Ministry of Agriculture, Fisheries and Food

Agricultural Land Classification

of

England and Wales

Revised guidelines and criteria for grading the quality of agricultural land

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PREFACE

This report provides revised guidelines and criteria for grading the quality of agricultural land using the Agricultural Land Classification (ALC) of England and Wales. The ALC was devised and introduced in the 1960s and Technical Report 11 (MAFF, 1966) outlined the national system, which forms the basis for advice given by the Ministry of Agriculture, Fisheries and Food (MAFF) and Welsh Office Agriculture Department (WOAD) on land use planning matters. Following a review of the system, criteria for the sub-division of Grade 3 were published in Technical Report 11/1 (MAFF, 1976). The classification is well established and understood in the planning system and provides an appropriate framework for determining the physical quality of the land at national, regional and local levels.

Experience gained has shown that some modifications to the ALC system can usefully be made to take advantage of new knowledge and data, to improve the objectivity and consistency of assessments and standardise terminology. The revised guidelines and criteria in this report have been developed and tested with the aim of updating the system without changing the original concepts. A further aim has been to calibrate the revised criteria with those used previously to maintain as far as possible the consistency of grading. The guidelines and methods used to define grades and subgrades are based on the best and most up to date information available but future revisions may be necessary to accommodate new information and technical innovation.

There is a continuing need to distinguish between the better land in Grade 3 and other land in this Grade but it is no longer considered necessary to maintain a threefold division. Two subgrades are now recognised: Subgrade 3a and Subgrade 3b, the latter being a combination of the previous Subgrades 3b and 3c.

Technical Report 11 included proposals for the development of an economic classification system linked to the physical classification. It also identified a number of significant disadvantages for a national system of economic classification, especially the problems associated with the acquisition of objective, up to date, accurate and consistent farm output data. No satisfactory means have been found of overcoming these problems and for this reason economic criteria for grading land have not been adopted. Similarly site specific crop yield data are not regarded as a reliable indication of land quality, because it is not possible to consistently make allowances for variables such as management skill, different levels of input and short-term weather factors.

The principal changes in this revision concern the criteria used to assess climatic limitations and the main limitations involving a climate-soil interaction, namely soil wetness and droughtiness. The revised methods have been developed and evaluated by the Agricultural Development and Advisory Service (ADAS) in close collaboration with the Soil Survey and Land Research Centre (SSLRC, incorporating the Soil Survey of England and Wales) and the Meteorological Office. A number of new and improved climatic datasets have been compiled on the same collaborative basis and these base data are held in LandIS, a computer information system funded by MAFF and developed by SSLRC. The datasets will also be published by the Meteorological Office (in press) and are described in Appendix 1.

The revised system incorporates some features of the 7-class Land Use Capability Classification formerly used by the Soil Survey of England and Wales (Bibby and Mackney, 1969) in which Classes 5, 6 and 7 broadly correspond to Grade 5 of the ALC system. In common with the Scottish Land Capability Classification for Agriculture (Bibby et al, 1982) some of the concepts now introduced originated from the ADAS Land Capability Working Party which met between 1974 and 1981. Although there are similarities with the Scottish system, the Agricultural Land Classification has been developed and calibrated specifically for use in England and Wales. This report describes the criteria and assessment methods which will be used by MAFF and WOAD to classify land. Wherever possible, definitions and methods common to both ADAS and SSLRC have been used.

Acknowledgements

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SECTION 1

INTRODUCTION

The Agricultural Land Classification provides a framework for classifying land according to the extent to which its physical or chemical characteristics impose long-term limitations on agricultural use. The limitations can operate in one or more of four principal ways: they may affect the range of crops which can be grown, the level of yield, the consistency of yield and the cost of obtaining it. The classification system gives considerable weight to flexibility of cropping, whether actual or potential, but the ability of some land to produce consistently high yields of a somewhat narrower range of crops is also taken into account.

The principal physical factors influencing agricultural production are climate, site and soil. These factors together with interactions between them form the basis for classifying land into one of five grades; Grade 1 land being of excellent quality and Grade 5 land of very poor quality. Grade 3, which constitutes about half of the agricultural land in England and Wales, is now divided into two subgrades designated 3a and 3b. General descriptions of the grades and subgrades are given in Section 2.

Guidelines for the assessment of the physical factors which determine the grade of land are given in Section 3. The main climatic factors are temperature and rainfall although account is taken of exposure, aspect and frost risk. The site factors used in the classification system are gradient, microrelief and flood risk. Soil characteristics of particular importance are texture, structure, depth and stoniness. In some situations, chemical properties can also influence the long-term potential of land and are taken into account. These climatic, site and soil factors result in varying degrees of constraint on agricultural production. They can act either separately or in combination, the most important interactive limitations being soil wetness and droughtiness.

The grade or subgrade of land is determined by the most limiting factor present. When classifying land the overall climate and site limitations should be considered first as these can have an overriding influence on the grade. Land is graded and mapped without regard to present field boundaries, except where they coincide with permanent physical features.

A degree of variability in physical characteristics within a discrete area is to be expected. If the area includes a small proportion of land of different quality, the variability can be considered as a function of the mapping scale. Thus, small, discrete areas of a different ALC grade may be identified on large scale maps, whereas on smaller scale maps it may only be feasible to show the predominant grade. However, where soil and site conditions vary significantly and repeatedly over short distances and impose a practical constraint on cropping and land management a 'pattern' limitation is said to exist. This variability becomes a significant limitation if, for example, soils of the same grade but of contrasting texture occur as an extensive patchwork thus complicating soil management and cropping decisions or resulting in uneven crop growth, maturation or quality. Similarly, a form of pattern limitation may arise where soil depth is highly variable or microrelief restricts the use of machinery. Because many different combinations of characteristics can occur no specific guidelines are given for pattern limitations. The effect on grading is judged according to the severity of the limitations imposed by the pattern on cropping and management, and is mapped where permitted by the scale of the survey.

The guidelines provide a consistent basis for land classification but, given the complex and variable nature of the factors assessed and the wide range of circumstances in which they can occur, it is not possible to prescribe for every possible situation. It may sometimes be necessary to take account of special or local circumstances when classifying land. For this reason, the physical criteria of eligibility in this report are regarded as guidelines rather than rules although departures from the guidance should be exceptional and based on expert knowledge. Physical conditions on restored land may take several years to stabilise; therefore, the land is not normally graded until the end of the statutory aftercare period, or otherwise not until 5 years after soil replacement.

To ensure a consistent approach when classifying land the following assumptions are made:

1. Land is graded according to the degree to which physical or chemical properties impose long-term limitations on agricultural use. It is assessed on its capability at a good[1] but not outstanding standard of management.

2. Where limitations can be reduced or removed by normal management operations or improvements, for example cultivations or the installation of an appropriate underdrainage system, the land is graded according to the severity of the remaining limitations. Where an adequate supply of irrigation water is available this may be taken into account when grading the land (Section 3.4). Chemical problems which cannot be rectified, such as high levels of toxic elements or extreme subsoil acidity, are also taken into account.

3. Where long-term limitations outside the control of the farmer or grower will be removed or reduced in the near future through the implementation of a major improvement scheme, such as new arterial drainage or sea defence improvements, the land is classified as if the improvements have already been carried out. Where no such scheme is proposed, or there is uncertainty about implementation, the limitations will be taken into account. Where limitations of uncertain but potentially long-term duration occur, such as subsoil compaction or gas-induced anaerobism, the grading will take account of the severity at the time of survey.

4. The grading does not necessarily reflect the current economic value of land, land use, range of crops, suitability for specific crops or level of yield. For reasons given in the preface, the grade cut-offs are not specified on the basis of crop yields as these can be misleading, although in some cases crop growth may give an indication of the relative severity of a limitation.

5. The size, structure and location of farms, the standard of fixed equipment and the accessibility of land do not affect grading, although they may influence land use decisions.

[1] Previously described as 'satisfactory'; no change in the assumed standard of management is intended.

SECTION 2

DESCRIPTION OF THE GRADES AND SUBGRADES

The ALC grades and subgrades are described below in terms of the types of limitation which can occur, typical cropping range and the expected level and consistency of yield. In practice, the grades are defined by reference to physical characteristics and the grading guidance and cut-offs for limitation factors in Section 3 enable land to be ranked in accordance with these general descriptions. The most productive and flexible land falls into Grades 1 and 2 and Subgrade 3a and collectively comprises about one-third of the agricultural land in England and Wales. About half the land is of moderate quality in Subgrade 3b or poor quality in Grade 4. Although less significant on a national scale such land can be locally valuable to agriculture and the rural economy where poorer farmland predominates. The remainder is very poor quality land in Grade 5, which mostly occurs in the uplands.

Descriptions are also given of other land categories which may be used on ALC maps.

Grade 1 - excellent quality agricultural land
Land with no or very minor limitations to agricultural use. A very wide range of agricultural and horticultural crops can be grown and commonly includes top fruit, soft fruit, salad crops and winter harvested vegetables. Yields are high and less variable than on land of lower quality.

Grade 2 - very good quality agricultural land
Land with minor limitations which affect crop yield, cultivations or harvesting. A wide range of agricultural and horticultural crops can usually be grown but on some land in the grade there may be reduced flexibility due to difficulties with the production of the more demanding crops such as winter harvested vegetables and arable root crops. The level of yield is generally high but may be lower or more variable than Grade 1.

Grade 3 - good to moderate quality agricultural land
Land with moderate limitations which affect the choice of crops, timing and type of cultivation, harvesting or the level of yield. Where more demanding crops are grown yields are generally lower or more variable than on land in Grades 1 and 2.

> **Subgrade 3a - good quality agricultural land**
> Land capable of consistently producing moderate to high yields of a narrow range of arable crops, especially cereals, or moderate yields of a wide range of crops including cereals, grass, oilseed rape, potatoes, sugar beet and the less demanding horticultural crops.
>
> **Subgrade 3b - moderate quality agricultural land**
> Land capable of producing moderate yields of a narrow range of crops, principally cereals and grass or lower yields of a wider range of crops or high yields of grass which can be grazed or harvested over most of the year.

Grade 4 - poor quality agricultural land
Land with severe limitations which significantly restrict the range of crops and/or level of yields. It is mainly suited to grass with occasional arable crops (e.g. cereals and forage crops) the yields of which are variable. In moist climates, yields of grass may be moderate to high but there may be difficulties in utilisation. The grade also includes very droughty arable land.

Grade 5 - very poor quality agricultural land
Land with very severe limitations which restrict use to permanent pasture or rough grazing, except for occasional pioneer forage crops.

Descriptions of other land categories used on ALC maps

Urban
Built-up or 'hard' uses with relatively little potential for a return to agriculture including: housing, industry, commerce, education, transport, religious buildings, cemeteries. Also, hard-surfaced sports facilities, permanent caravan sites and vacant land; all types of derelict land, including mineral workings which are only likely to be reclaimed using derelict land grants.

Non-agricultural
'Soft' uses where most of the land could be returned relatively easily to agriculture, including: golf courses, private parkland, public open spaces, sports fields, allotments and soft-surfaced areas on airports/ airfields. Also active mineral workings and refuse tips where restoration conditions to 'soft' after-uses may apply.

Woodland
Includes commercial and non-commercial woodland. A distinction may be made as necessary between farm and non-farm woodland.

Agricultural buildings
Includes the normal range of agricultural buildings as well as other relatively permanent structures such as glasshouses. Temporary structures (e.g. polythene tunnels erected for lambing) may be ignored.

Open water
Includes lakes, ponds and rivers as map scale permits.

Land not surveyed
Agricultural land which has not been surveyed,

Where the land use includes more than one of the above land cover types, e.g. buildings in large grounds, and where map scale permits, the cover types may be shown separately. Otherwise, the most extensive cover type will usually be shown.

SECTION 3

GUIDELINES FOR ASSESSING LIMITATIONS

This section explains why and how the main limiting factors used in the ALC system influence the grade of land.

3.1 Climatic Limitations

Climate has a major, and in places overriding, influence on land quality by affecting both the range of potential agricultural uses and the cost and level of production. Its most fundamental influence is on the potential for plant growth, by determining the energy available for photosynthesis and water supply to plant roots. The effect on plant growth occurs partly through interactions with soil and site properties which determine soil wetness and droughtiness. There are also more direct effects on crops or stock such as exposure to damaging wind, persistent wetness or high humidity and frost which can cause physical damage, disease or stress. It is therefore necessary to include in the ALC an assessment of the overall climatic limitation in addition to the interactive limitations which are assessed separately (Section 3.4).

The climatic criteria are considered first when classifying land. Climate can be overriding in the sense that severe limitations will restrict land to low grades irrespective of favourable soil or site conditions. The general principle followed is to assign increasing degrees of limitation to agricultural use as rainfall increases and average temperature decreases. Thus, in climatic terms, the poorest areas are both the wettest and coldest and conversely the climate is regarded as more favourable as temperature increases and rainfall moderates.

The main parameters used in the assessment of the climatic limitation are average annual rainfall (AAR), as a measure of overall wetness; and accumulated temperature, as a measure of the relative warmth of a locality. Accumulated temperature is the excess of daily air temperatures above a selected threshold temperature, summed over a specified period. When calculated over an appropriate part of the growing season it can be used as an indication of heat energy input and soil drying potential and has been shown to correlate with crop growth and yield. Work on grass (Peacock, 1975) and cereals (Biscoe and Gallagher, 1978) showed that leaf extension occurs, albeit slowly, down to temperatures as low as 0° Celsius, which is adopted as the threshold temperature for the ALC system. For the climatic assessment, accumulated temperature is calculated, using an established algorithm (Meteorological Office, 1969), for the period January to June (AT0); this being the critical growth period for most crops.

The above parameters provide the basis for the evaluation of overall climate. Local climatic factors including aspect, exposure and frost risk are also considered when grading land but are not easily quantified and require careful judgement for individual sites.

Assessment of the overall climate limitation

The permitted combinations of AAR and AT0 for each ALC grade and subgrade are defined graphically in Figure 1. The AAR and AT0 datasets used for this assessment are described in Appendix 1.

Local climatic factors
At the local scale differences in the aspect, gradient and elevation of the land can significantly modify the overall climate, particularly in relation to temperature, exposure and frost risk.

Aspect can have a marked influence on the amount of solar radiation that a site receives. In general, mean daily temperatures and hence accumulated temperatures in spring and early summer are higher on slopes with sheltered southerly aspects than on those facing in northerly directions. Radiation intensity also varies with slope angle such that differences due to aspect are more marked on steeper slopes. In valleys, the relationships are often more complex due to the effect of shading, which can moderate the benefits of a southerly aspect and increase the penalties on north facing slopes.

The influence of a favourable aspect on mean temperatures may be reduced or removed by exposure. In certain situations exposure may constitute a significant climatic factor in its own right. Persistent strong or cold winds can be damaging to crops or cause stress to livestock, especially in wet weather. Upland areas, and land which stands above the surrounding countryside, are often exposed. Many coastal districts are exposed to strong, salt-laden winds and their effects can extend for several miles inland. Windspeed is strongly influenced by topography. In general, wind velocities increase with altitude and decrease with distance from the west coast, while the funnelling of winds along valleys, particularly in the uplands, may result in consistently higher windspeeds.

The incidence of damaging frost is also closely related to topography and can be localised. Spring frosts can cause serious damage to fruit crops and may check the growth of arable crops. A slope of 2° is sufficient to initiate the movement of cold air downslope, and valley bottoms and basin sites are particularly susceptible to frost. The assessment of frost risk is most significant in relation to the better quality land where the more sensitive horticultural crops are likely to be grown. Soil type also influences frost risk, with sandy and dry peat soils being more prone to late spring frosts than other soils.

The interactions between topography and climate are often complex and it is not possible to give detailed guidance for their assessment. Where the overall climate is liable to be modified significantly by local factors, the effect on grading should be assessed on the basis of expert agrometeorological advice.

3.2 Site Limitations

The assessment of site factors is primarily concerned with the way in which topography influences the use of agricultural machinery and hence the cropping potential of the land. Flood risk is also regarded as a site limitation as it is usually associated with well-defined topographic features.

Gradient
Gradient has a significant effect on mechanised farm operations since most conventional agricultural machinery performs best on level ground. The safe and

efficient use of machinery on sloping land depends very much on the type and design of the machine and on the nature of the slope being farmed. For example, slopes with adequate turning space at the top and bottom may be negotiated safely whereas similar slopes without turning space may not. The bearing strength of the topsoil is also critical in the safe operation of machinery on slopes. Where surfaces have a low bearing strength the safe angle for working is reduced.

Table 1 gives the gradient limits for each grade and subgrade of land. They are based primarily on the type of machinery which can be safely and efficiently operated. The grade cut-offs are modelled principally on the use of two-wheel drive machines. The ability to work on steeply sloping land has increased to some extent with the wider use of four-wheel drive machines. However, where cultivation is involved there is often an attendant risk of soil erosion particularly if the soil is weakly structured. For this reason, and on safety grounds, the previous limits of 11° and 18° are retained. Grade 1, 2 and 3a land is suitable for most kinds of agricultural machinery including precision seeding and harvesting equipment.

Table 1 Grade according to gradient

Grade/ Subgrade	Gradient limits (degrees)
1, 2, 3a	7
3b	11
4	18
5	>18

Microrelief

Complex changes of slope angle and direction over short distances, or the presence of boulders or rock outcrops, even on level ground or gentle slopes, can severely limit the use of agricultural machinery. The degree of limitation depends upon the distribution and severity of such features. For example, relatively few abrupt changes of slope angle on a site with a gentle overall slope may preclude the use of precision sowing or planting equipment. On steep slopes, rock outcrops, or frequent changes of slope direction, may prevent the safe use of a tractor with mounted equipment. Level sites may be impossible to cultivate satisfactorily because of frequent rock outcrops. Differential settlement can create a microrelief limitation on restored land, which may only become apparent some years after soil replacement, and may also give rise to a pattern limitation if it causes patchy wetness over a significant area.

The effect of microrelief is considered in conjunction with overall gradient, though detailed guidance is not feasible. The degree of limitation should be assessed in relation to the hindrance to mechanical operations.

Flooding

The incidence of flooding is strongly influenced by topography but the extent, duration, frequency and timing can be difficult to establish precisely. The risk of flooding may be significant in affecting the choice of crops to be grown, because at certain times of the year it can have a detrimental effect on yield, and may give rise to soil management problems. The overall effect of flooding depends on a range of circumstances. The after-effects of inundation depend in part on soil type and will generally be more serious on impermeable soils, which remain saturated for longer periods than permeable soils. Flood-plain morphology influences water velocities and therefore affects the amount of soil erosion, siltation and physical damage to crops. The time of year at which flooding occurs is particularly significant. Floods which occur in summer are generally more damaging than winter floods because the crop root systems are active and more likely to be affected by waterlogging. Crops vary in their tolerance to flooding and this is reflected in the stricter limits on high quality land where flexibility of cropping is required.

The guidelines in Tables 2 and 3 take account of frequency, duration and timing of flooding and apply to soils of good or moderate permeability. Further downgrading may be justified where flooding affects soils of low permeability. The year is divided into two parts, with a long 'summer' period which includes the spring sowing and late autumn harvesting seasons. When grading land, the flood limitation is assessed separately for the summer and winter seasons and, applying the 'most limiting factor' principle, either assessment can determine the grade. Information on flooding at a local scale is often fragmentary and the assessment may have to be based on local knowledge, together with any information or advice which can be obtained from Water Authorities. Most weight should be given to the predicted long-term risk, or the return periods used in the design of flood protection schemes, rather than to the average incidence of flooding in recent years, which may have been influenced by atypical climatic conditions.

Table 2 Grade according to flood risk in summer

Grade/ Subgrade		Flood limits	
		frequency	*duration*
1		very rare	short
2		rare	short
3a		very rare	medium or long
	or	rare	medium
	or	occasional	short
3b		rare	long
	or	occasional	medium
4		occasional	long
	or	frequent	short or medium
5		frequent	long

Table 3 Grade according to flood risk in winter

Grade/ Subgrade		Flood limits	
		frequency	*duration*
1		rare	short
2		rare	medium
	or	occasional	short
3a		rare	long
	or	occasional	medium
	or	frequent	short
3b		occasional	long
	or	frequent	medium
4		frequent	long

The terms used in Tables 2 and 3 are defined as follows:

Season summer - mid March to mid November
winter - mid November to mid March

Duration short - not more than 2 days (48 hours)
medium - more than 2 but not more than 4 days
long - more than 4 days

Frequency very rare - not more than once in 15 years
rare - once in 10 to once in 14 years
occasional - once in 3 to once in 9 years
frequent - more than once in 3 years

3.3 Soil Limitations

The main soil properties which affect the cropping potential and management requirements of land are texture, structure, depth, stoniness and chemical fertility. These may act as limitations separately, in combination or through interactions with climate or site factors. The interactive limitations of soil wetness, droughtiness and erosion risk are discussed separately in Section 3.4. The relationships are often complex and the criteria used in this land classification are designed to provide a practical method for grading land on the basis of field assessments.

In this document the term 'topsoil' refers to true topsoil material which developed originally at the top of a soil profile and is characteristically darker in colour and has a higher organic matter content than subsoil material. The term 'top 25 cm' is used to refer to the uppermost 25 cm of the soil profile which defines, for ALC purposes, the depth zone within which the soil is most frequently cultivated.

It is generally assumed in the soil related assessments that natural topsoil is in *situ.* If the land has been disturbed and there is little or no topsoil, this may be an additional limitation which needs to be taken into account when grading the land.

Soil texture and structure
Soil texture and structure have a major influence on water retention, water movement and aeration in soils and therefore on workability, trafficability, poaching risk and suitability as a medium for plant growth. Texture class is determined by the relative proportions of sand, silt and clay particles and the amount of organic matter in a soil horizon and may be assessed in the field by hand texturing or measured in a laboratory by particle-size analysis. The soil texture system used for ALC purposes is described in Appendix 2.

In most soils the primary particles are aggregated into structural units called peds. Soil structure is influenced considerably by soil texture and is described by reference to the size, shape and degree of development of the peds and the pores and fissures within and between them (Hodgson, 1976). A well structured soil is characterised by clearly identifiable, stable peds with a high proportion of pores and fissures which allow easy movement of air, water and roots through the soil. Such soils are often found under permanent pasture where the soil has not been disturbed by cultivation and prolonged root action has assisted structural development.

Clay soils tend to be coarse structured and the peds swell on wetting, thus closing fissures and reducing permeability. The risk of damage to soil structure by cultivation generally increases with increasing clay content. Clay soils tend to form large, hard surface clods when dry and are plastic when wet. They can therefore only be cultivated satisfactorily under a relatively narrow range of soil moisture conditions. Calcareous clay soils are generally better structured than non-calcareous clays and are consequently better drained and easier to cultivate.

Soils with a high proportion of silt or fine sand are inherently weakly structured and are prone to surface capping and slaking, especially if the topsoils have a low organic matter content. Sandy soils are more easily worked but are weakly structured and readily form compacted layers if cultivated or traversed when wet. They may also be susceptible to erosion and drought.

Soil texture and structure are therefore significant parameters in the assessments of droughtiness and wetness. Texture is a key variable for estimating the available water capacity of a soil profile, as explained in Section 3.4 and Appendix 4. The coarser sandy soils are very susceptible to drought stress in dry periods. Irrespective of the moisture balances which result from the droughtiness assessment, soils with sand topsoils are not eligible for Grades 1, 2 or 3a and those with loamy sand topsoils are not eligible for Grade 1.

Soil wetness is assessed in the field by identifying the depth to any slowly permeable soil horizon, which is defined in terms of soil texture, structure and gleying and relating this to the texture of the top 25 cm (Section 3.4 and Appendix 3). For certain combinations of wetness class, texture and field capacity days (FCD, see page 31), a distinction is made between some naturally calcareous (i.e. those in which the calcium carbonate is derived from the soil parent material and not artificial liming) and other soils, as the former are usually better structured and therefore more workable. The distinction applies where a soil:

- i) has at least 1% calcium carbonate in the top 25 cm and a similar or greater calcium carbonate content below 25 cm, *and*
- ii) has between 18 and 50% clay content in the top 25 cm, *and*
- iii) occurs in an area with not more than 150 FCD.

Similarly, under favourable climatic and soil water regimes, some medium and heavy textured soils are more workable if there is a high organic matter content within the top 25 cm and this is reflected in the higher grades for such soils given in Table 7.

Soil structure can be damaged by agricultural use. Most structural problems which occur in the upper soil profile are caused by mechanical operations or grazing carried out when the soil is too wet. Where such damage can be corrected by normal soil management methods it is regarded as a short-term limitation and does not affect grading. However, more persistent problems can occur, particularly on disturbed soils. On land which has been restored, soil structure is often weakened and can be significantly damaged by soil movement and storage. The return of a restored soil to a stable and more natural structural condition is normally a gradual process which needs to be encouraged over a period of years by maintaining an appropriate cropping and soil management regime. Some soils can be rendered very unstable by such disturbance and therefore respond very slowly to remedial measures, even in the topsoil. In such circumstances, it cannot be assumed (as applies to undisturbed soils, see page 37) that any slowly permeable layer within 35 cm can be removed satisfactorily. Thus where very unstable structure gives rise to wetness problems which are likely to persist, it should be taken into account when grading the land (see page 22). Similarly, unstable structure is a factor to be considered when grading saline soils which have slaked as a consequence of deflocculation (see page 19). Where significant compaction occurs below 35 cm, for example on disturbed or restored land, it may be difficult or impossible to ameliorate practically or economically. Such compaction is therefore a long-term limitation which is taken into account through reduced permeability and available water capacity in the wetness and droughtiness assessments (see pages 37 and 26 respectively).

A soil limitation can sometimes occur on sites restored to agriculture where different soils, or topsoil and subsoil, have been mixed. If the physical characteristics of the materials are very different, such as large clay inclusions within a sandy matrix, and are likely to cause significant management problems for many years, the limitation will be assessed and the land graded accordingly.

Soil depth

Soil depth is an important factor in determining the available water capacity of a soil and is considered in that context in Section 3.4. Shallowness affects cropping in other ways, notably by influencing the range and type of cultivations which can be carried out but also by restricting nutrient uptake, root growth and, in the case of fruit trees, root anchorage. It is therefore necessary to specify minimum soil depth requirements for the grades and subgrades.

Limiting depths are given in Table 4 for soil overlying consolidated or fragmented rock which cannot be penetrated satisfactorily by cultivation implements.

Table 4 Grade according to soil depth

Grade/ Subgrade	Depth limits (cm)
1	60
2	45
3a	30
3b	20
4	15
5	<15

Stoniness

The main effects of stones are to act as an impediment to cultivation, harvesting and crop growth and to cause a reduction in the available water capacity of a soil. This section is concerned with the 'mechanical' limitations and refers to stoniness in the top 25 cm of the soil. The effect on available water capacity is considered in Section 3.4 and Appendix 4.

A high stone content can increase production costs by causing extra wear and tear to implements and tyres. Crop quality may also be reduced in stony soil by causing, for example, the distortion of root crops or bruising of potatoes during harvesting. Stones can impair crop establishment by causing reduced plant populations in precision-drilled crops, and they reduce the nutrient capacity of the soil.

The degree of limitation imposed by stones depends on their quantity, size, shape and hardness. Stoniness can vary markedly over short distances and is time-consuming to measure. The size limits specified in Table 5 are for volumes of stones which will not pass through sieves with 2 cm or 6 cm square mesh. Grade limits have been specified for stones retained on a 6 cm sieve because they usually have a more detrimental effect than smaller stones. The limits apply to hard stones; where the stones are of soft lithology, such as soft chalk, weakly cemented sandstones or siltstones, the limits are relaxed by one grade or subgrade. Both stone percentage columns in Table 5 are expressed in terms of the percentage of total volume of the top 25 cm of the soil; either can be most limiting and determine the grade. Thus, if 30% of the top 25 cm comprises hard stones larger than 2 cm, the land cannot be graded higher than 3b. However, if that same soil layer contains 25% stones larger than 6 cm the land cannot be graded higher than Grade 4. Small numbers of large boulders or stones which can be removed easily should be ignored. Stones smaller than 2 cm, which have no or only minor effects on cultivation, should also be ignored.

Table 5 Grade according to stoniness

Grade/ Subgrade	Limiting percentages (volume) of hard stones in the top 25cm of soil	
	stones larger than 2 cm[1]	*Stones larger than 6 cm*[1]
1	5	5
2	10	5
3a	15	10
3b	35	20
4	50	35
5	>50	>35

[1] Stones retained on a 2 cm or 6 cm square mesh sieve, as appropriate.

Chemical Limitations

The chemical status of a soil does not affect ALC grading where nutrient levels can be maintained or corrected by normal applications of fertiliser or lime. Chemical factors will only affect grading where they have, or are likely to have, a detrimental long- term effect on the physical condition of the soil, the crop yield, the range of crops that may be safely grown, stocking rates or grazing management.

Physical limitations induced by soil chemical properties are most likely to be encountered with saline or certain organic mineral or peat soils. Sodium-rich clay and silty clay soils developed in marine alluvium are potentially unstable if the land is drained. Progressive leaching of salt from the soil profile causes deflocculation of the clay particles and may lead to structural collapse (slaking) and drain failure through siltation. Measures to avoid or ameliorate these conditions may be unsuccessful.

Where such land is currently undrained and expert advice indicates that it is not prudent to drain it, the land should be graded in the undrained condition.

When peat or marine alluvium rich in iron sulphide is drained, iron compounds may be released and deposited in the form of iron ochre, which can block pipe drainage systems. The problem can sometimes be ameliorated, but in severe cases may justify downgrading. Where expert advice indicates that new drainage work is likely to be uneconomic, the land should be graded in the undrained condition. The chemical reactions which produce ochre can cause extreme subsoil acidity which is difficult to rectify. This limitation should be taken into account and assessed according to the effect on the flexibility and productivity of the land.

Where landfill containing organic material has been used in the restoration of land to agriculture, gases such as methane can be generated when the waste decomposes. Where methods for sealing the landfill surface and venting gas emissions are not used or are not fully effective, such gas can create anaerobic conditions in the overlying soil affecting plant roots and therefore reducing crop yield. The effect on plant growth varies according to the degree of oxygen depletion and concentration of phytotoxic gases which may also be present in the soil atmosphere. In severe situations crop growth may be absent or stunted. The production and release of landfill gases can vary according to site conditions and may be very localised. Severe gas-induced anaerobism is often indicated by a foul-smelling greenish or bluish mottled subsoil. Gases may also be present at lower concentration in the soil above such visually anaerobic soil horizons. The duration of gas emission and the long-term effect on productivity of the land are unpredictable and grading will take account of the degree of limitation at the time of survey. The data available on the effect of such anaerobism on crops are very limited and the following guidance is therefore provisional. Where such anaerobism is visible within one metre of the soil surface the land will not be graded higher than Subgrade 3b. Where the anaerobism is within 50 cm of the surface the land will be Grade 4 or, if within 30 cm, Grade 5.

Toxic elements can occur at levels which adversely affect plant growth (phytotoxicity) or are potentially harmful to animals or man (zootoxicity). The most commonly occurring toxic elements are zinc, copper, lead and cadmium although others including mercury, arsenic, nickel, chromium and fluorine are also found. High concentrations of these elements are most likely to be associated with spoil heaps from metalliferous mining, industrial waste and sewage disposal. The level of toxicity depends on the type, form and concentration of elements present and on complex chemical interactions which may be influenced by soil pH, texture and organic matter content. It is therefore not practicable to indicate precise concentrations as limits for grades or subgrades.

The effect of soil toxicity on grading is assessed in relation to the effects on plant growth and any limitations placed on the management or use of the land, such as restrictions on cultivation (which may bring contaminated material to the surface), stocking levels or grazing periods, or on the use made of produce obtained from it. Land will not be graded higher than Subgrade 3b if it is considered to be unsuitable for growing crops for direct human consumption. Land which is limited to grass production and on which there are significant restrictions on grassland management will be no better than Grade 4. Where only extensive grazing is possible the land will be Grade 5 and, where it is unfit for all forms of agricultural production, can be regarded as non-agricultural.

3.4 Interactive Limitations

The physical limitations which result from interactions between climate, site and soil are soil wetness, droughtiness and erosion. Soil wetness expresses the extent to which excess water imposes restrictions on crop growth and cultivations while droughtiness indicates the degree to which a shortage of soil water influences the range of crops which may be grown and level of yield which may be achieved. The limitations are not mutually exclusive in that some soils can be wet in winter but droughty in summer. For ALC purposes wetness and droughtiness are assessed separately by relating soil profile characteristics to appropriate climatic parameters.

Soil Wetness

A soil wetness limitation exists where the soil water regime adversely affects plant growth or imposes restrictions on cultivations or grazing by livestock. The importance of this limitation is reflected by the widespread use of and dependence on field drainage in both arable and grassland areas in England and Wales. Excessive soil wetness adversely affects seed germination and survival, partly by a reduction in soil temperature and partly because of anaerobism. It also inhibits the development of a good root system and can, in extreme cases, lead to plant death. Soil wetness also influences the sensitivity of the soil to structural damage and is therefore a major factor in determining the number of days when the soil is in a suitable condition for cultivation, trafficking by machinery or grazing by livestock.

The severity of the limitation is influenced by the amount and frequency of rain in relation to evapotranspiration, the duration of waterlogging and the texture of the uppermost layers of the soil. A wetness limitation can exist in both permeable and impermeable soils. Permeable soils are most significantly affected by wetness where there is a ground water table that cannot be removed by normal field drainage improvements. In less permeable soils the degree of waterlogging depends in part on the depth at which the soil becomes slowly permeable. Topsoil texture influences the wetness limitation because of its effect on soil water retention and the mechanical properties of the soil. Soils with a high clay content tend to retain more water than sandy soils and are therefore slower to return to a workable condition after wetting. Such soils also have a higher mechanical strength when dry, which further reduces the period during which they can be effectively cultivated.

For ALC purposes the soil wetness assessment takes account of:

i) the climatic regime
ii) the soil water regime
iii) the texture of the top 25 cm of the soil

Climatic regime

The influence of climate on soil wetness is assessed by reference to median field capacity days (FCD). FCD ranges are specified within which similar soils are expected to have similar degrees of wetness limitation. The spatial distribution of

FCD has been mapped at a scale of 1:1 million by the SSLRC (Jones and Thomasson, 1985) and there is also a gridpoint dataset (Appendix 1).

Soil water regime
This assessment is based on soil wetness classes (Hodgson, in preparation) which are defined in terms of the average duration of waterlogging at specified depths in the soil profile. The procedure for inferring soil wetness class from observed soil profile characteristics is described in Appendix 3.

Soil texture
Mineral soil texture classes are divided into four groups according to ease of cultivation and susceptibility to damage by grazing animals. Where appropriate, a distinction is also made between mineral textures, their organic variants (organic mineral textures) and peaty textures. The system of soil texture classification used is given in Appendix 2.

Wetness assessment
For most soils, the overall wetness limitation is assessed in two stages, namely:

i) determine the soil wetness class, according to Appendix 3
ii) relate soil wetness class to soil texture and median field capacity days, using Table 6 where the top 25 cm is a mineral texture or Table 7 where the top 25 cm is an organic mineral or peaty texture.

On restored soils structural instability in the top 35 cm (see page 17) may have a significant effect on permeability and therefore soil wetness. Where this condition is unlikely to be ameliorated in the short-term by normal improvement techniques, assess the wetness limitation using the procedure described above and then downgrade by one grade or subgrade. This limitation may be ignored where the dominant texture is sand, loamy sand or sandy loam.

Table 6 Grade according to soil wetness - mineral soils

Wetness Class	Texture[1] of the top 25 cm	Field Capacity Days				
		<126	126-150	151-175	176-225	>225
I	S[2] LS[3] SL SZL	1	1	1	1	2
	ZL MZCL MCL SCL	1	1	1	2	3a
	HZCL HCL	2	2	2	3a	3b
	SC ZC C	3a(2)	3a(2)	3a	3b	3b
II	S[2] LS[3] SL SZL	1	1	1	2	3a
	ZL MZCL MCL SCL	2	2	2	3a	3b
	HZCL HCL	3a(2)	3a(2)	3a	3a	3b
	SC ZC C	3a(2)	3b(3a)	3b	3b	3b
III	S[2] LS SL SZL	2	2	2	3a	3b
	ZL MZCL MCL SCL	3a(2)	3a(2)	3a	3a	3b
	HZCL HCL	3b(3a)	3b(3a)	3b	3b	4
	SC ZC C	3b(3a)	3b(3a)	3b	4	4
IV	S[2] LS SL SZL	3a	3a	3a	3b	3b
	ZL MZCL MCL SCL	3b	3b	3b	3b	3b
	HZCL HCL	3b	3b	3b	4	4
	SC ZC C	3b	3b	3b	4	5
V	S LS SL SZL	4	4	4	4	4
	ZL MZCL MCL SCL	4	4	4	4	4
	HZCL HCL	4	4	4	4	4
	SC ZC C	4	4	4	5	5
Soils in Wetness Class VI - Grade 5						

[1]For naturally calcareous soils with more than 1% $CaCO_3$ and between 18% and 50% clay in the top 25 cm, the grade, where different from that of other soils, is shown *in brackets* (see page 16).

[2] Sand is not eligible for Grades 1, 2 or 3a (see page 16).

[3] Loamy sand is not eligible for Grade 1 (see page 16).

Table 7 Grade according to soil wetness - organic mineral and peaty[1] soils

Wetness Class	Texture of the top 25 cm	Field Capacity Days <126	126 -175	175 - 225	>225
	PTY	1	1	1	*
	S LS SL SZL	1	1	1	*
I	ZL MZCL MCL SCL	1	1	2	*
	HZCL HCL	1	2	3a	*
	SC ZC C	1	2	3b	*
	PTY	1	1	1	*
	S LS SL SZL	1	1	2	*
II	ZL MZCL MCL SCL	1	1	3a	*
	HZCL HCL	2	2	3a	*
	SC ZC C	2	3a	3b	*
	PTY	2	2	2	*
	S LS SL SZL	2	2	3a	*
III	ZL MZCL MCL SCL	2	2	3a	*
	HZCL HCL	3a	3a	3b	*
	SC ZC C	3a	3a	4	*
	PTY	3a	3a	3a	*
	S LS SL SZL	3a	3a	3b	*
IV	ZL MZCL MCL SCL	3b	3b	3b	*
	HZCL HCL	3b	3b	4	*
	SC ZC C	4	4	4	*
	PTY	4	4	4	5
	S LS SL SZL	4	4	4	4
V	ZL MZCL MCL SCL	4	4	4	4
	HZCL HCL	4	4	4	5
	SC ZC C	5	5	5	5
Soils in Wetness Class VI - Grade 5					

[1] For the definitions of 'organic mineral' and 'peaty' see Appendix 2.

* Combinations which do not occur or occur very rarely.

Droughtiness

To achieve full yield potential a crop requires an adequate supply of soil moisture throughout the growing season. Soil moisture requirements vary considerably between crops and according to growth stage. The potential demand for moisture generally rises as leaf cover, and hence transpiration, increases. In addition, deep rooting crops are able to exploit the moisture reserves of a larger volume of soil than shallow rooting crops. Thus the extent to which yield is depressed when moisture is in short supply is influenced by the crop type, amount and duration of the shortfall, and the growth stage at which it occurs.

Droughtiness is most likely to be a significant limitation to crop growth in areas with relatively low rainfall or high evapotranspiration, or where the soil holds only small reserves of moisture available to plant roots. The severity of the limitation in an area depends on the relationship between the soil properties and climatic factors and the moisture requirements of the crops grown. These relationships are complex and the degree of moisture stress varies from year to year according to the weather.

In the ALC system the method used to assess droughtiness is based on work by Thomasson (1979). It provides an indication of the average drought risk based on two reference crops, winter wheat and maincrop potatoes. These crops have been selected because they are widely grown and, in terms of their susceptibility to drought, are representative of a broad range of crops. The method used to assess droughtiness takes account of crop rooting and foliar characteristics to obtain an estimate of the average soil moisture balance (MB) for the reference crops at a given location. MB is calculated on the basis of two parameters namely:

i) crop-adjusted available water capacity of the soil profile (AP)
ii) moisture deficit (MD).

Crop-adjusted available water capacity (AP)

AP is a measure of the quantity of water held in the soil profile which can be taken up by a specified crop. The water storage capacity of soil is strongly influenced by texture, structure, organic matter content and stone content. The method used to calculate crop-adjusted AP values for wheat and potatoes is described in detail in Appendix 4. Table 14 gives available water values for different combinations of texture and structure. A distinction is made according to textures in the topsoil and subsoil, to take account of the higher organic matter content of topsoils. These values are used to calculate the amount of available water, adjusted for stone content, in each soil horizon within the rooting depth of the crop concerned. The horizon values are added together to give a total crop-adjusted AP (in mm). Typically, wheat will root to about 120 cm and horizon values are summed to this depth. However, allowance is made for the fact that the root system of winter wheat is less well developed, and therefore less efficient at water extraction, in the subsoil below 50 cm. Thus below that depth only easily available (as opposed to total available) water is taken into account. For potatoes the values for total available water are used for all horizons down to the full rooting depth of 70 cm.

Although crop-adjusted AP provides a measure of the amount of available water retained in a soil, it does not allow for the fact that the rate at which moisture is conducted to roots from the surrounding soil not occupied by roots varies between soil types, especially in relation to texture and structure. Hydraulic conductivity is generally adequate, in terms of moisture supply, in medium and fine textured soils over a wide range of soil moisture content. However, in the case of the coarser sands and loamy sands conductivity is adequate when the soil is at or near to field capacity but decreases very rapidly as the soil dries because there are few medium or fine pores through which moisture can be transmitted (Salter and Williams 1965; Craull 1985). This factor, in combination with low AP, makes such soils extremely susceptible to drought stress because wilting point is reached more rapidly and frequently in dry periods. Allowance is made for this limitation in the droughtiness assessment by reducing by 20% the AP of subsoil horizons with coarse sand, medium sand, loamy coarse sand or loamy medium sand textures.

Where significant subsoil compaction occurs, root penetration is generally restricted and moisture reserves in the soil below a severely compacted, very poorly structured horizon will make a negligible contribution to plant growth. In such cases the calculation of AP should be limited to the soil horizons above the compacted layer.

Moisture deficit (MD)

The moisture deficit term used in the ALC droughtiness assessment is a crop-related meteorological variable which represents the balance between rainfall and potential evapotranspiration calculated over a critical portion of the growing season. The concept of potential evapotranspiration (PE) was introduced by Penman (1948) who defined it as the water transpired by a short green crop, such as grass, which completely covers the ground surface and has an ample supply of water around its roots. PE is used in combination with rainfall (R) to calculate the potential soil moisture deficit, PSMD (Smith, 1967) as follows:

$$PSMD = \sum (R-PE)$$

where (R-PE) is calculated daily and summed for a defined period.

In lowland situations a deficit will typically develop in April or May and will reach a maximum in July, August or September; thereafter it will decrease as temperatures, and hence evapotranspiration, decline in the autumn. PSMD can be calculated for daily or monthly periods and the maximum value in any year used to indicate the shortfall in moisture supply for that year. For land classification purposes the PSMD needs to be averaged over a period of years and selecting the median value of PSMD avoids the bias of extreme years. Potential deficits under grass are greater than for arable crops which do not attain full ground cover early in the growing season. For example, winter wheat does not usually develop full leaf cover until the end of April. Maincrop potatoes have negligible leaf cover until mid-May and full cover is not usually achieved until the end of June. Jones and Thomasson (1985) describe a method for deriving MD values (in mm) for wheat and potatoes from end-of-month and mid-month accumulated values of PSMD (under grass) as follows:

MD (Winter Wheat) = mid-July PSMD -1/3 April PSMD
MD (Potatoes) = August PSMD -1/3 June PSMD -1/3 mid-May PSMD

Crop-adjusted values of MD based on these formulae are used for droughtiness assessment in the ALC system and are obtained by means of regression techniques from accumulated summer temperature (ATS) and summer rainfall (ASR) data (Appendix 1).

Moisture balance (MB)

Droughtiness limits for grades and subgrades are defined in terms of moisture balances (MB, in mm) for wheat and potatoes which are calculated using the following formulae:

MB (Wheat) = **AP** (Wheat) **-** **MD** (Wheat)
MB (Potatoes) = **AP** (Potatoes) **-** **MD** (Potatoes)

The MB limits for each grade and sub grade are shown in Table 8. To be eligible for Grades 1 to 3b the MBs must be equal to, or exceed, the stated minimum values for *both* wheat and potatoes. If the MB for *either* crop is less (i.e. more negative) than that shown for Subgrade 3b, the soil is Grade 4 on droughtiness. It should be noted that, as explained on page 16, soils with sand topsoils are not eligible for Grades 1,2 or 3a and those with loamy sand topsoils are not eligible for Grade 1.

Table 8 Grade according to droughtiness

Grade/ Subgrade	Moisture Balance limits (mm) *wheat*		*potatoes*
1	+30	*and*	+10
2	+5	*and*	-10
3a	-20	*and*	-30
3b	-50	*and*	-55
4	<-50	*or*	<-55

Irrigation
Irrigation can significantly enhance the potential of agricultural land, especially in drier areas, and should therefore be taken into account in ALC grading where it is current or recent practice. In determining the effect of irrigation on ALC grade, the following factors should be taken into account:

i) adequacy of irrigation water supply
ii) the range of crops to which water is usually applied
iii) climate and soil factors.

When considering the effects of irrigation on ALC grading, it should normally be assumed that potatoes, responsive field vegetable and fruit crops and, in drier areas, sugarbeet would receive irrigation water but that cereals, oilseed rape and grass would not. Furthermore, irrigation will generally be of less benefit, and therefore have less influence on ALC grade in wetter areas and on heavier land which may not be well suited to growing irrigation-responsive crops. Even on more flexible land in drier areas, because irrigation is likely to benefit only part of the full range of crops which could be grown, it will usually upgrade land by no more than one grade or subgrade.

Soil erosion
Soil erosion is mainly caused by wind or water action, although the wastage of peat can also be regarded as a form of erosion. The incidence of erosion is determined by interactions between weather, soil type and condition, topography and the amount

and type of vegetative cover. It is also strongly influenced by land management practices. In agricultural terms, the problem is most significant in the arable lowlands.

Water-induced erosion is more widespread than wind erosion. It occurs most frequently on sloping land with bare soil or sparse crop cover where the soil is weakly structured and has a fine sandy or coarse silty texture. The risk is greatest during periods of heavy rainfall when the soil has become saturated and surface soil structure broken down by the impact of raindrops. The resulting run-off can quickly form rills and gullies which destroy crops in localised areas or bury them under deposited sediment downslope. The use of farm machinery may be hindered subsequently where gullies are wide and deep.

Significant wind erosion (or 'blowing') is restricted to a relatively narrow range of susceptible soil types. The risk is greatest in spring or early summer on flat or gently sloping land where light textured, bare or sparsely vegetated soil is exposed to strong wind and the surface is dry. The soils most at risk are sands and loamy sands with a high fine sand content, organic sand, sandy and loamy peats and peats. The presence of stones reduces erosion risk to some extent. Blowing can result in the loss of topsoil, seeds, seedlings and fertiliser and cause damage by abrasion to remaining plants. Yields of re-sown crops are often reduced through late establishment and development.

Soil wastage is a form of erosion confined to peaty soils and is the result of shrinkage and biochemical degradation. Loss of soil by this process can result in a gradual change in cropping potential as the depth of peat over the substratum is reduced.

The effects of soil erosion on land quality may be expressed in two ways. Firstly, erosion may have directly affected physical characteristics by, for example, reducing soil depth or creating steep sided gullies which inhibit the use of machinery. Such problems are taken into account by using the standard assessments of soil depth, droughtiness, gradient and microrelief. The second, rare circumstance is when soils especially prone to erosion may be downgraded because the risk of erosion constrains management to a degree which significantly reduces the range of crops which can be grown or markedly raises production costs. In nearly all cases where such a significant management problem occurs, erosion will tend to be a secondary factor accompanying other, more critical limitations such as slope or droughtiness.

APPENDIX 1

AGROCLIMATIC DATASETS

Introduction

Climatic data are used in the assessment of the climate, droughtiness and wetness limitations. To provide consistency in those assessments a standard data source is required for the calibration and operation of the system. Traditionally, maps or meteorological station data have been used to estimate climatic parameters at a site. However, the manual interpretation of maps or extrapolation of values from recording stations to sites under investigation involves subjective judgements, and even where data are available from a nearby meteorological station it cannot be assumed that the station value is representative of the surrounding area. A number of gridpoint datasets with a spacing of 5 km have therefore been developed covering the whole of England and Wales and standard methods have been devised for estimating the value of each parameter at any location. The grid is coincident with the 5 km intervals of the Ordnance Survey National Grid, having its origin south-west of the Scilly Isles.

The use of gridpoint data has significant advantages for computerised storage and manipulation of information. The datasets are held in LandIS, a computer-based land information system developed by the SSLRC and funded by MAFF. The system can be used to obtain both gridpoint and interpolated values for specified grid references. The complete dataset will also be published by the Meteorological Office (in press) and the procedure for obtaining interpolated values will be explained in that publication.

Climate Datasets

The five agroclimatic parameters used in the ALC system and the associated limitation factors are listed in Table 9. The FCD dataset was compiled by the SSLRC on the basis of Meteorological Office data. The other datasets were compiled by the Meteorological Office and processed by the SSLRC prior to their incorporation in LandIS. Datasets of altitude and of average annual rainfall change with altitude (ie lapse rate of AAR) are also held on LandIS for use in the interpolation from gridpoint values to site values.

Table 9 Limitation factors and associated agroclimatic parameters

Limitation Factor	Parameter	Observation period
Climate	Average Annual Rainfall (AAR)	1941 - 1970
	Median Accumulated Temperature above 0°C, January to June (AT0)	1961 - 1980
Soil Wetness	Median Duration of Field Capacity Days (FCD)	1941 - 1970
Soil Droughtiness	Average Summer Rainfall, April to September (ASR)	1941 - 1970
	Median Accumulated Temperature above 0°C, April to September (ATS)	1961 - 1980

The data sources were as follows:

Average annual rainfall (AAR)

Gridpoint AAR values (mm) were interpolated from unpublished rainfall maps at a scale of 1:250,000, on which the published 1:625,000 map for 1941-70 was originally based (Meteorological Office, 1977).

Average summer rainfall (ASR)

Gridpoint ASR values (mm) were manually interpolated from an unpublished 1:625,000 scale map of average summer rainfall for 1941-70.

Median accumulated temperature above 0°C, January to June (AT0)

The AT0 dataset is based on temperature data from the 94 stations in the Complete Agromet Database (Field, 1983), which have complete records over the period 1961-1980. Accumulated temperatures for the period January to June each year were computed for each station from daily measurements of maximum and minimum temperature and the median value of AT0 in the period 1961-80 was determined. The median values were then extrapolated to gridpoints by means of a regression equation which relates accumulated temperature, altitude, latitude (National Grid northing) and longitude (National Grid easting). The following equation was used:

AT0 (day degrees Celsius) = 1708 -1.14A -0.023E -0.044N
where
A is altitude above mean sea level (metres)
E is National Grid easting to 100 m (four significant figures)
N is National Grid northing to 100 m (four significant figures)

This equation explains approximately 90% of the variation in AT0 for the 94 agrometeorological recording stations.

Median accumulated temperature above 0°C, April to *September (ATS)*

The ATS dataset (1961-80) was created directly from the AT0 dataset using the following linear regression:
ATS (day degrees Celsius) = 611 + 1.11AT0 + 0.042E
where
AT0 is the grid point AT0 value
E is the National Grid easting to 100 m (four significant figures)

This regression explains more than 90% of the variation in ATS for the 94 stations.

Median duration of field capacity (FCD)

FCD is a meteorological parameter which estimates the duration of the period when the soil moisture deficit is zero. Soils usually return to field capacity (zero deficit) during the autumn or early winter and the field capacity period, measured in days, ends in the spring when evapotranspiration exceeds rainfall and a moisture deficit begins to accumulate. Smith and Trafford (1976) described a method for estimating the average period of meteorological field capacity from rainfall and evapotranspiration for the period 1941-70 and listed median dates for the return to and end of field capacity for 52 MAFF agroclimatological areas. These dates were regressed on AAR by the SSLRC to generate a 10 km grid dataset which has subsequently been resolved to 5 km using the gridpoint values of AAR described above (Jones and Thomasson, 1985; Ragg et al, 1988).

MOISTURE DEFICIT (MD) DATA

The gridpoint values (in mm) of crop-adjusted moisture deficit required for droughtiness assessments (Section 3.4, page 26) are obtained by regression from ATS and ASR using the following equations:

MD (Winter Wheat) = 325.4 -162.3 $\log_{10}$ ASR + 0.08022 ATS
MD (Potatoes) = 326.4 -196.5 $\log_{10}$ ASR + 0.1127 ATS

The above equations are based on an analysis of station data in the Complete Agromet Database and explain approximately 90% of the variation in crop-adjusted MD at those stations. When these equations result in negative values (ie a moisture surplus) they are assumed to be zero for the purpose of droughtiness calculations.

INTERPOLATION FROM GRIDPOINTS TO INTERMEDIATE SITES

For sites not located precisely at a 5 km gridpoint standard routines are available in LandIS to calculate the value of any climatic parameter by interpolation from adjacent gridpoint values. The routines make adjustments for height differences between the site and up to four adjacent gridpoints, using the appropriate lapse rate or altitude correction factor, and then interpolate by calculating a distance weighted mean. Where a site falls exactly on an easting or northing which passes through two gridpoints the interpolation uses only those two gridpoint values. Interpolated values do not take account of microclimatic factors.

APPENDIX 2

SOIL TEXTURE

TEXTURE CLASSIFICATION – MINERALS SOILS

The mineral texture classes used for ALC purposes are defined in Figure 2 according to the relative proportions of sand, silt and clay fractions.

Figure 2 Limiting percentages of sand, silt and clay fractions for mineral texture classes

The particle size fractions used are given in Table 10.

Table 10 Particle size fractions

		(mm)
Clay		<0.002
Silt		0.002 – 0.06
Sand	(fine	0.06 – 0.2
	(medium	0.2 – 0.6
	(coarse	0.6 – 2.0

For the ALC wetness assessment (Tables 6 and 7) the clay loam and silty clay loam texture classes are divided into 'medium' and 'heavy' subclasses, the 'medium' subclasses having less than 27% clay content.

TEXTURE CLASSIFICATION -ORGANIC MINERAL AND PEAT SOILS

Class limits for organic mineral and peaty textures are defined in Figure 3.

For references to peat soils and textures, the following terminology is used in this document:

Peat is a soil texture class (Figure 3);

Peaty refers to a soil texture group comprising peat, loamy peat, sandy peat, peaty loam and peaty sand textures;

Peat soil is a soil which meets both of the following criteria:

i) more than 40 cm of peaty textured material within the upper 80 cm of the soil profile, *and*

ii) organic mineral or peaty textures present within 30 cm depth.

Figure 3 Limiting percentages of organic matter, clay and sand for peaty and organic mineral texture classes

NOTATION

The texture classes are denoted by the following abbreviations:

Sand	S
Loamy sand	LS
Sandy loam	SL
Sandy silt loam	SZL
Silt loam	ZL
Sandy clay loam	SCL
Clay loam	CL
Silty clay loam	ZCL
Clay	C
Silty Clay	ZC
Sandy Clay	SC
Peat	P
Sandy peat	SP
Loamy peat	LP
Peaty loam	PL
Peaty sand	PS
Marine light silts	MZ

For the *sand, loamy sand, sandy loam and sandy silt loam* classes the predominant size of sand fraction (see Table 10) may be indicated by the use of prefixes, thus:

F	fine	(more than ⅔ of sand less than 0.2 mm)
C	coarse	(more than ⅓ of sand greater than 0.6 mm)
M	medium	(less than ⅔ fine sand and less than ⅓ coarse sand).

The subdivisions of *clay loam and silty clay loam* classes according to clay content are indicated as follows:

M	medium	(less than 27% clay)
H	heavy	(27 - 35% clay)

The prefix 'Calc' is used to identify naturally calcareous soils containing more than 1% calcium carbonate.

For organic mineral soils, the texture of the mineral fraction is prefixed by the term 'organic' or the abbreviation 'Org' e.g. organic (or org) clay loam.

Peaty textures, as a group, are denoted by the abbreviation 'PTY'.

APPENDIX 3

FIELD ASSESSMENT OF SOIL WETNESS CLASS

SOIL WETNESS CLASSIFICATION

Soil wetness is classified according to the depth and duration of waterlogging in the soil profile. Six revised soil wetness classes (Hodgson, in preparation) are identified and are defined in Table 11.

Table 11 Definition of Soil Wetness Classes

Wetness Class	Duration of Waterlogging[1]
I	The soil profile is not wet within 70 cm depth for more than 30 days in most years[2].
II	The soil profile is wet within 70 cm depth for 31-90 days in most years *or,* if there is no slowly permeable layer within 80 cm depth, it is wet within 70 cm for more than 90 days, but not wet within 40 cm depth for more than 30 days in most years.
III	The soil profile is wet within 70 cm depth for 91-180 days in most years *or,* if there is no slowly permeable layer within 80 cm depth, it is wet within 70 cm for more than 180 days, but only wet within 40 cm depth for between 31 and 90 days in most years.
IV	The soil profile is wet within 70 cm depth for more than 180 days but not within 40 cm depth for more than 210 days in most years *or,* if there is no slowly permeable layer within 80 cm depth, it is wet within 40 cm depth for 91-210 days in most years.
V	The soil profile is wet within 40 cm depth for 211- 335 days in most years.
VI	The soil profile is wet within 40 cm depth for more than 335 days in most years.

[1] The number of days specified is not necessarily a continuous period.
[2] 'In most years' is defined as more than 10 out of 20 years.

Soils can be allocated to a wetness class on the basis of quantitative data recorded over a period of many years or by the interpretation of soil profile characteristics, site and climatic factors. Adequate quantitative data will rarely be available for ALC surveys and therefore the interpretative method of field assessment is used to identify soil wetness class in the field. The method adopted here is common to ADAS and the SSLRC.

CLIMATE AND SOIL CHARACTERISTICS USED TO ASSESS SOIL WETNESS CLASS

Soil wetness class is normally assessed in the field by reference to:

i) the duration of field capacity

ii) the presence of a gleyed horizon

iii) the depth to a slowly permeable layer.

In disturbed soils, the assessment is made without reference to gley morphology because any gleying present may not be a true reflection of the prevailing soil water regime. The procedure also provides for situations where reddish soils with slowly permeable layers do not exhibit gleying.

Duration of field capacity

This provides a measure of the effect of climate on the soil water regime and is expressed in terms of field capacity days (FCD). Details of data sources for FCD are given in Appendix 1.

Identification of *a gleyed horizon*

A gleyed horizon has one of the following features:

either greyish or pale colours dominant in the matrix or on ped faces and at least 2% ochreous (rusty) mottles;

or if it underlies an organic mineral or peaty topsoil and there are less than 2% ochreous mottles, grey colours are dominant in the matrix;

or if reddish colours are dominant in the matrix, it has at least 2% greyish, brownish or ochreous mottles or ferri-manganiferous concentrations, and dominantly pale coloured ped faces;

the above colours being defined as follows:

greyish is a Munsell soil colour of any hue with chroma 2 or less and value more than 3;

pale is a Munsell soil colour of any hue with *either* chroma 3 and value more than 4 *or* chroma 4 and value more than 5;

brownish is Munsell soil colour of hues 7.5YR to 10YR with *either* chroma 3 and value 4 *or* chroma 4 and value 4 or 5;

ochreous is Munsell soil colour of hue 10YR or redder with chroma more than 4 and value less than 7;

reddish is Munsell soil colour of hue 5YR or redder.

The above gley colours (greyish, pale, brownish and ochreous) are shown diagrammatically in Munsell Soil Colour Chart notation in Figure 4.

Identification of *a slowly permeable layer*

This is defined as being a layer at least 15 cm in thickness with the upper boundary within 80 cm of the surface and having the following characteristics:

either C, SC, ZC, MCL, HCL, MZCL, HZCL or SCL texture *and* massive, platy, medium or coarse or very coarse prismatic, weakly developed fine prismatic, coarse or very coarse angular blocky, weakly developed fine or medium angular blocky, or weakly developed coarse or very coarse subangular blocky structure[1];

or ZL, SZL, or any type of SL with massive structure[1] *and* at least firm consistence[1];

and less than 0.5% biopores greater then 0.5 mm diameter;

and evidence of wetness in, or immediately above the layer, such as ochreous mottles, ferri-manganiferous concentrations or gleying.

The combinations of texture, structure and consistence[1] defined in the 'either' and 'or' options above are shown diagrammatically in Figure 5.

[1]See Hodgson, 1976, pages 30 to 50, for detailed descriptions and definitions related to soil structure and consistence.

Figure 4 **Diagrammatic representation of gley colours defined according to the Munsell soil colour system**

Figure 5 **Diagrammatic representation of the combinations of structure, texture and consistence which are characteristic of slowly permeable layers**

It should be noted that:

i) soils developed in marine alluvium can have very porous subsoils due to the presence of vertical channels and such soils often do not have slowly permeable horizons

ii) if the soil comprises artificially replaced or disturbed material or has a Munsell hue of 5YR or redder, only the textural, structural and porosity characteristics given above need be present (see (v) and (vi), page 37)

iii) severely compacted horizons, as sometimes found in restored soils, may be virtually impermeable (see (v), page 37).

PROCEDURE FOR ASSESSING WETNESS CLASS

Introduction

This method assumes that soils have an appropriate underdrainage system and that there are satisfactory outfalls (see assumption (2), page 8). It is not suitable for soils which are affected by high groundwater tables which cannot be drained effectively. Such soils can only be assigned objectively to a wetness class on the basis of long-term dipwell measurements. In the absence of such data the assessment of wetness class requires specialist knowledge and needs to take account of profile morphology, climate, site characteristics, prevailing water levels and time of year.

On sites with less than 225 FCD it is assumed that, with the exception of certain soils with very unstable structure (see pages 17 and 22), any slowly permeable layer near the surface can be removed by cultivation. The assumed potential depth of loosening decreases from 35 cm, for sites with not more than 150 FCD, to 0 cm at 225 FCD (see Figures 7 and 8).

Method

The method and sequence for assessing the wetness class of soils which can be drained is described below and shown diagrammatically in Figure 6.

i) Examine the soil profile to a depth of 1 metre to identify the presence of any peaty or organic mineral topsoil, the depth to gleying and depth to a slowly permeable layer. Establish whether or not the soil has been significantly disturbed or restored. Note whether the soil is reddish and has a slowly permeable layer starting within 80 cm but is not gleyed within 70 cm depth.

ii) If the soil is undisturbed, has no slowly permeable layer starting within 80 cm depth and no gleyed subsoil is present within 70 cm depth, the soil is **Wetness Class I.**

iii) If the site has at least 225 FCD *and* there is a peat soil, or the topsoil is peaty or organic mineral texture with a gleyed subsoil or rock immediately below, the soil is **Wetness Class V or VI**. Soils in Wetness Class VI are more or less perpetually waterlogged and will have standing surface water for long periods. Such soils are most likely to occur in areas with more than 300 FCD or in basin sites.

iv) If the site has less than 225 FCD and there is an undisturbed peat soil, the assessment is made as follows:
-if there is a slowly permeable layer which starts within 80 cm depth, refer to Figure 7;
-if there is no slowly permeable layer starting within 80 cm depth, refer to Table 12.

v) If the soil has been significantly disturbed or restored, the assessment of wetness class is made without reference to gleying as follows:
-if there is a slowly permeable layer starting within 60 cm depth, refer to Figure 7;
-if there is a slowly permeable layer starting between 60 and 80 cm depth, refer to Figure 8;

-if there is no slowly permeable layer starting within 80 cm depth, assess the likelihood and degree of waterlogging from any available evidence and, if there is uncertainty make clear the tentative nature of the assessment when assigning a grade.

It should be noted that severely compacted layers may be virtually impermeable (rather than slowly permeable) and that consequently, in such cases, Figures 7 and 8 may give an underestimate of the duration of waterlogging.

vi) If the soil is reddish (5YR or redder) and not gleyed within 70 cm depth, the assessment is made as follows:
-if there is no slowly permeable layer within 80 cm depth, the soil is **Wetness Class I**;
-if there is a slowly permeable layer that starts within 60 cm depth and extends to at least 100 cm, refer to Figure 7;
-in all other cases, refer to Figure 8.

vii) If there is a mineral or organic mineral soil which has no slowly permeable layer starting within 80 cm and has a subsoil which is gleyed within 70 cm depth, refer to Table 13.

viii) If there is a mineral or organic mineral soil which has a slowly permeable layer starting within 80 cm, the assessment is made as follows:
-if gleying is present within 40 cm depth, refer to Figure 7;
-if gleying is present within 70 cm depth but not within 40 cm, refer to Figure 8.

Table 12 Estimation of Wetness Class of peat soils with no slowly permeable layer starting within 80 cm depth

FCD range	Peat soils with coarse textured subsoil[1]	Other peat soils
≤ 100	I	I
101 - 150	I	II
151 - 200	I	II - IV
201 - 225	II	II - IV

[1]Peat soils in which the mineral subsoil horizons are predominantly coarse textured (ie contain less than 18% clay) within, and are coarse textured at and immediately below, 80 cm.

Table 13 Estimation of Wetness Class of mineral or organic mineral soils with no slowly permeable layer starting within 80 cm depth but with gleying present within 70 cm

FCD range	Gleyed within 70 cm but not within 40 cm		Gleyed within 40 cm	
	Coarse textured subsoil[1]	*Other soils*	*Coarse textured subsoil[1] or in marine alluvium with a peaty or organic mineral topsoil*	*Other soils*
≤ 100	I	I	I	I
101 - 200	I	I	I	II
201 - 250	I	II	II	III
> 250	II	II	III	III

[1] Mineral soils in which the subsoil is predominantly coarse textured (i.e. contains less than 18% clay) within 80 cm depth and is coarse textured at and immediately below 80 cm depth.

APPENDIX 4

THE CALCULATION OF CROP-ADJUSTED SOIL AVAILABLE WATER CAPACITY (AP) FOR WHEAT AND POTATOES

THE CONCEPT AND ESTIMATION OF 'AVAILABLE WATER'

The total amount of soil water available to plants (TA_v) is considered to be the volumetric soil water content between 0.05 and 15 bar suction or, in the case of sands and loamy sands, 0.10 and 15 bar suction. These suctions approximate to the conditions of *field capacity,* when all excess water has drained away under the influence of gravity, and *wilting point,* when the plants can extract no more moisture from the soil. The TA_v of any soil layer can be measured in the laboratory from representative undisturbed cores (Avery and Bascomb, 1982), but as this method is both expensive and time-consuming, values of TA_v for combinations of texture and structure, which can be assessed in the field, are given in Table 14. The values are based on a dataset[1] of about 3,600 TA_v measurements from different layers in over 1,000 soil profiles throughout England and Wales.

A previous analysis of these data (Hall et al, 1977) showed that the main factors affecting TA_v are texture, structure and organic matter content and the TA_v values for each texture are therefore stratified according to whether they are for topsoils or subsoils and according to whether the subsoil layers have good, moderate or poor structural development. To help in this assessment definitions of good, moderate and poor subsoil structural conditions are given in Figures 9, 10 & 11. In topsoils, structural conditions depend very much on previous management and, under arable cultivation, can have an annual cycle encompassing all three states. Because of this, and bearing in mind that ALC assessments assume a good management standard only one TA_v value, that for moderate structural conditions, is given for topsoils. The values for poor structural conditions in Table 14 are based on measurements from undisturbed soils. These values may overestimate the available water in artificially compacted horizons which occur in some restored soils.

THE CALCULATION OF CROP-ADJUSTED AVAILABLE WATER CAPACITY (AP)

The amount of soil water that is available to a growing crop depends on both soil properties and crop rooting patterns. The rooting models used to assess AP for ALC purposes are based on those of Thomasson (1979). These suggest that, under favourable conditions, cereals will root to about 120 cm, whereas potato roots rarely extend below 70 cm. However, the root systems of cereals are less well developed below 50 cm and their ability to extract water below this depth is thus diminished. Below 50 cm therefore, the model for calculating cereal available water capacity uses only the volume of ‘easily available water' (EA_v) held in the soil between 0.05 and 2.0 bar suction. EA_v values for texture and structure combinations are given in brackets in Table 14.

[1]This dataset was collected by staff of the Soil Survey and Land Research Centre and is stored in LandIS, a computerised Land Information System based at their Headquarters at Silsoe Campus, Silsoe, Beds MK45 4DT.

For wheat, the soil available water capacity in millimetres is calculated by multiplying either the TA_v or the EA_v (whichever is applicable) of each soil layer by its thickness, adding the products for all layers to a depth of 120 cm and dividing the result by 10. This can be expressed as follows:

$$\text{AP wheat (mm)} = \frac{TA_{vt} \times LT_t + \Sigma\,(TA_{vs} \times LT_{50}) + \Sigma\,(EA_{vs} \times LT_{50\text{-}120})}{10}$$

where

TA_{vt} is Total available water (TA_v) for the topsoil texture

TA_{vs} is Total available water (TA_v) for each subsoil layer

EA_{vs} is Easily available water (EA_v) for each subsoil layer

LT_t is thickness (cm) of topsoil layer

LT_{50} is thickness (cm) of each subsoil layer to 50 cm depth

$LT_{50\text{-}120}$ is thickness (cm) of each subsoil layer between 50 and 120 cm depth

Σ means 'sum of'.

For potatoes no adjustments using EA_v are necessary. The soil available water capacity is calculated simply by multiplying the TA_v of each layer by its thickness, adding the products to a depth of 70 cm and dividing by 10. Thus:

$$\text{AP potatoes (mm)} = \frac{TA_{vt} \times LT_t + \Sigma\,(TA_{vs} \times LT_{70})}{10}$$

where

LT_{70} is thickness (cm) of each subsoil layer to 70 cm depth

ADJUSTMENTS TO SOIL AVAILABLE WATER CAPACITY TO TAKE INTO ACCOUNT THE PRESENCE OF STONES, ROCK OR A VERY POORLY STRUCTURED HORIZON

The values for TA_v and EA_v given in Table 14 are for the fine earth fraction of soils (material less than 2 mm in diameter) and adjustments are therefore necessary to take into account the presence of stones in soil layers. Such adjustments are only made for layers with less than 70% stones by volume and further modification of AP is necessary where gravelly layers (defined as containing at least 70% rounded stones by volume) or massive, fissured or shattered rock material (defined as having at least 70% angular stones by volume) occur within the model rooting depths.

Where massive, non-rootable rock of any kind restricts rooting, then soil available water is calculated only for those layers above the rock. Usually, however, massive rock is overlain by a transitional layer of fissured or shattered rock material that can be exploited by roots to a limited extent. The amount of available water in such layers depends on their lithology and values for different types are given in Table 15[1]. Where layers of gravel, fissured or shattered rock occur within 120 cm depth, the appropriate TA_v or EA_v values from Table 15 are used in the calculation of soil available water capacity.

The values for rocks given in Table 15 are also used when adjusting TA_v or EA_v values for stony soil layers with less than 70% stones by volume. Adjustments are made as follows:

$$\text{Stone-adjusted } TA_v \text{ or } EA_v = \frac{A_{vf} \times \%f + (A_{vr} \times \% \text{ Stones})}{100}$$

where

f is fine earth component, i.e. (100-% volume of stone)

A_{vf} is TA_v or EA_v (as appropriate) of fine earth component

A_{vr} is TA_v or EA_v (as appropriate) of stone component

Where the soil has a severely compacted layer with very poor structure which generally restricts root penetration, soil available water is calculated only for layers above the compacted layer.

[1] There is little information on the amount of available water in different rocks and the values used in Table 15 are mostly estimates based on a few, as yet unpublished measurements. They should be regarded as tentative values and should only be used where actual site measurements are unavailable.

EXAMPLES

The following examples illustrate how crop-adjusted APs are calculated.

Example 1. A stoneless clayey soil with slowly permeable subsoil

Soil data

Layer	Depth (cm)	Texture	Structural Condition	Stones
Topsoil	30	clay loam	-	0
Subsoil 1	30 - 60	clay	moderate	0
Subsoil 2	60 - 120	clay	poor	0

Variables

		%
From Table 14	Topsoil TA_v	18
	Subsoil 1 TA_v	16
	Subsoil 1 EA_v	8
	Subsoil 2 TA_v	13
	Subsoil 2 EA_v	7

Calculation: AP Wheat

	cm	
Topsoil	0 - 30	30 x 18 = 540
Subsoil 1	30 - 50	20 x 16 = 320
Subsoil 1	50 - 60	10 x 8 = 80
Subsoil 2	60 - 120	60 x 7 = 420

$$\textbf{AP wheat} = \frac{540 + 320 + 80 + 420}{10} = \textbf{136 mm}$$

Calculation: AP potatoes

	cm	
Topsoil	0 - 30	30 x 18 = 540
Subsoil 1	30 - 60	30 x 16 = 480
Subsoil 2	60 - 70	10 x 13 = 130

$$\textbf{AP potatoes} = \frac{540 + 480 + 130}{10} = \textbf{115 mm}$$

Example 2. A deep loamy soil in till with few to common hard quartzite stones (Bunter pebbles) and a slowly permeable subsoil at depth

Soil data

Layer	Depth (cm)	Texture	Structural Condition	Stones
Topsoil	0 - 35	medium sandy loam	-	6%
Subsoil 1	35 - 60	medium sandy loam	moderate	8%
Subsoil 2	60 - 120	clay loam	poor	3%

Variables

		%
From Table 14	Topsoil TA_v	17
	Subsoil 1 TA_v	15
	Subsoil 1 EA_v	11
	Subsoil 2 TA_v	12
	Subsoil 2 EA_v	7
From Table 15	TA_v stones	1
	EA_v stones	0.5

Calculation: AP Wheat

	cm		
Topsoil	0 - 35	$\frac{(17 \times 94) + (1 \times 6)}{100}$	x 35 = 561.4
Subsoil 1	30 - 50	$\frac{(15 \times 92) + (1 \times 8)}{100}$	x15 = 208.2
Subsoil 1	50 - 60	$\frac{(11 \times 92) + (0.5 \times 8)}{100}$	x 10 = 101.6
Subsoil 2	60 - 120	$\frac{(7 \times 97) + (0.5 \times 3)}{100}$	x 60 = 408.3

$$\textbf{AP wheat} = \frac{561.4 + 208.2 + 101.6 + 408.3}{10} = \textbf{128 mm}$$

Calculation: AP potatoes

	cm		
Topsoil	0 - 35	$\frac{(17 \times 94) + (1 \times 6)}{100}$	x 35 = 561.4
Subsoil 1	35 - 60	$\frac{(15 \times 92) + (1 \times 8)}{100}$	x 25 = 347
Subsoil 2	60 - 70	$\frac{(12 \times 97) + (1 \times 3)}{100}$	x 10 = 116.7

$$\textbf{AP potatoes} = \frac{561.4 + 347 + 116.7}{10} = \textbf{102 mm}$$

Table 14 Estimation of available water (%) from texture class, horizon and structural conditions

Texture Class	Topsoil TA_v	Subsoil TA_v (EA_v in brackets)		
		good[1]	*moderate*[1]	*poor*[1]
Clay	17	21 (15)	16 (8)	13 (7)
Silty clay	17	21 (15)	15 (8)	12 (7)
Sandy clay	17	19 (14)	15 (10)	13 (8)
Sandy clay loam	17	19 (14)	15 (10)	13 (8)
Clay loam	18	21 (14)	16 (10)	12 (7)
Silty clay loam	19	21 (12)	17 (10)	12 (6)
Silt loam	23	23 (17)	22 (14)	15 (9)
Fine sandy silt loam	22	22 (16)	21 (15)	15 (9)
Medium sandy silt loam	19	19 (13)	17 (11)	15 (9)
Coarse sandy silt loam	19	23 (17)	19 (11)	15 (7)
Fine sandy loam	18	22 (17)	18 (13)	17 (11)
Medium sandy loam	17	17 (13)	15 (11)	11 (8)
Coarse sandy loam	17	22 (15)	16 (11)	11 (8)
Loamy fine sand	18	15 (13)	15 (13)	*
Loamy medium sand	13	12 (9)	9 (6)	*
Loamy coarse sand	11	11 (7)	8 (6)	*
Fine sand	*	14 (12)	14 (12)	*
Medium sand	12	7 (5)	7 (5)	*
Coarse sand	*	5 (4)	5 (4)	*
Marine light silts[2]		33 (30)	28 (22)	*
	All Horizons			
Organic sands	23 (16)			
Organic loams	28 (20)			
Organic clays	23 (16)			
Peaty sands	39 (36)			
Peaty loams	27 (18)			
Sandy peats	45 (30)			
Loamy peats	35 (26)			
Humified peats	33 (24)			
Fibrous and semi-fibrous peats	44 (35)			

[1] Criteria for good, moderate and poor structural conditions are given in Figures 9, 10 & 11.

[2] Use these figures only for subsoils in marine alluvium where textures are fine sandy silt loam, fine sandy loam or loamy fine sand *and* most of the sand is finer than 0.1 mm.

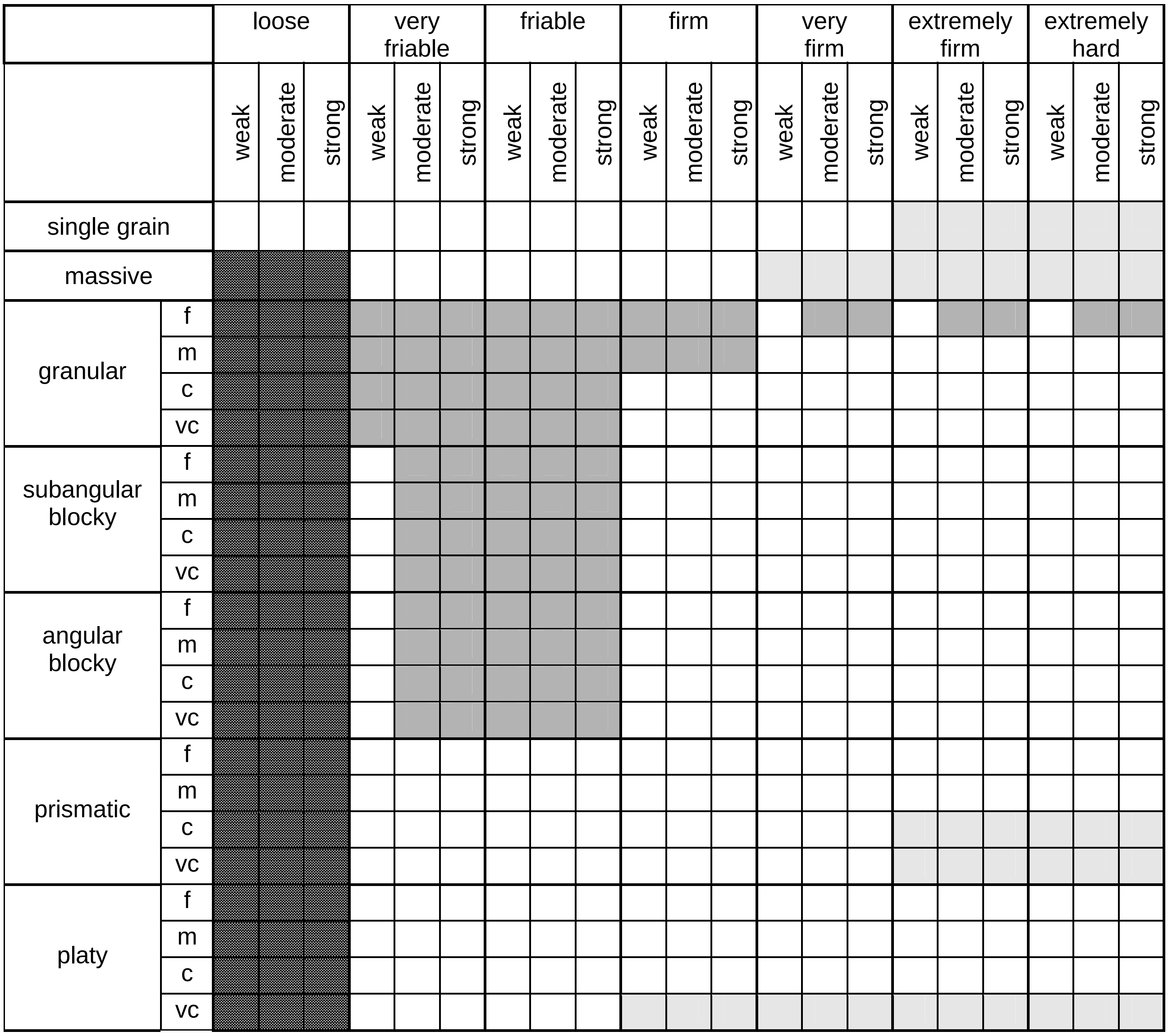
* Rare occurrences for which there are no data.

Table 15 Available water in stones and rocks (%)

Rock, gravel or stone type	TA_v	EA_v
All hard rocks or stones (i.e. those which cannot be scratched with a finger nail)	1	0.5
Soft, medium or coarse grained sandstones	3	2
Soft 'weathered' igneous or metamorphic rocks or stones	4	2
Soft oolitic or dolomitic limestones	4	3
Soft fine grained sandstones	5	3
Soft, argillaceous or silty rocks or stones	8	5
Chalk or chalk stones	10	7
Gravel[1] with non-porous (hard) stones	2	1
Gravel[1] with porous stones (mainly soft stone types listed above)	5	3

[1]Gravel with at least 70% rounded stones by volume

Figure 9. Assessment of structural conditions[1] in subsoil horizons with S or LS texture



Good structure

Moderate structure

Poor structure

Combinations which are very rare or do not occur

f fine

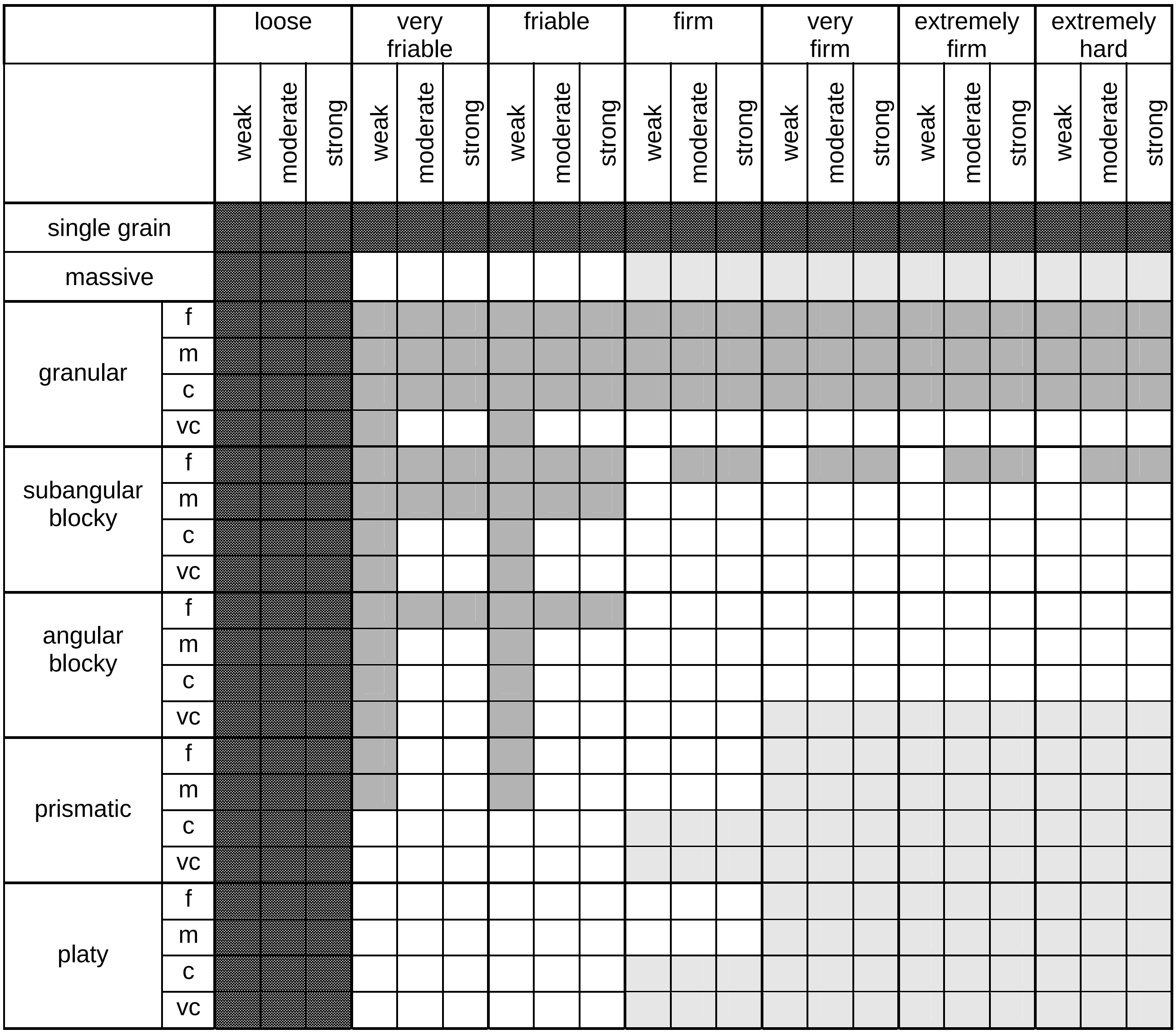
m medium

c coarse

vc very coarse

[1]See Hodgson, 1976, pages 30 to 50, and Hodgson (in preparation) for detailed descriptions and definitions related to soil structure and consistence.

Figure 10. Assessment of structural conditions[1] in subsoil horizons with SL, SZL or ZL texture



Good structure

Moderate structure

Poor structure

Combinations which are very rare or do not occur

f fine

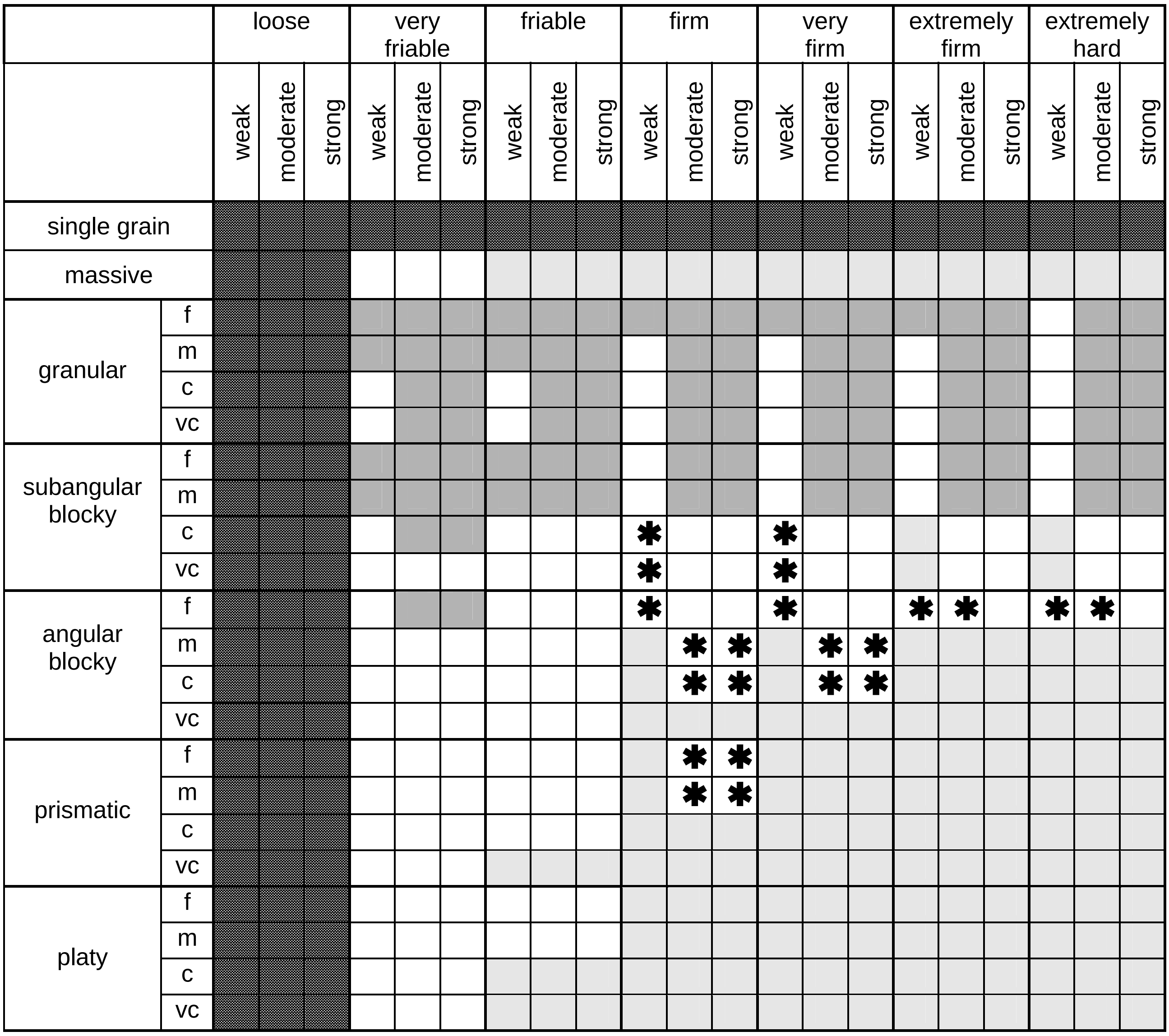
m medium

c coarse

vc very coarse

[1]See Hodgson, 1976, pages 30 to 50, and Hodgson (in preparation) for detailed descriptions and definitions related to soil structure and consistence.

Figure 11. Assessment of structural conditions[1] in subsoil horizons with SCL, CL, ZCL, SC, C or ZC texture



Good structure

Moderate structure

Poor structure

Combinations which are very rare or do not occur

✱ Poor structure if ped faces are gleyed

f fine

m medium

c coarse

vc very coarse

[1]See Hodgson, 1976, pages 30 to 50, and Hodgson (in preparation) for detailed descriptions and definitions related to soil structure and consistence.

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Figure 1

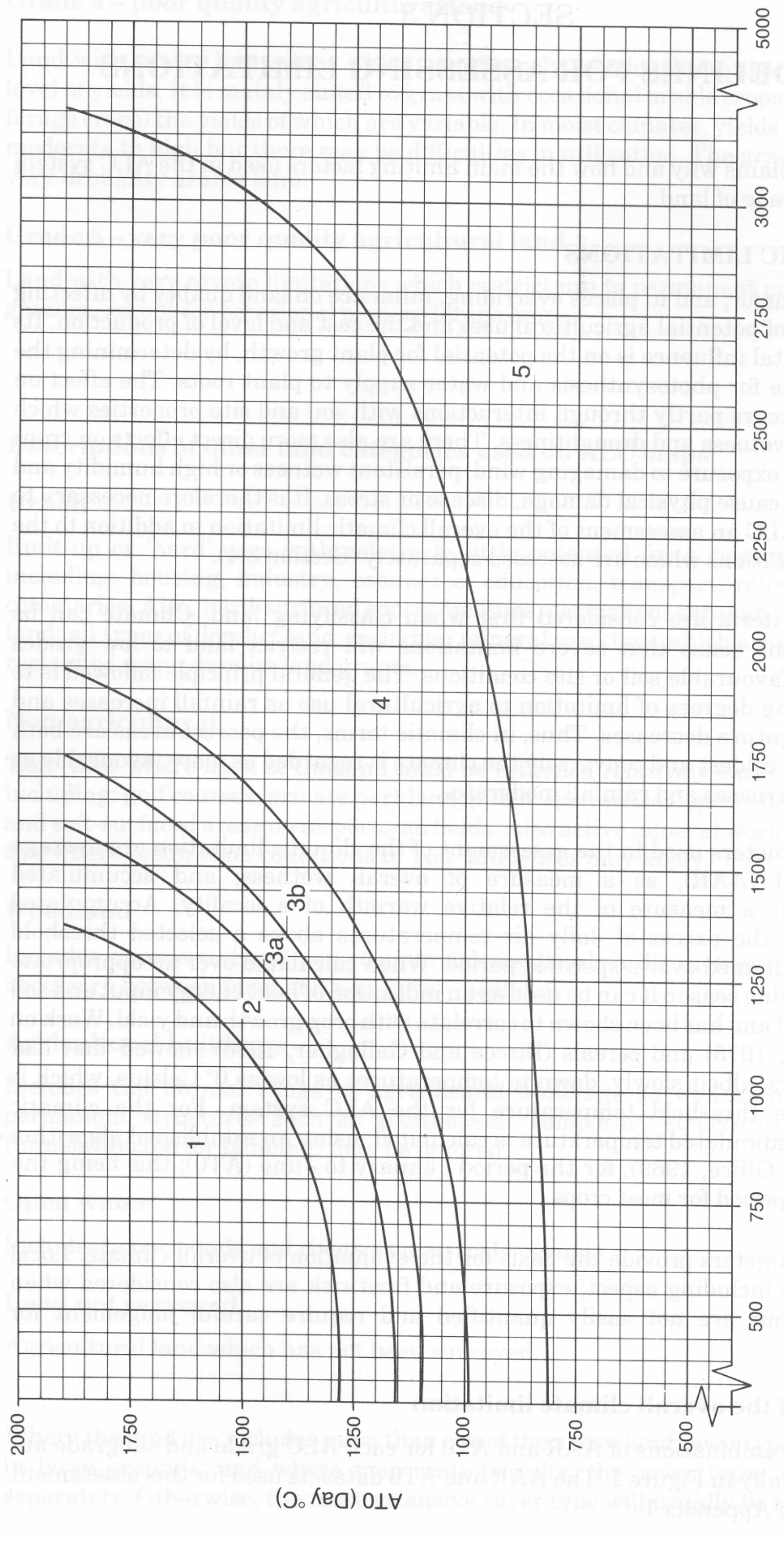

Figure 1. Grade according to climate

Figure 2

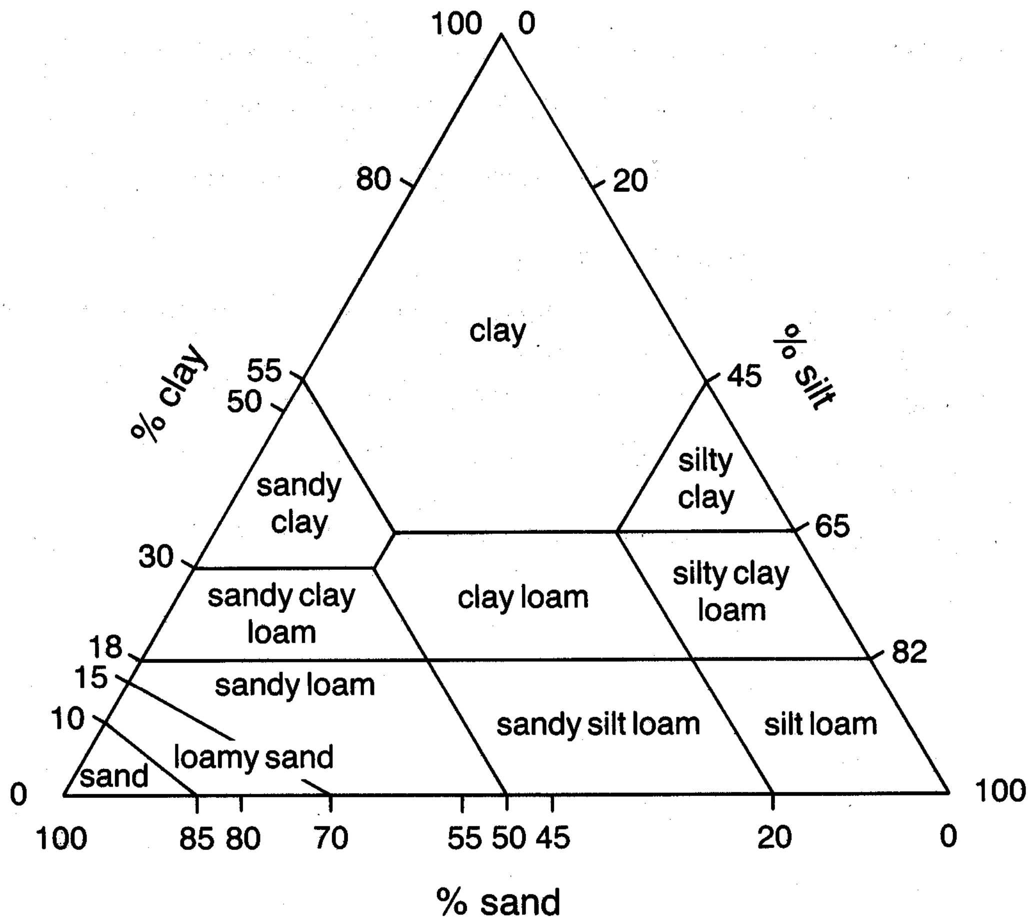

Figure 2. Limiting percentages of sand, silt and clay fractions for mineral texture classes

The particle size fractions used are given in Table 10.

Figure 3

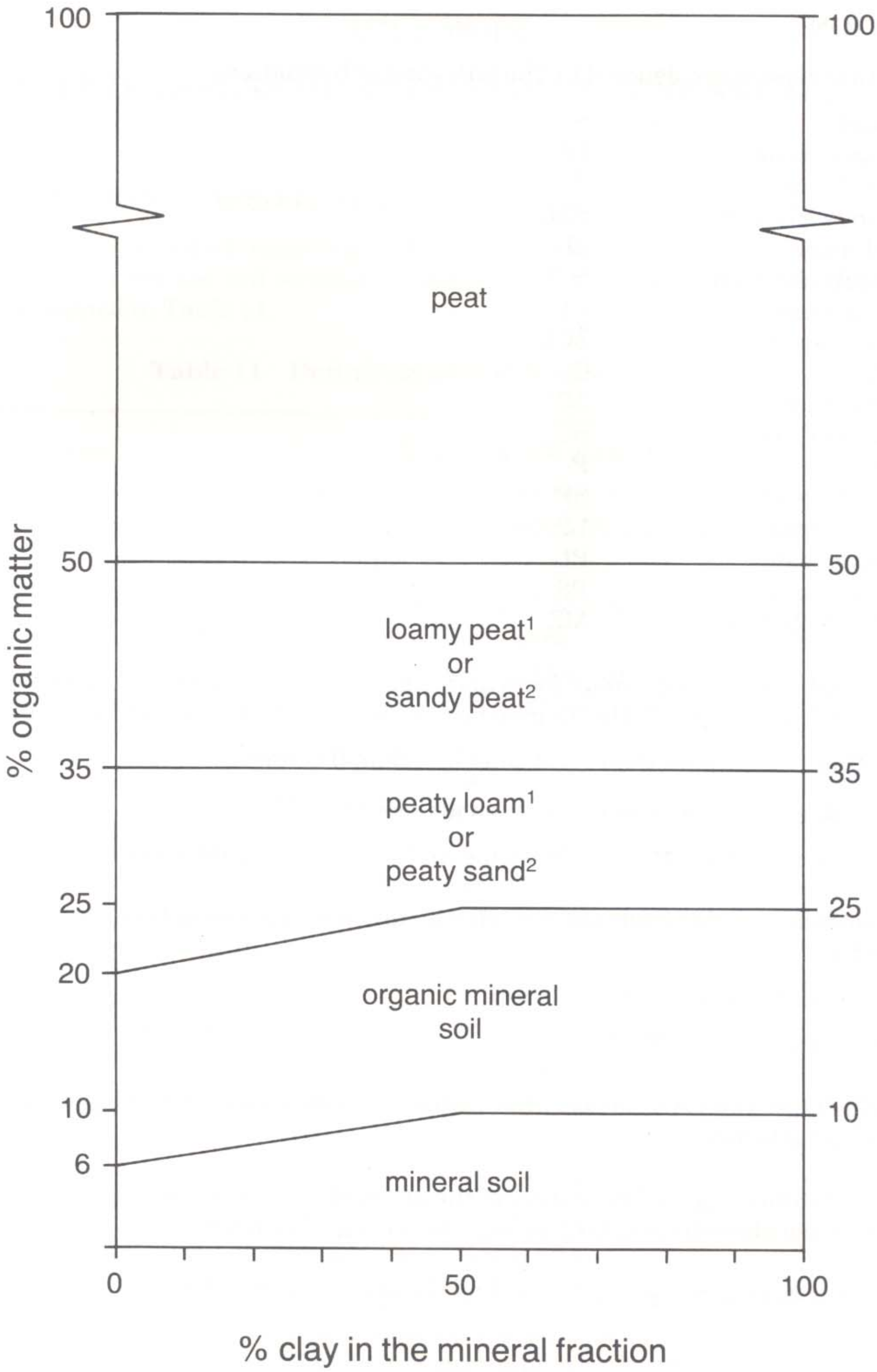

Figure 3. Limiting percentages of organic matter, clay and sand for peaty and organic mineral texture classes

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[1] Less than 50% sand in the mineral fraction
[2] 50% sand or more in the mineral fraction

Figure 4

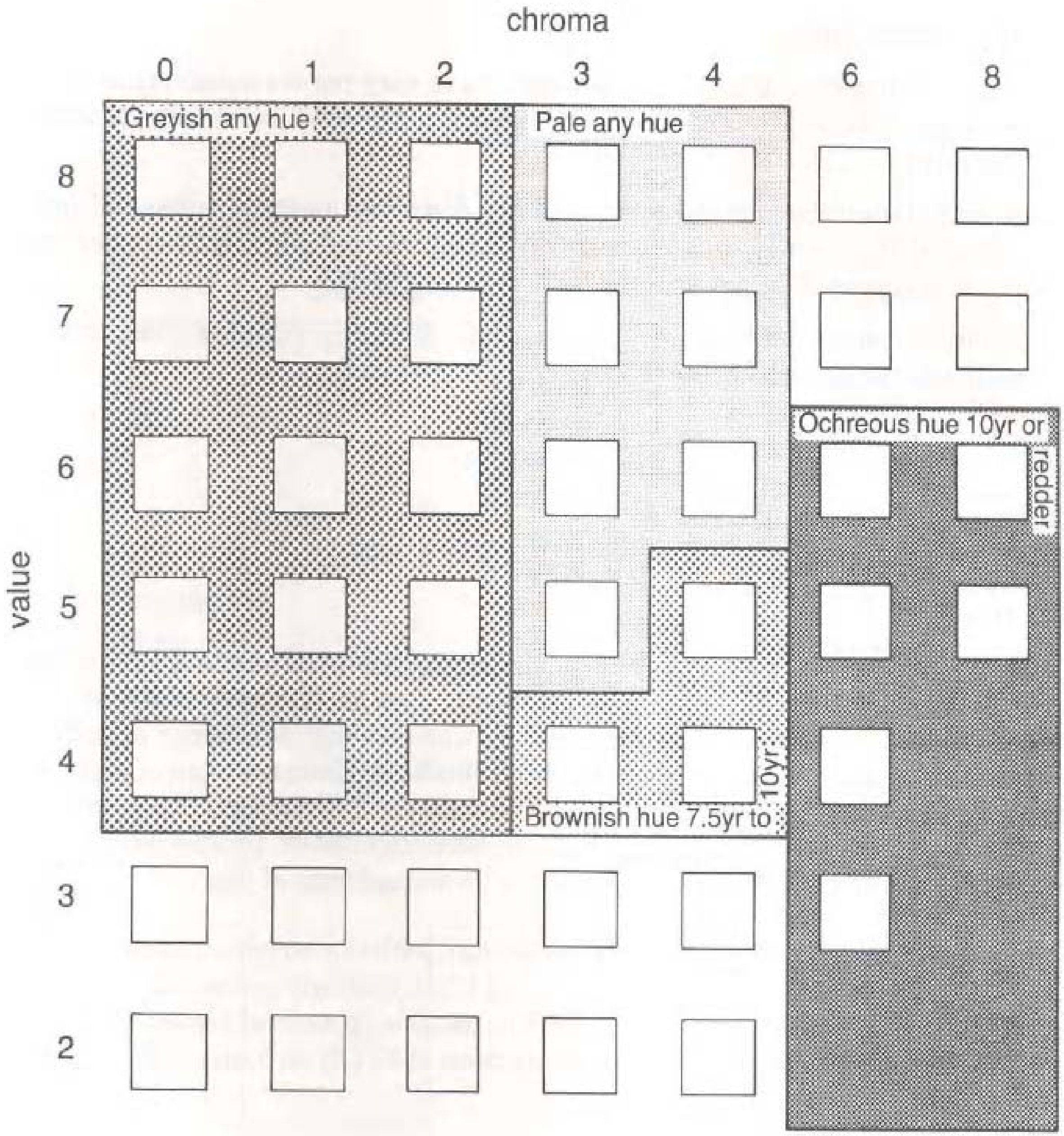

Figure 4. Diagrammatic representation of gley colours defined according to the Munsell[1] soil colour system

Figure 5

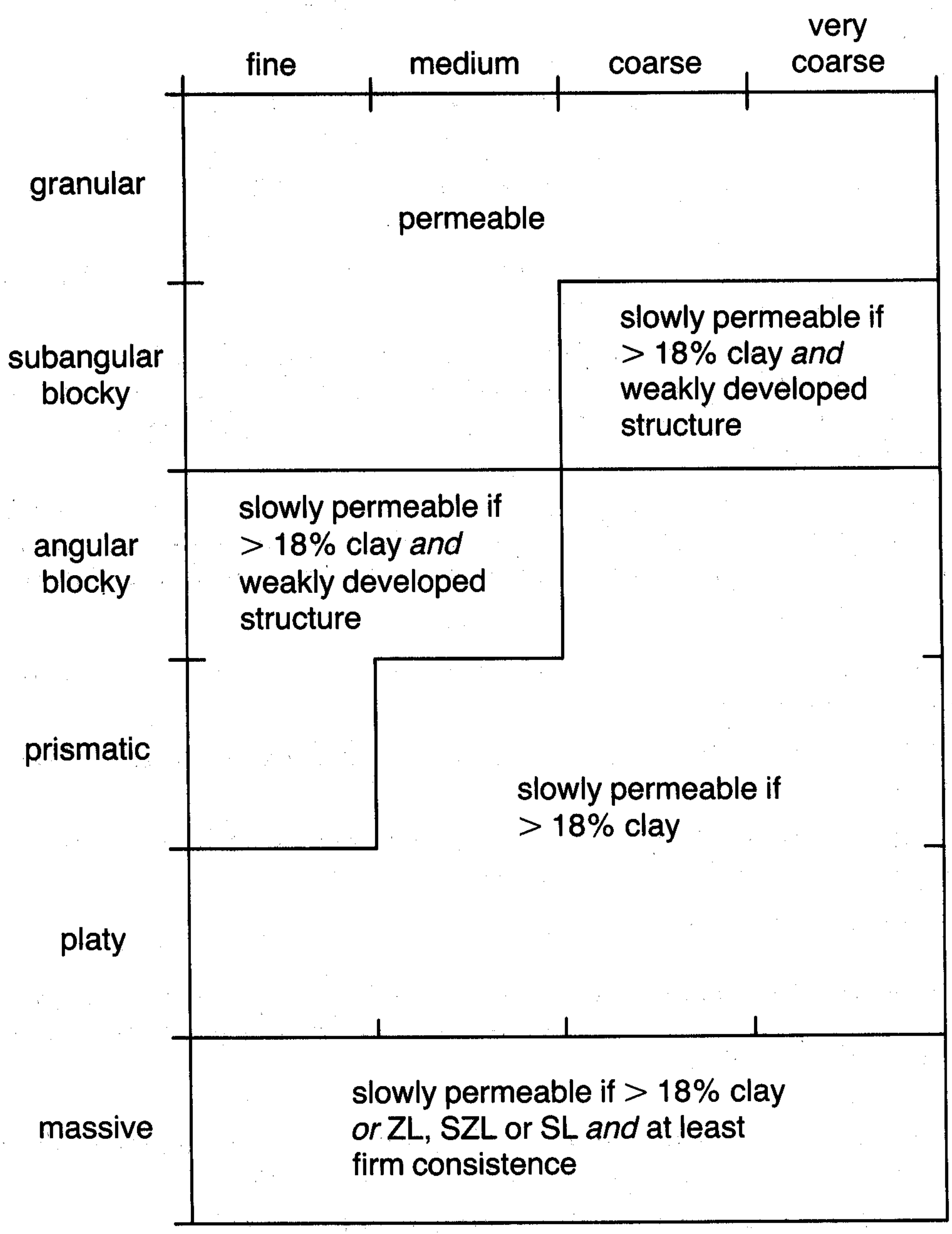

Figure 5. Diagrammatic representation of the combinations of structure, texture and consistence which are characteristic of slowly permeable layers

Figure 6

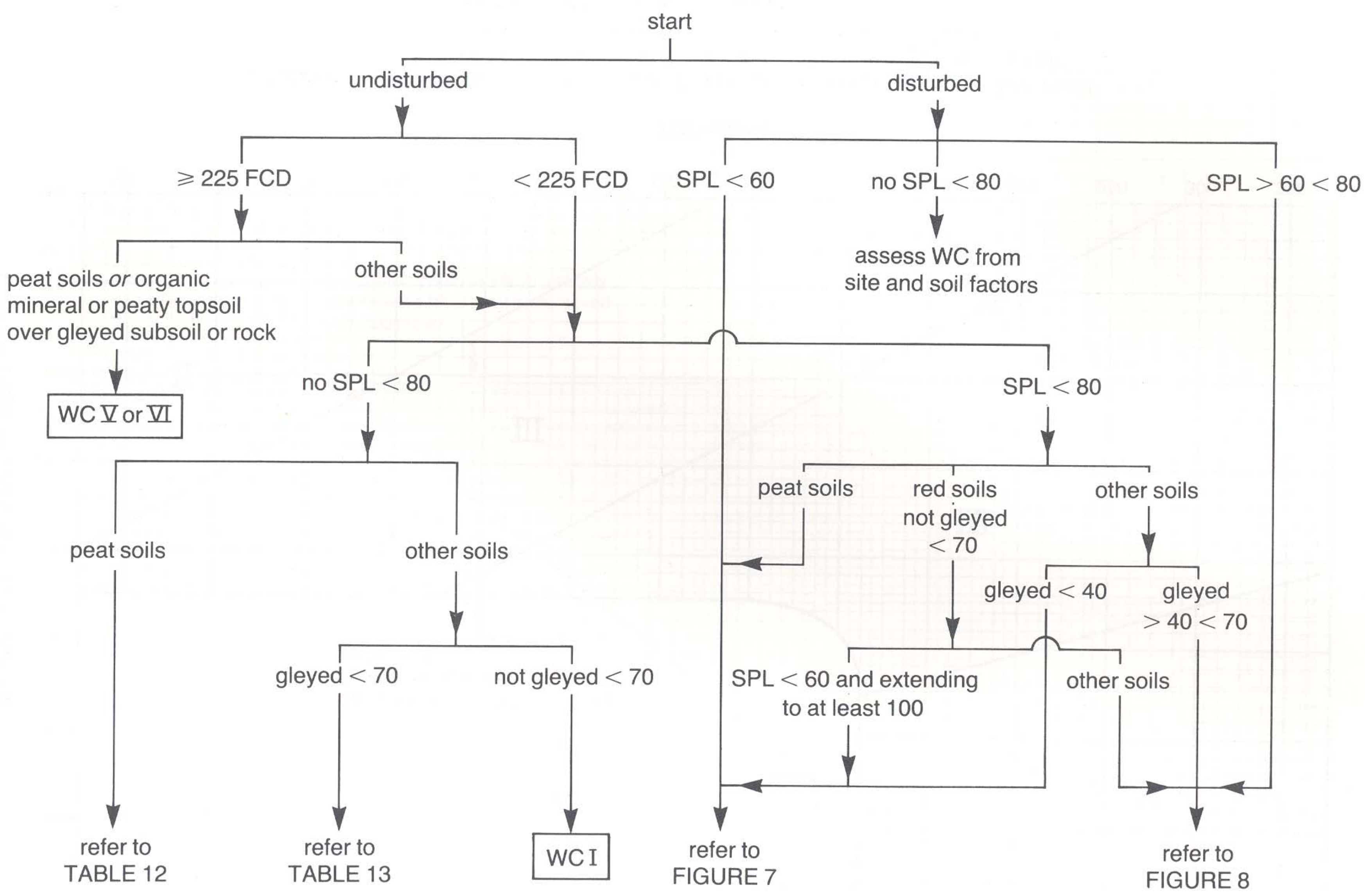

Figure 6. Flow diagram for assessing soil wetness class (WC) from field capacity days (FCD), depth to gleying (in cm) and depth to a slowly permeable layer (SPL, in cm)

Figure 7

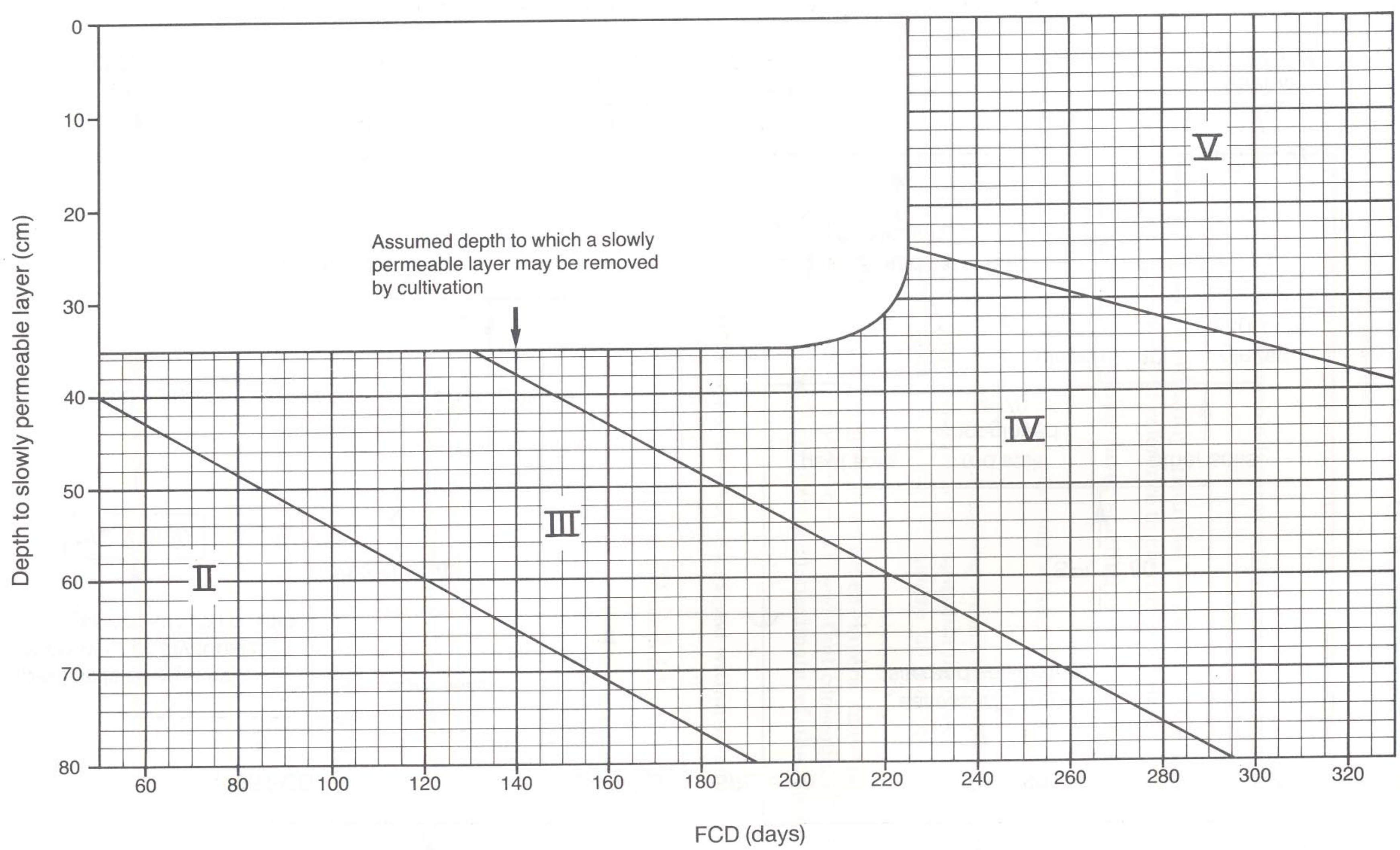

Figure 7. Estimation of Wetness Class from depth to slowly permeable layer and duration of field capacity (FCD) for soils with gleying present within 40 cm depth and a slowly permeable layer starting within 80 cm depth; and for peat soils with a slowly permeable layer

Figure 8

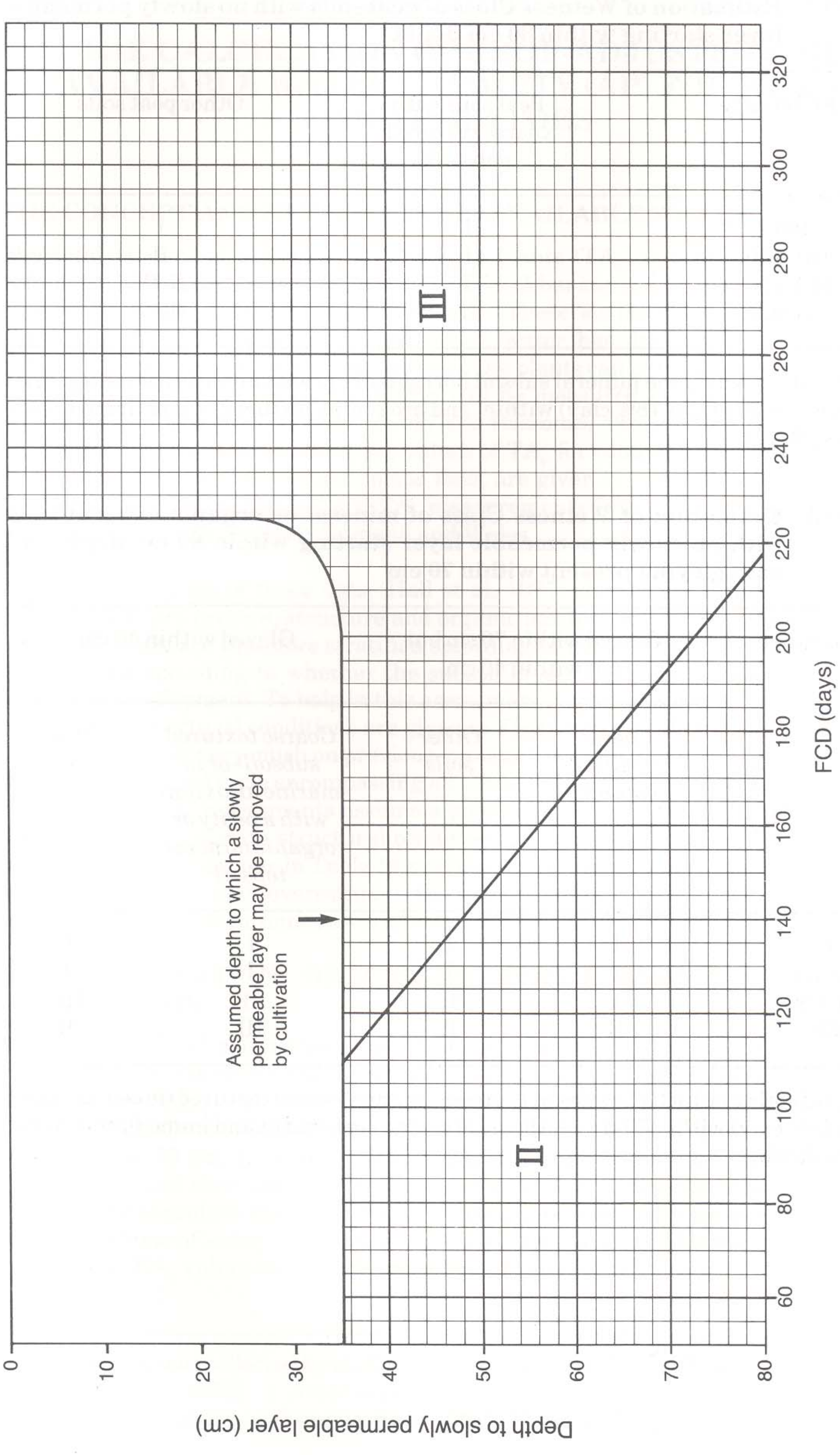

Figure 8. Estimation of Wetness Class from depth to slowly permeable layer and duration of field capacity (FCD) for soils with gleying present within 70 cm depth but not within 40 cm and a slowly permeable layer starting within 80 cm depth