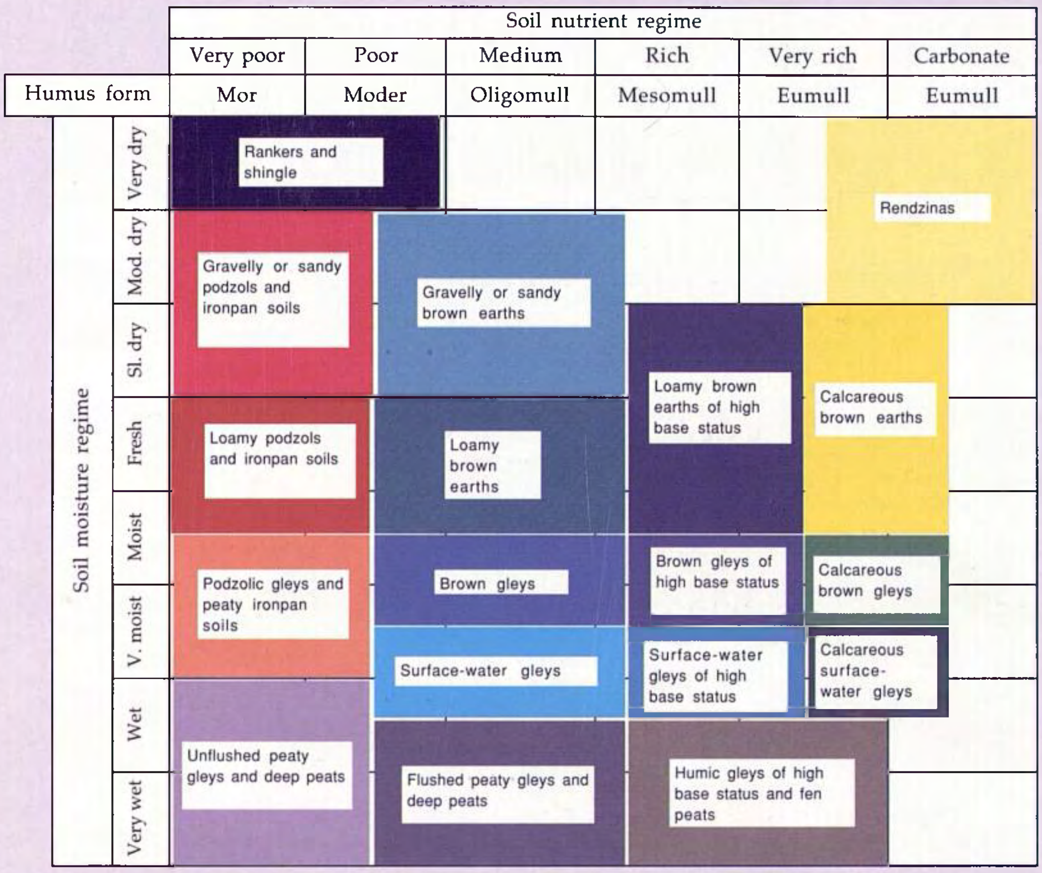
scale 1:625 000

A Aberdeen
B Ballater
E Elgin
H Huntly

Oceanicity classes in Grampian



Soil quality, soil types and humus forms



The site classification in this Technical Paper provides a sound ecological basis for the sustainable management of forests for timber production, wildlife conservation and other benefits. Applicable to all kinds of woodlands, from plantations of a single species through the range to semi-natural woodlands of many species, it incorporates the existing classification of soil types used as the basis of silviculture for many years.

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