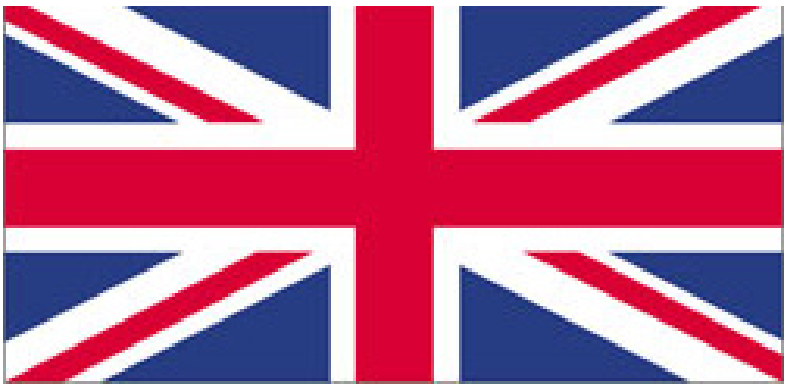
Country Pasture/Forage Resource Profiles

UNITED KINGDOM



by

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1. INTRODUCTION

Location

The geographical position of the United Kingdom (UK) off the western coast of north-west Europe means that it enjoys a cool maritime climate. The UK is contained within the latitudinal range of 49° 57′ and 60° 51′ N (between southern England and the northern Scottish Isles) and the longitudinal range within 1° 45′ E and 8° W (between eastern England and the west of Northern Ireland) (see Figure 1).

Figure 1. Map of the UK
Source: World Factbook

Government and administration

The UK comprises Great Britain (England, Wales and Scotland) and Northern Ireland. The Isle of Man and the Channel Islands are Crown dependencies with their own legislative systems and are not part of the UK. The UK is a constitutional monarchy, governed by Ministers of the Crown in the name of the Sovereign, who is both head of state and head of the government. The powers of the monarchy are now very limited, and are restricted mainly to advisory and ceremonial duties, though many acts of government still require the participation of the Sovereign. These include summoning and dissolving Parliament, giving royal assent to new legislation, appointing important office holders and conferring honours. The Prime Minister is also appointed by the Sovereign, though by convention he or she is the leader of the political party that secures the majority of votes in the House of Commons, and who is elected from within the ruling party. As the Sovereign entrusts executive power to Ministers and acts on their advice, in practice royal prerogative powers are exercised by Ministers who are responsible to Parliament. Parliament itself is therefore the law-making authority and its main functions are to pass laws, raise taxation to carry out the work of government, and to scrutinize government policy and administration.

The UK constitution has evolved in the course of time, formed partly by statute, partly by common law and partly by convention. England has existed as a unified entity since the 10th century and the English Parliament emerged during the late 13th and 14th centuries. It has evolved progressively and extended its jurisdiction beyond England to the present arrangement, with an Act of Union with Wales begun in 1284 and formalised in 1536. In another Act of Union in 1707, England and Scotland agreed to permanently join as Great Britain, and the union of Great Britain and Ireland was implemented in 1801, with the adoption of the name the United Kingdom of Great Britain and Ireland. The Anglo-Irish treaty of 1921 formalized a partition of Ireland in which six northern Irish counties remained part of the United Kingdom as Northern Ireland and the current name of the country, the United Kingdom of Great Britain and Northern Ireland, was adopted in 1927. In the UK parliament in London (Westminster) there are two Houses, the House of Commons and the House of Lords, which together form the Houses of Parliament. The House of Commons consists of 646 publicly elected Members of Parliament each of whom represents a constituency, the elected member being the candidate who obtains the largest number of votes cast in the constituency, every adult in the UK being entitled to vote in the constituency in which they are normally resident and registered. The maximum duration of a Parliament is five years. The House of Lords is the Upper House of Parliament, which formerly was the more powerful house

though its influence was greatly reduced by reforms in 1911, and by further reforms in 2007 with moves towards a more fully elected chamber.

Whilst Parliament is responsible for the government of the whole of the UK, since 1999 greater powers of regional government have been devolved to Wales and Scotland. The National Assembly for Wales in Cardiff has responsibility in Wales for a number of functions including agriculture, fisheries, environmental protection, land use, planning, countryside and nature conservation, health, education and culture. The Scottish Parliament in Edinburgh has primary legislative responsibility in Scotland for areas including agriculture, food standards, forestry, education, health, law enforcement and economic development. In Belfast, the Northern Ireland Assembly is the devolved legislative body for Northern Ireland, with responsibility for functions similar to those for Scotland and Wales. It consists of 108 democratically elected members. Its full powers were restored as recently as May 2007 following an election in March that year. In London, an elected Greater London Authority also has similar devolved legislative functions.

In England the Government Ministry responsible for agriculture and environmental matters is the Department for Environment and Rural Affairs (DEFRA). In Scotland its functions are devolved to the Scottish Executive Environment and Rural Affairs Department (SEERAD), and in Wales to the Welsh Assembly Government Department for Environment, Planning and Countryside. The Northern Ireland Assembly has a Department of Agriculture and Rural Development.

As a full member of the European Union the UK is subject to EU agreements on farm support under the terms of the Common Agriculture Policy (CAP). Reform of the CAP has led to a progressive movement towards measures that address the environment and socio-economic aspects of rural areas rather than encouraging further agricultural commodity production. Since 2006 in England a scheme called Environmental Stewardship has operated in which farmers are encouraged to develop an environmental plan for their farm, with payments made to a set of criteria that acknowledge the value of environmental outcomes and the implications in terms of production foregone (similar arrangements also exist in other parts of the UK). This replaced several previous schemes, of which the main one consisted of payments for agri-environmental measures within defined areas (Environmentally Sensitive Areas).

Currency, language and population

The UK currency is the pound sterling, the value of which relative to other convertible currencies fluctuates on the world currency markets.

English is the normal language for all means of communication throughout the UK. In Wales, the Welsh language (a Celtic language) is also widely understood and used as a second official language. It has enjoyed an increase in popularity within Wales in recent years and spoken on a daily basis in many localities, as well as being used in official documents. In Scotland, Scottish Gaelic (a Celtic language though from a different linguistic group than Welsh) is also spoken, though its usage it predominantly in the north-west and the Western Isles such as Skye and Lewis. Irish (or Gaelige) is related to Scottish Gaelic and is widely spoken in the Republic of Ireland where it is upheld as its official language, though in Northern Ireland around 10% of the population also claim to have some knowledge of the Irish language. In London and many other cities a wide range of languages are in use among immigrant communities.

Population censuses are taken at ten-year intervals and show a progressive increase in population numbers. The 2001 National Census [see Table 1] showed a 4% increase over the previous decade, attributed to net immigration and greater life expectancy [Total UK population was 58 790 000]. The present population of ca. 61 million [according to the World Factbook the estimated July 2008 population is 60 943 912 with a growth rate of 0.276%] makes the UK one of the most densely populated countries in Europe, with areas of England (in the south-east and north-west of England in particular) having very dense urban populations. According to projections from the Office for National Statistics the population could reach 65M by 2016 and 71M by 2031, largely as a result of rapid inward migration.

Table 1. Population and land area

	Land area km²	Population	Population density per km²
England	129 600	49 139 000	379
Wales	20 600	2 903 000	141
Scotland	77 100	5 062 000	66
N. Ireland	13 500	1 685 000	125
Total UK	240 800	58 790 000	244

Source: 2001 Census data

Natural conditions and land

There is permitted public access on foot to many areas of farmed land and other rural land in most parts of the UK. Footpaths marked as public rights of way (usually marked by direction signs) are shown on Ordnance Survey maps at scales of 1:50 000 and 1:25 000 that can be purchased as paper copies or downloaded from the Ordnance Survey website. In England and Wales there is also more general right of access to private land (subject to some restrictions) that has been classified as 'mountain, moorland, heathland and downland' under the Countryside and Rights of Way Act. Such land is also shaded appropriately on Ordnance Survey maps. These arrangements enable visitors as well as residents to enjoy a degree of access on to privately owned UK farmland, and thus experience farming activity at first hand, subject to compliance with any restrictions that might apply. A number of farms, especially in popular vacation areas, also hold public open days and farm walks to help inform the public about their work.

2. SOILS AND TOPOGRAPHY

The geology and geomorphology of the UK are extremely complex (see Figure 2), giving rise to an intricate pattern of soil type distributions and marked differences in landscape and relief, often within relatively small areas .

Periods of mountain building and the effects of the Quaternary glaciation have exerted a profound impact on the landscape. Variation within relative short distances is far greater than in many other countries, and this in turn contributes to the varied patterns of agriculture and land use. In England most of the underlying rocks are sedimentary rocks of the late Palaeozoic and Mesozoic, and there are extensive areas of Tertiary formations around and to the east of London. A range of parent materials (chalk, limestone, sandstones, and clays) influence the soil and relief and thus the suitability of land for cropping relative to grassland or forestry. Where these sedimentary rocks occur the landscape is generally flat or gently rolling; almost all the land below 300 m elevation, and the relief and type of rock below the soil surface have been influenced greatly by uplift at the end of the Cretaceous period. The lowlands of central and eastern England are overlain by glacial and fluvio-glacial deposits. In the far south west of England (counties of Devon and Cornwall) and also the north west (Cumbria) the surface geology includes areas with igneous rocks giving rise to generally higher

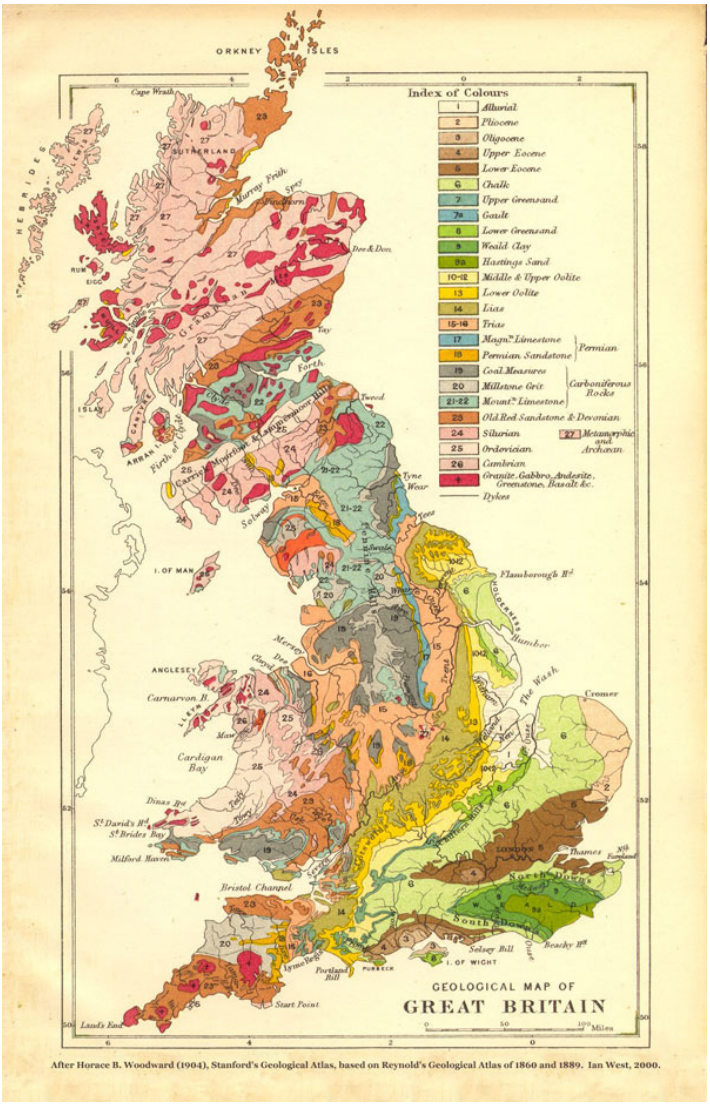


Figure 2. Geological map of Great Britain
Source: www.soton.ac.uk/~imw/Geology-Britain.htm

ground with soils suited only to extensive grazing (the highest land in England being in Cumbria, rising to over 900 m elevation). In the central and eastern parts of northern England there is a predominance of Carboniferous rocks in the Pennine and Cheviot Hills (limestone, gritstone and Coal Measures) with substantial areas being in the elevation range of 200–600 m. These present areas with steep or sloping land, frequently with shallow soils, and are generally given over to pastoral agriculture in varying degrees of intensity of management depending on local conditions.

In Wales, Scotland and Northern Ireland the geology is predominantly of early Palaeozoic or Pre-Cambrian igneous and metamorphic rocks. Large areas of southern and eastern Wales have Devonian and Carboniferous sedimentary rocks below the surface, but here elevation rises to over 800 m. At lower elevations in the west of Wales conditions give rise to some of the most productive grassland soils in the UK. In North Wales a highly complex pattern of ancient rocks produce steep mountain areas rising to over 1 000 m.

In Scotland there is an immensely complex geology with a trend of fault lines running along a SW/NE axis (and reappearing in Northern Ireland). Scotland's main centres of population, the cities of Glasgow and Edinburgh and their surrounding towns, are within a central valley bounded by two parallel faults, with Carboniferous and Devonian sedimentary rocks giving rise to a pattern of low relief interspersed with older volcanic and intrusive rock formations. Particularly in the eastern part of this region conditions allow arable cropping. However, to the north and west of this zone the predominant geology is of igneous and intrusive rocks with substantial variations in relief rising to over 1 200 m, and there are thin acid soils even at low elevations. In Northern Ireland this pattern is repeated, though elevations are lower (mountains are in the 500–700 m range), and in the lowlands are areas with good soils that support productive grassland.

In the lowland areas of Scotland, Wales and Northern Ireland, as well as in northern England, there are widespread glacial deposits which exert a major effect on soil formation and potential for agriculture. In most of the lowland Britain deciduous forest developed in the post-glacial period and the present soils of agricultural land are largely anthropogenic. In upland Britain soils are more closely related to geology and recent environmental influences such as weathering and leaching under heavy rainfall.

The UK was relatively late in developing soil mapping and adopted a system based on information about soil profiles, using named classes which are sub-divided or aggregated into associations. Profile descriptions are based on features that are easy to recognize in the field and that relate to environmental features such as land form and geology, and on properties that affect land-use capability. Most soils fall within six basic types: podzols, brown earths, gleyed brown earths, gley soils, calcareous soils, and organic (peaty) soils.

In the uplands (most of Scotland, north Wales and parts of northern and south west England) the dominant geology is Palaeozoic and ancient rocks that are relatively hard and of low base status. These give rise to silty/clay gley soils, or coarse brown earths, depending on rock texture. On the uplands (moors) of south-west England and through much of upland Wales, acid brown earth soils are widespread but organic (blanket peat) soils and peaty gleyed podzols predominate on the high ground (above 600 m). In the Pennine Hills of northern England blanket peat soils and peaty gleyed podzols predominate, while in Cumbria acid brown earths and semi-podzolic soils are more general. (See Figure 3 showing the dominant great soil groups [according to the FAO classification]).

The pattern of soil types in most of England (and the lowlands of other parts of the UK) can only be summarized in general terms because of the intricate variations in soil type distribution. On the drier lowlands where chalk or limestone are close to the surface, or where chalky drift has been deposited, calcareous brown earths predominate, allowing a range of agriculture including arable, dairying and cattle rearing (e.g. in areas of central southern England and south east England, and the Cotswolds of western central England). Substantial areas with clay and clay loam soils derived from either weathered rock or from glacial deposits occur over the Midlands and north west of England, parts of East Anglia and on the relatively higher parts of south east England. These give rise to predominately clay soils, though often interspersed with sandy soils, and with varying degrees of drainage. Here, agriculture is based on arable cropping or livestock utilizing permanent grassland and sown grass leys, depending on the suitability for frequent cultivation. In the south western counties of England (Devon and Cornwall) there are large areas of gley soils and gleyed brown earths, loamy or clayey in texture, derived from

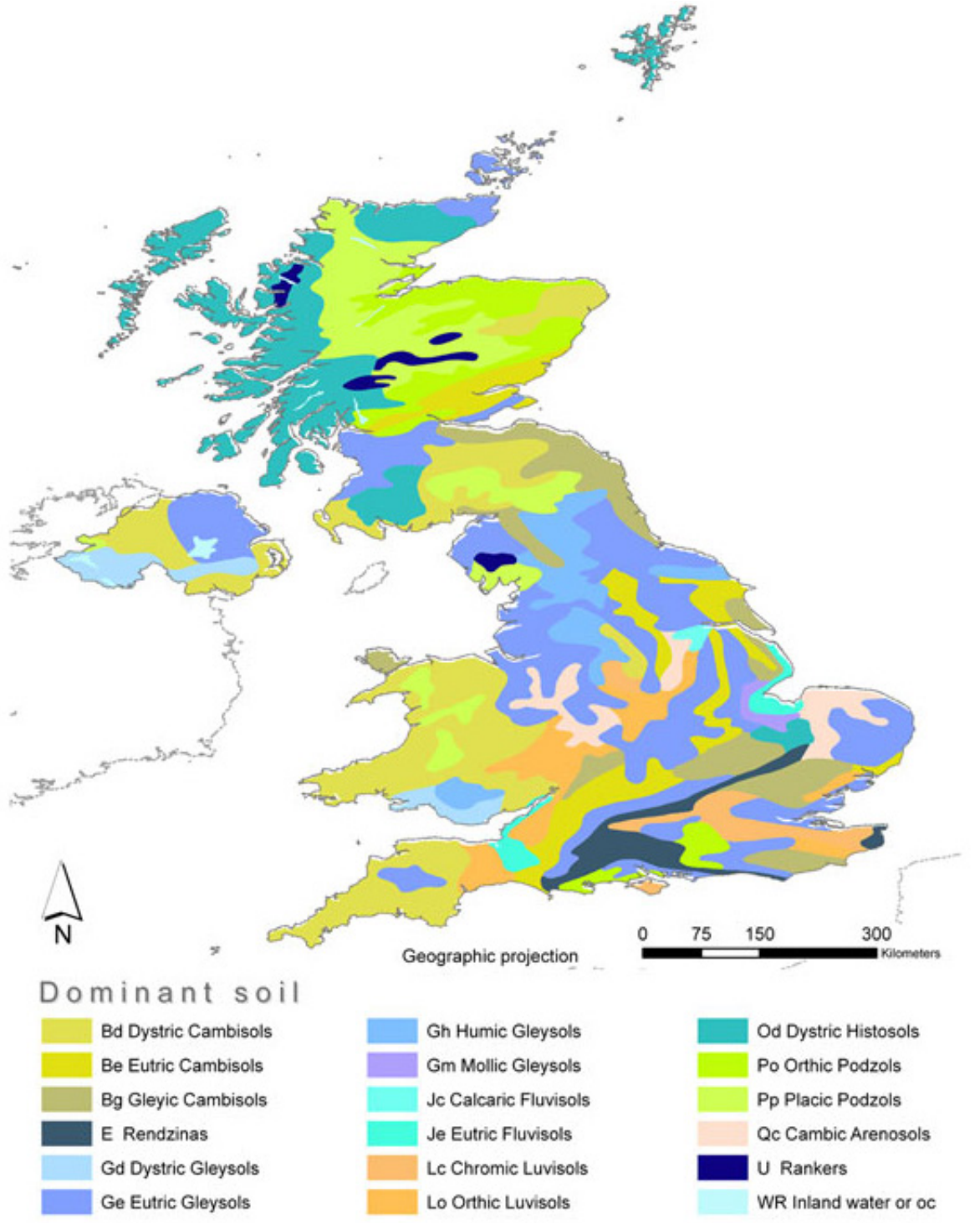


Figure 3. UK - Dominant Soil Groups (according to the FAO Classification)
[Digital soil map of the world and derived soil properties. Land and Water Development Division, Land and Water Digital Media Series n.1, FAO, Rome.]

weathered shales. Arable cropping is limited to areas with better natural drainage (or artificially improved drainage). These counties and the neighbouring ones of Somerset and Dorset support some of the main cattle farming (dairy and beef) in the UK.

3. CLIMATE AND AGRO-ECOLOGICAL ZONES

General climate

The climate of the UK is under the control of North Atlantic weather systems. Low pressure systems that develop over Iceland ensure a generally moist climate with frequent rainfall particularly in the winter months, and the anticyclones from the Azores are responsible for periods of hot or warm dry weather in summer. The effects of the Gulf Stream are responsible for the UK enjoying a milder climate than would otherwise be the case for land in its latitudinal range. This effect is particularly felt on western areas near the coast where the number of grass-growing days can exceed 300 per year (see Figure 4). Large areas of central and southern England have over 250 grass-growing days, decreasing to around 200 in the more elevated northern areas and on drier soils in eastern England where summer drought can reduce grass growth in summer, but weather conditions allow arable cropping in most years.

The latitudinal range of mainland UK ranges from 50° to 59° N, and the mean temperature during the growing season decreases by about 4°C from south to north. However, climatic differences between west and east (decreasing oceanicity) and those associated with altitude are of greater significance for agriculture. There is a reduction in mean temperature of about 0.6 °C for each 100 m rise in elevation. There is also an increase in the quantity of rain as well as its frequency and duration with increasing altitude, combined with increased cloud cover, higher humidity, mist and reduced sunshine hours.

Average annual rainfall in England and Wales is ca. 800 mm and in Scotland 1 100 mm. On average rainfall is well distributed throughout the year, though autumn and winter months show higher mean values than spring and summer. Western areas, particularly on higher ground, receive more rainfall than low-lying eastern areas. Over much of eastern England annual rainfall is below 650 mm, while in central and northern Britain, and Northern Ireland, it is typically in the range 700–1 500 mm on land below 400 m elevation, rising to over 2 500 mm on the highest ground. Winter snowfall is common in Scotland and on high ground elsewhere; it is also more frequent in eastern England when weather conditions are influenced by easterly and northerly airstreams. Soil moisture, which is affected by the amount and distribution of rainfall as well as by temperature and soil conditions (texture and depth) is an important factor affecting agriculture, particularly forage production in summer. Average temperatures in July are 16 °C and 4 °C in January, though western coastal area of England and Wales maintain winter mean temperatures closer to 7 °C, and hotter summer temperatures are more usual in southern and south-eastern England. Sunshine hours per day also vary markedly between southern England (mean of 6–8 hours per day in July) to the northerly and high ground in Scotland (3–5 hours). Most parts of the UK receive only 1–2 hours per day of sunshine in January (see Table 2). This partly reflects the latitudinal effects of day length, which ranges from around 16 hours in mid-summer to less than 8 hours in winter.

Although it is relatively free from the most extreme weather events, a feature of the UK climate is its year-to-year variability about mean values for temperature, rainfall and sunshine. Winter gales and snowfall, heavy rain at any time of year, and heat waves and periods of drought in summer, are events that are all within the climatic variability and that can present problems or uncertainties for agricultural utilization.

Table 2 presents monthly mean data for rainfall, temperatures, frost days and sunshine for seven locations in the UK. These emphasise the differences in good grass-growing conditions between the western areas of the country and the drier summer/colder winter conditions as exemplified by the Cambridge data, and the effects of altitude as exemplified by the Braemar and Malham Tarn data. Further information of the UK climate, including summaries of climate for England, Wales, Scotland and Northern Ireland can be found on http://www.metoffice.gov.uk/climate/uk/

Climate zones

The UK does not readily fit a zonal classification of climate types. This is largely because the effects of maritime influences from west to east, with the north-south latitudinal range, and with changes in land height relative to sea level, all tend to be gradual rather than abrupt. In winter the west-east effect is greater, and it influences both rainfall and temperatures. In summer the latitudinal effects are greater, with a north-south temperature gradient. At its simplest we can recognize a climate zoning based on four

Table 2. Monthly long-term mean weather data for different areas of the UK

Yeovilton, 20 m above sea-level (SW England: 51 00 N, 2 38 W)					
Month	Max Temp	Min Temp	Days of air frost	Sunshine	Rainfall
	°C	°C	days	hours	mm
Jan	8.1	1.4	11.1	50.2	72.0
Feb	8.3	1.3	10.3	68.9	55.6
Mar	10.6	2.7	7.5	107.6	56.6
Apr	12.9	3.7	5.0	155.4	47.3
May	16.5	6.8	0.7	193.1	48.9
Jun	19.3	9.7	0.0	186.0	57.2
Jul	21.7	11.9	0.0	205.8	48.9
Aug	21.5	11.7	0.0	197.8	56.6
Sep	18.6	9.6	0.0	139.8	64.5
Oct	14.8	6.9	2.0	101.1	67.9
Nov	11.1	3.6	7.0	70.2	65.8
Dec	9.0	2.4	9.2	46.8	83.3
Year	14.4	6.0	52.8	1 522.7	724.5

Cambridge, 26 m above sea-level (Eastern England: 52 13 N, 0 8 E)					
Month	Max Temp	Min Temp	Days of air frost	Sunshine	Rainfall
	°C	°C	days	hours	mm
Jan	7.0	1.3	9.7	55.5	45.0
Feb	7.4	1.1	9.5	72.6	32.7
Mar	10.2	2.9	4.9	107.0	41.5
Apr	12.6	4.0	3.2	145.8	43.1
May	16.5	6.7	0.5	189.7	44.5
Jun	19.4	9.8	0.0	180.0	53.8
Jul	22.2	12.0	0.0	191.3	38.2
Aug	22.3	11.9	0.0	186.9	48.8
Sep	18.9	10.1	0.0	141.6	51.0
Oct	14.6	7.1	1.2	115.0	53.8
Nov	9.9	3.7	4.8	68.1	51.1
Dec	7.8	2.3	8.0	47.7	50.0
Year	14.1	6.1	41.9	1 501.2	553.5

Malham Tarn, 381 m above sea-level: 54 5 N, 2 10 W)					
Month	Max Temp	Min Temp	Days of air frost	Sunshine	Rainfall
	°C	°C	days	hours	mm
Jan	4.1	-0.6	17.7	36.3	165.0
Feb	4.1	-0.6	15.7	52.8	115.5
Mar	6.3	0.5	13.2	79.1	134.2
Apr	8.9	2.0	7.2	117.0	90.7
May	12.6	4.7	1.5	164.3	84.8
Jun	14.9	7.5	0.1	141.0	96.8
Jul	17.1	9.7	0.0	144.8	94.9
Aug	16.6	9.6	0.0	146.3	122.8
Sep	14.0	7.7	0.1	106.2	129.8
Oct	10.6	4.9	1.8	78.7	152.3
Nov	6.9	1.9	8.4	49.5	156.3
Dec	5.0	0.3	13.5	32.9	175.3
Year	10.1	4.0	79.1	1 148.8	1 518.4

Aberporth, 133 m above sea-level (West Wales: 52 5 N, 4 30 W)					
Month	Max Temp	Min Temp	Days of air frost	Sunshine	Rainfall
	°C	°C	days	hours	mm
Jan	7.3	2.9	5.6	54.6	88.5
Feb	7.3	2.6	5.6	74.0	62.7
Mar	8.7	3.8	2.1	109.7	63.7
Apr	10.6	4.9	0.6	168.6	50.7
May	13.7	7.5	0.0	213.6	48.2
Jun	15.9	10.0	0.0	190.5	61.1
Jul	18.0	12.2	0.0	198.7	49.5
Aug	18.1	12.3	0.0	184.8	68.2
Sep	16.1	10.7	0.0	141.0	75.7
Oct	13.2	8.4	0.0	100.1	104.2
Nov	10.0	5.6	1.0	63.3	98.3
Dec	8.3	3.9	3.4	45.6	99.2
Year	12.3	7.1	18.3	1 544.5	870.2

Auchincruive, 48 m above sea-level (SW Scotland: 55 30 N, 4 40 W)					
Month	Max Temp	Min Temp	Days of air frost	Sunshine	Rainfall
	°C	°C	days	hours	mm
Jan	6.7	1.6	8.9	44.3	97.3
Feb	7.0	1.7	7.5	66.1	71.1
Mar	8.6	2.8	5.1	91.5	80.4
Apr	11.0	3.9	2.9	143.7	51.7
May	14.6	6.2	0.8	198.4	51.0
Jun	16.6	9.0	0.0	178.5	56.7
Jul	18.3	11.2	0.0	167.4	70.0
Aug	18.1	11.0	0.0	152.8	83.0
Sep	15.7	9.1	0.1	118.2	101.5
Oct	12.7	6.7	1.7	86.2	112.9
Nov	9.3	3.7	5.3	57.3	105.4
Dec	7.5	2.3	7.8	37.8	103.5
Year	12.2	5.8	40.1	1 342.2	984.4

Armagh, 62 m above sea-level (Northern Ireland: 54 20 N, 6 40 W)					
Month	Max Temp	Min Temp	Days of air frost	Sunshine	Rainfall
	°C	°C	days	hours	mm
Jan	7.0	1.7	9.3	44.0	79.8
Feb	7.6	1.7	8.3	61.9	57.5
Mar	9.7	2.9	5.1	89.3	64.9
Apr	12.2	4.0	3.3	133.2	55.4
May	15.2	6.3	0.5	165.2	54.4
Jun	17.7	9.1	0.0	141.6	55.7
Jul	19.6	11.4	0.0	134.9	52.3
Aug	19.2	11.0	0.0	133.0	71.9
Sep	16.6	9.0	0.0	110.7	67.1
Oct	13.0	6.7	0.9	86.5	81.1
Nov	9.5	3.5	5.4	57.0	72.1
Dec	7.6	2.4	7.5	34.4	83.4
Year	12.9	5.8	40.4	1 191.6	795.4

Braemar, 339 m above sea-level (Scotland: 57 02 N, 3 20 W)											
Month	Max Temp	Min Temp	Days of air frost	Sunshine	Rainfall	Month	Max Temp	Min Temp	Days of air frost	Sunshine	Rainfall
	°C	°C	days	hours	mm		°C	°C	days	hours	mm
Jan	3.8	-2.3	19.1	24.8	106.6	Jul	17.5	8.4	0.0	159.3	54.2
Feb	3.9	-2.8	18.7	56.5	63.2	Aug	17.0	8.1	0.4	146.9	70.6
Mar	6.0	-0.8	16.9	94.9	71.7	Sep	14.0	6.3	1.5	103.5	80.8
Apr	9.2	0.6	11.7	139.8	48.3	Oct	10.8	3.8	5.0	67.9	92.8
May	12.8	3.4	4.5	162.1	66.2	Nov	6.3	0.1	12.8	36.0	86.4
Jun	16.2	6.5	0.5	168.9	58.1	Dec	4.6	-1.1	15.8	18.6	89.1
						Year	10.2	2.6	106.9	1 179.3	887.9

(source: http://www.metoffice.gov.uk/climate/uk/)

quarters. (1): The north-west, including the Western Isles of Scotland, Northern Ireland and Cumbria, typically has relatively mild winters for this latitude (mean temperature 4-6 °C) and cool summers (mean 13–15 °C) (see data for Armagh and Auchincruive in Table 2); (2): the south-west quarter, comprising Wales and south-west England, has mild winters (mean 5–7 °C) and warmer summers (mean 15–16 °C) (see Table 2 data for Aberporth and Yeovilton sites). Because of the maritime influence these two zones receive more rainfall than the eastern zones, which are rain shadow zones in the lee of the high ground of Wales, the Pennines and the Scottish mountains. (3): the north-east zone, which includes eastern Scotland and north-east England, has cold winters (mean 3–4 °C), and cool summers, see e.g. the Braemar data; and (4): central, eastern and south-east England have relatively cold winters and warm summers (influenced by proximity to continental Europe; see data for the Cambridge site, Table 2).

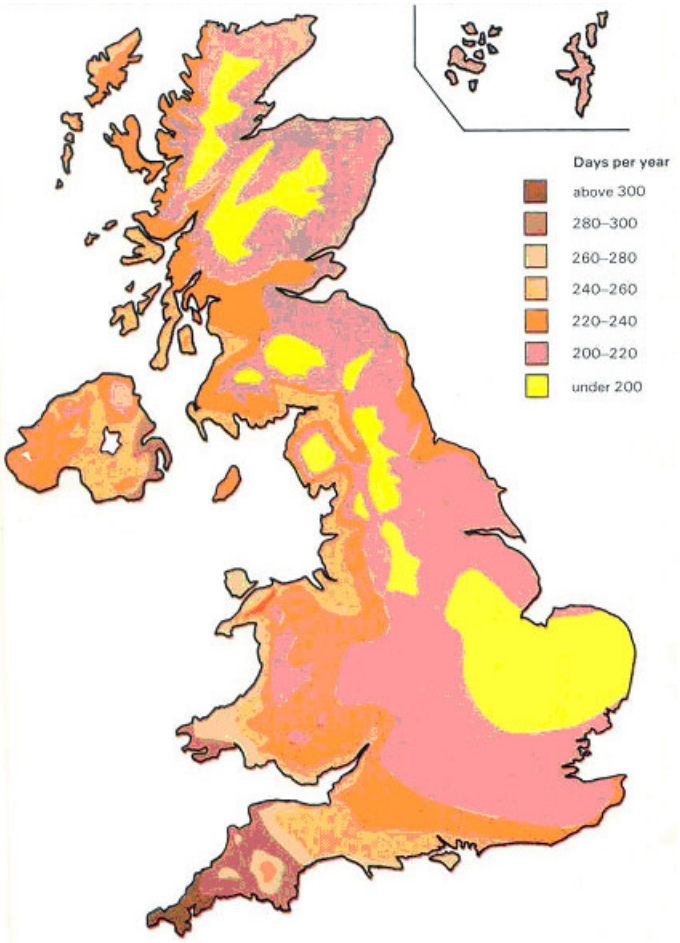


Figure 4. Number of grass growing days in UK; soil temperature adjusted for drought factor and altitude
Source: Down et al. *(1981)*

Agro-ecological zones

Using the USDA concept of Hardiness Zones (see USDA (2003) and [www.usna.usda.gov/Hardzone/hrdzon3.html]), almost all of the UK falls into zones 7–9 (with a few western coastal locations in zone 10). Most of England and Wales, and lowland Scotland apart from western coastal areas, lies within zone 8; while the south-west peninsula, south coast and western coastal areas of Britain, and most of Northern Ireland are in Zone 7. Because of the effects of the maritime influences and the Gulf Stream the UK climate is milder than its latitudinal equivalents elsewhere. However, as far as climate influence on forage growth are concerned the effects of soil moisture deficits in summer, and autumn-spring temperatures, combine to cause considerable regional variation in the potential for grass growth.

A classification (for England and Wales only) into 50 agro-climatic zones was published in 1976 (MAFF, 1976). This classification used information of soil temperature and soil moisture deficit in summer, and on temperatures, to calculate grass-growing days and other small-scale indices affecting agriculture. The basis of this classification of agro-climatic zones has recently been re-examined (White and Perry, 2006).

Based partly on the 1976 MAFF Bulletin and other sources, grass-growing days were mapped for the whole UK (see Figure 4) , Lazenby, 1981) into seven zones, and range from <200 days/year in the dry lowlands of eastern England and on high (>600 m) ground in northern Britain, to over 300 days in south-west England.

4. RUMINANT LIVESTOCK PRODUCTION SYSTEMS

The distribution of ruminant livestock production closely follows that of grassland and forage (see section 5). Dairy farming occurs predominantly in lowland western areas that have soil and climate

conditions suitable for sustaining high yields of quality forage production. Beef cattle are more widespread in their distribution, including farms on areas with relatively marginal conditions for forage production engaged in calf rearing by suckler cows, producing weaned calves for sale as store cattle for fattening on lowland farms. Sheep are also widely distributed, being most evident in hill and moorland areas where they are often the only, or the main, farm enterprise, but elsewhere are often integrated with other ruminant enterprises. Sheep and cattle are predominantly kept out of doors for all or most of the year, or housed in the winter months when grazed forage is unavailable or weather conditions create animal welfare problems or might lead to soil damage under grazing (poaching). The UK pig industry is based mainly on indoor production, with specialist pig farms being concentrated in the main arable farming areas, but there are also systems based on outdoor fattening. For details of UK livestock numbers see Table 3.

Table 3. UK livestock numbers (in thousands)

	England	Wales	Scotland	Northern Ireland	All UK
Dairy cows	1 316	265	199	291	2071*
Beef cows	752	221	498	297	1 768
Ewes and shearlings	7 289	4 732	3 887	1 027	16 935
All sheep and lambs	15 877	9 510	7 883	2 145	35 415**

Based on June 2005 Agricultural Census data.
*[Note:FAOSTAT accessed in May 2008 has the following figures, which are close to those in Table 3: *Dairy cows 2005 – 2152; 2006 - 2152 **Sheep 2005 – 35253; 2006 – 34722]*

Dairy farming

The UK is the ninth largest milk producer in the world and its current production of around 14 m tonnes per annum is similar to that of New Zealand. The size and productivity of the dairy sector, and the distribution of UK dairy farms, have evolved in relation to a number of historic, economic and environmental factors. These include market demand from a large, predominantly urban population for fresh milk and milk products; the suitability of large areas of lowland farmland for low-cost grass production over a long growing season; the availability of inputs such as cattle feed by-products and fertilizers (such as brewers grains, cotton seed cake, phosphorus-rich slag from iron making) all associated with other industrial and food processing industries; the development in the nineteenth century of a railway network that enabled produce from livestock farming areas to be brought rapidly from the countryside to the cities; and, in the recent past, a number of institutional and marketing arrangements that were relatively advantageous to dairy producers. Between the nineteen-thirties and the early nineteen-nineties the milk price to producers was guaranteed by marketing boards that regulated the price to give all farmers a common price, a system that enabled small producers to remain competitive. Since the mid-nineteen-nineties the dairy sector in the UK has undergone a transformation with the number of dairy farms falling by about 45% to fewer than 20 000.

Over the same period the number of dairy cows has also fallen by about 20% to stand at about 2 million (Tables 3 and 4), a trend that began in the early 1980s when the national herd was about 3 000 000 and there was over-production in the EU. These two trends have, however, been accompanied by an increase in the average milk yield per cow, from ca. 5 000 L/cow in the late 980s to about 6 800 L/cow at present. Thus, despite these major structural changes, the total UK milk output has remained relatively stable. Dairy cow herd sizes are typically in the range of 80–120, with a significant number of herds of over 500 cows.

Plate 1. Dairy farming on permanent pasture, Somerset, south-west England

Dairy farming is still widely distributed in the UK but remains concentrated in the areas where it has had traditional advantages associated with good grass-growing conditions: the south west of England (see Plate 1), the lowland areas of south and south-west Wales, the north Midlands and north-west of England (centred on the

counties of Staffordshire, Cheshire, Lancashire and the lowland areas of Cumbria) and the lowland areas of Northern Ireland and of south-west Scotland. Upland dairy farms are now very few. The decline in dairy farms in recent years has not been evenly distributed, with the largest reductions having occurred in areas of eastern and south-east England.

Table 4. Recent changes in UK dairy farm and cow numbers

	2005	2004	1995
Changes in UK dairy farm numbers			
England & Wales	14 732	15 846	28 093
Scotland	1 523	1 569	2 239
N. Ireland	4 058	4 201	5 409
All UK	20 313	21 616	35 741
Changes in UK dairy cow numbers (in thousands)			
England & Wales	1 581	1 643	2 103
Scotland	199	197	226
N. Ireland	291	288	271
All UK	2 071	2 128	2 600

Source: MDC (2004)

Apart from a few, mainly small-scale, specialist producers of dairy goat or dairy sheep products, UK dairying is based almost entirely on cattle. The predominant breeds are 'black and white': Holstein or Friesian, or crosses of these. The development of the high genetic merit cow capable of milk yields of over 7 000 litres in a 305-day annual lactation has been focused on these breeds. Nevertheless, advocates of other more traditional dairy breeds remain, and there are over 100 000 Channel Island cattle (mainly cows and heifers of the Jersey breed) and over 60 000 Ayrshire cattle. These breeds are noted for their high butterfat content and suitability for producing high-value dairy products. Many farms have also developed high-yielding pedigree herds of these breeds.

Grass and forage crops form the basis of the diet of dairy cows and replacement heifers and associated livestock, and the spring-summer months of March - July is the peak period for milk yield. For individual producers their herd output is limited by EU milk quota. However, the increased use of high-yielding cows has necessitated a greater contribution of concentrate feed in the diet and the adoption of rations tailored to the cows' needs and outputs. This can be justified when the value of additional milk exceeds the additional feeding costs. However, on most dairy farms at least 50% of cows' metabolizable energy requirements will be met from grazed grass or, in winter, from silage. The usual practice is for dairy cows to be winter-housed for a period of 3–5 months, depending on local soil and climate. Most cows are kept outdoors at pasture from spring to autumn, possibly with part of their diet supplied as silage or cut forage during any periods of grazing forage deficiency. The widespread adoption of grass silage making from the early nineteen-seventies greatly transformed the winter feeding of dairy cows, though quality issues limited the potential from being fully realised. There have been progressive improvements in silage making on many farms (e.g. through better wilting, use of additives, and general attention to detail, and more widespread adoption of silage stored as wrapped bales) and in recent years there has also been an expansion in the use of silages made from immature grain crops (whole-crop) and from maize. On most dairy farms the period for making the main (first-cut) of grass silage (typically in mid-May) is a particularly important part of the grassland management, with large financial and nutritional implications for winter feeding.

There is an improved understanding of grazing management on the better-managed and more productive farms. A number of dairy farms are starting to realise the potential benefits of using legume-based swards, either in grazing or more commonly for silage (e.g. red clover silage). However, grassland for dairy farming is still predominantly based on using sown grass leys (usually of perennial ryegrass *Lolium perenne* sown at about 25 kg seed per ha). Leys are typically cultivated and reseeded at intervals of about six years (sometimes less) and supplied with nitrogen-based fertilisers and farm manures (usually slurry, from winter-housed livestock). Typical amounts applied on grazed dairy swards would be the equivalent 1–2 kg N per ha per day during periods of active growth, and on fields used primarily for silage the amounts would be closer to 2 kg/day, i.e. over 300 kg N/year. These amounts are greater than is usual on most beef and sheep farms.

The market for fresh liquid milk in the UK is high, because of both a high per capita consumption and a high population, so that liquid milk sales account for >45% of total milk production. There has been a small decline in per capita milk consumption during the past decade but this has been partly offset by growth in consumption of yoghurts and low-fat desserts. The UK is self-sufficient in fresh milk but is a net importer (by about one-third) of both butter and cheese. Over 25% of UK milk is used for cheese making, mainly as hard Cheddar-type cheeses of varying grades and prices, processed in large plants. In recent years there has been increased domestic demand for quality and speciality cheeses,

and while much of this is supplied through imports, it has also given rise to the growth of small-scale cheese-making operations (often as on-farm or farmer-controlled small businesses). Another trend in recent years has been the expansion of sales of fresh milk and milk products produced organically, as the capacity for processing and distribution has increased and allowed the market to expand.

Beef production

The UK achieves about 80% net self-sufficiency in beef. Production of beef is more widely distributed than dairying and is practised on a wider range of pasture types, and a range of structures operate in the beef production chain. There are about 1.8 million beef cows in the UK but the total beef herd includes not only their own calves but many from the dairy herd also. There are beef cattle farms in the upland and marginal areas (mountains, moorlands, lowland dry heaths, coastal marshes etc.). Many such farms specialise in rearing suckler calves which are sold on as store cattle of varying ages to be fattened to an optimum slaughter weight on better quality grasslands, with supplementary grain or concentrate feeds when necessary. On productive lowland grasslands beef farming may be operated as a fully integrated enterprise from calf rearing to final slaughter weight, in some cases managed at similar levels of inputs and intensity as dairy farms. In between these two systems are a number of arrangements, including the rearing of surplus young cattle purchased from dairy farms, or store feeding of purchased young cattle which are sold on to specialist fattening farms. In all cases there is a need to take beef cattle to slaughter weight within 30 months of age (regulations introduced in the nineteen-nineties required all beef entering the food chain to be from cattle of less than 30 months).

In recent years beef production has been relatively unprofitable and many beef farmers have derived their main income from support payments rather than from livestock sales. In general, beef production is a low-cost system, often based on grazing permanent pasture (a term which includes deteriorated sown grassland as well as pastures of uncultivated grass species) with limited winter housing. In parts of the UK with a milder climate it is not uncommon for beef cattle to remain outdoors for all or most of the year (see Plate 2), and fed hay or silage when the opportunities for winter grazing are limited. Use of artificial fertilizers is generally below the biological optimum, and there is considerable potential for a greater adoption of grass-clover swards in such situations.

The principal breeds of beef cattle in the UK are Holstein/Friesian (including a large number of male calves originating from dairy farms) and European beef breeds (principally Limousin, followed in popularity by Charolais, Simmental and Belgian Blue). The presence of a very large number of cross-bred beef cattle prevents precise comments on breed numbers. However, of the traditional UK breeds the Aberdeen Angus is the most numerous, being adapted to a range of environments. There has been a marked decline in the use of Hereford cattle. Changes in breed partly reflect meat characteristics and consumer preference for lean cuts of meat, and the influence of supermarket buyers. A number of traditional breeds do, however, have desired traits, often linked to their production system or locality, and there is some resurgence in popularity with specialist producers and outlets such as farm markets. Hardy and regionally distinctive breeds such as Highland, Galloway, Welsh Black and North Devon are frequently kept on marginal grazing lands.

Plate 2. Beef cattle outwintered on improved permanent grassland, Cornwall south west England

Sheep production

Sheep production in the UK is associated mainly with relatively marginal land, especially in the uplands, or as an enterprise that can be combined at minimal cost with either beef or dairy production on fertile lowland grasslands. The UK sheep flock stands at about 16 million ewes and the total sheep and lamb population in summer reaches about 35 million animals. The highest densities of sheep are to be found

in Wales. The principal aim of most UK sheep producers is to raise two lambs per ewe, which can be reared either to slaughter weight, or sold as store lambs for fattening on lowland pastures, or retained (or sold) as ewe replacements. The UK achieves near to net self-sufficiency in sheep meat. Wool sheared from ewes annually is a by-product of sheep production, but the labour costs of shearing can account for much of the value of the wool. Historically, sheep rearing for wool was more important than for meat, and in the Middle Ages some areas of England (especially East Anglia and the Cotswolds) grew immensely wealthy on the proceeds of wool sales.

Plate 3. Sheep production on moorland rough grazing, with areas of enclosed permanent grassland around the farmstead

Sheep production is generally a lost-cost system, based on permanent pastures and young sown-grass leys rotated within an all-grass farm. In hill and upland areas hardy breeds of sheep such as the Welsh Mountain, Herdwick and Scottish Blackface are the only livestock (and sometimes the only possible agricultural enterprise) that can be kept. For example, in the hill and mountain areas of Wales, Scotland and northern England, the valley-floor fields are used to support ewes with young lambs in spring, before these fields are closed to grow grass for hay or silage and the ewes and lambs are either sold or moved on to higher ground and rough grazings (see Plate 3). Upland sheep production also has an important environmental function in maintaining the green upland landscapes of areas that would otherwise remain ungrazed.

The time of lambing is influenced by the breed and the farming environment, but early spring lambing is often preferred as earlier finished lambs can command higher prices. In upland areas the weather conditions and later spring grass growth mean that late-spring lambing is the usual option. In milder areas autumn-lambing (based on the Dorset Horn breed) is practised in order to raise finished lambs for the lucrative Easter market. Thus, 'spring' lambs can be seen outdoors in winter, but this a high-cost system requiring a high level of supplementary feeding at a time of limited grazing.

Horses and deer

The annual agricultural surveys (census) of farms in the UK do not record horse numbers but the national horse population is known to have increased greatly in recent years and is likely to be in the range 0.7 to 1.0 million. Horses are kept mainly for sporting and leisure purposes and the horse industry makes a valuable contribution to the rural economy. There is often great competition for the purchase or rent of pastures close to urban areas for the purpose of horse keeping, with many horse paddocks poorly maintained at excessive stocking densities. Horse keepers provide a ready market for hay that might otherwise be fed to cattle or sheep, and a business opportunity for grassland producers to provide baled hay or haylage of a specification that meets the more exacting requirements of the horse. There are several areas in the UK where horses are traditionally kept on open land or common land in an apparently untamed state (though they are not wild, but owned by local people and farms). These include the New Forest in southern England (which supports the native New Forest breed) and Dartmoor in south-west England. At particular times of year they are rounded up by their owners and either retained or sold, usually as riding ponies.

The UK deer population has also greatly increased in recent years. Several hundred of farms have specialised deer farming businesses (mainly red deer) to supply venison and other deer products, and deer have long been kept in large enclosed areas on country estates. The vast majority of deer in the UK are, however, wild animals, of which red deer (*Cervus elephas*) and roe deer (*Capreolus capreolus*) are native species. Population estimates seem difficult: up to 600 000 roe deer in the UK, over 300 000 red deer in Scotland plus many more in other parts of the UK, as well as fallow and other introduced species that have established large feral populations. Deer have few natural predators and they can compete with

domestic livestock for forage resources on farms and have a severe impact of woodland regeneration. They can also act as a reservoir for a number of diseases of farm livestock, including foot-and-mouth disease, TB and blue tongue (see next section).

Veterinary and animal health problems

The UK's island position has enabled it to maintain quarantine regulations and minimise the impact of many livestock diseases. There is also a high level of surveillance and monitoring of animal health problems through a state veterinary service and in recent years through an independent Food Standards Agency. Almost all the fresh milk and milk products produced in the UK are from pasteurised milk. Meat sold can be traced back to the producer. Individual cattle have a 'passport' so that movements between farms can be traced at any stage, allowing any disease outbreaks, and possible animal contacts to be investigated. Oral dosing of anthelmintics for gastro-intestinal parasites, and external treatment against fly strike, are routine, but as disease-free status is important for producers of breeding stock there has been a policy of not allowing vaccination against Foot and Mouth Disease (FMD). Outbreaks of FMD are infrequent, and have been controlled by slaughtering of all herds and flocks showing symptoms or that may have had contact with affected animals. A serious epidemic in 2001, the origin of which was never proven, was the first for 35 years, and led to the on-farm slaughter and disposal of over 6 million livestock.

Scrapie in sheep has been recognized in Britain since the 18th century but its causative agent, as a Transmissible Spongiform Encephalopathy, has been known only in recent years. The UK has had a National Scrapie Plan in place since 2001 with the aim of eradicating it, partly through increasing the proportion of sheep that are immune to the disease. In recent years reported cases of scrapie have averaged around 200–300 per year.

Bovine Spongiform Encephalopathy (BSE) became a serious problem in the late nineteen-eighties and nineteen-nineties. Its emergence in cattle was thought to have been linked to scrapie in sheep, and infection via contaminated feed, and BSE has serious implications for human health if meat from affected cattle enters the food chain. Measures were put into place from 1992 to eradicate BSE from herds and to prevent affected animals, and all spinal cord tissues, from entering the human food chain. Numbers of affected animals have been reducing progressively and there are now comparatively few new cases.

Bovine tuberculosis is a problem affecting cattle farms in parts of the UK. Incidence is highest in the south-western counties of England from where it appears to have spread to other regions. Affected animals are slaughtered and producers face problems due to restrictions on animal movements from their farms.

Blue Tongue was first recognised in the UK in 2007 when there were several incidents in livestock in eastern England. This disease, which is spread by biting insects, has been widespread in mainland Europe for some years.

5. THE PASTURE RESOURCE

Grassland is the main category of agricultural land use in the UK. Table 5 indicates that of the total agricultural area 6.4% consists of recently sown grassland (<5 years old), and 32.3% consists of either older (>5 years) sown grassland or permanent grass swards. The area of land in crops is about 31% of the total. The remaining 30.3% consists of rough grazings and common grazings (much of this in upland or other marginal areas). (see Figure 5)

Table 5. Areas of grassland and other agricultural land use in UK (as '000 ha)

	England	Wales	Scotland	N. Ireland	All UK
Crops and tillage	3 840	66	1 566	187	5 659
Grass <5 years old	590	115	325	136	1 166
Grass >5 years old	3 330	982	910	676	5 898
Rough grazing in sole rights	640	221	3 340	149	4 350
Common rough grazing	395	180	598	29	1 202
Total agricultural land†	8 795	1 564	6 739	1 177	18 275

† excludes woodland on farms and set-aside land
[Based on 2006 data]

Until the early twentieth century, virtually all grassland,

with the exception of short-term forages such as red clover, was permanent, having developed from natural vegetation under human influence. However, the emergence of improved grass and legume varieties and the recognition that grass could be managed as a crop led to the development of sown grasslands, sometimes in rotational systems with other crops, often referred to as ley farming. In the second half of the twentieth century, advances in agricultural machinery and other scientific and technological improvements in silage making, plant and animal breeding, fertilizers and herbicides greatly affected grassland botanical composition and productivity (Frame *et al.*, 1995; Hopkins and Wilkins, 2006). Political and other socio-economic influences, such as the Common Agricultural Policy in the European Community, have also contributed to the application into farm practice of new technologies, changes in the balance of crops, permanent grassland and sown grassland, and to the need to address the wider environmental implications of these changes.

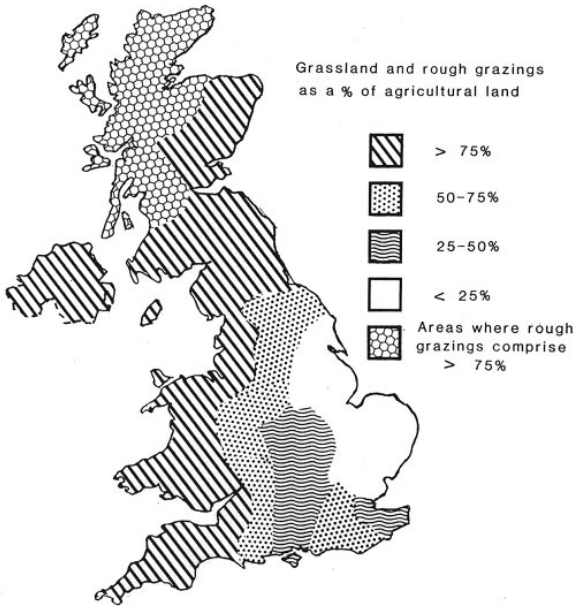


Figure 5. Grassland and rough grazing land distribution in the UK
(Based on general information and verified by various national agricultural census information)

Temporary and recently sown grassland

The predominant sown species is perennial ryegrass (*Lolium perenne*), with at least 80% of the grass seed sold being of this one species. Italian ryegrass (*Lolium multiflorum*) was for many years widely used as the major component of short-term leys, and while there is still substantial use of this species, its importance has declined with the decreased use of such leys and increased availability of more persistent hybrids between Italian and perennial ryegrass. Small quantities of cocksfoot (*Dactylis glomerata*), timothy (*Phleum pratense*) and fescues (*Festuca* spp.) are sown in situations where their attributes (e.g. tolerance of cold or drought) are required. The main sown legume is white clover (*Trifolium repens*), mainly for low-input grazing situations (see Plate 4), and red clover (*Trifolium pratense*) and lucerne (*Medicago sativa*) occupy small areas. There has been a recent increase in interest in these species as special forages for silage (see Plate 5) in both organic and non-organic systems (Wilkins and Paul, 2002).

Plate 4. Productive white clover-based sward managed without nitrogen fertilizers

There has also been a recent increase in use of grass in rotations, due to the popularity of grass-maize rotations and the expansion of organic farming. With organic farming, the short-term ley is particularly important as a fertility-building phase in arable rotations, repeating the significance of such leys in production systems that were followed prior to the widespread use of mineral fertilizers. The

Table 6. Annual dry matter production harvested from first-year sown perennial ryegrass at a range of lowland grassland sites in the UK, under moderate and high inputs of nitrogen fertilizers

	Site location							
(kgN/ha)	North Yorks.	South Yorks	S.W. Wales	N.W. Wales	Gloucester	Hampshire	Devon	Berkshire
125	13.7	9.9	14.0	7.9	7.4	9.1	11.2	11.9
250	17.3	12.5	18.2	12.8	11.0	12.7	13.8	13.5

(Ref: Hopkins et al.*, 1995)*

reasons for renewing grassland, other than as part of a grass/arable rotation are varied, but predominantly relate to a farmer's perception that herbage production and/or the quality of the sward has declined. Herbage varieties are subject to trial evaluation for National List status (NIAB, 2007, and previous years).

In the absence of legumes, newly sown grassland swards tend to be fertilized at levels close to their economic potential. Depending on site environment this can be up to 300 kg N/ha, mainly from artificial fertilizer nitrogen (urea or ammonium nitrate), with supporting potassium and phosphorus (depending on soil nutrient status and supplies of nutrients from any added farm manures or slurry). Production will vary according to soil nutrient status, inputs and management, as well as weather and soil water supplies. Table 6 summarizes herbage dry matter production from a field trial on eight lowland (<260 m above sea level) sites, sown with *Lolium perenne* and harvested as 4 cuts per year at a silage-stage of growth. These sites were mainly good grass-growing sites, but grass production is much lower where summer drought and soil texture combine to limit soil available water capacity, and also on upland sites having poorer soils and a short growing season.

Plate 5. Intensively managed sown ryegrass-dominated grassland managed for high-yielding silage crops and dairy grazing, Cheshire, north-west England

Plate 6. Permanent grassland in central Wales. Grassland dominates the landscape here and its agricultural productivity has been greatly improved through management, fertilizers and past reseeding.

Establishment of grassland swards generally follows conventional cultivation practices and seed drilling. The favoured period for grassland reseeding is in late summer or early autumn. Herbicides such as glyphosate may be used to kill the old sward before ploughing, with additional cultivations, especially on heavy clay soils, required to produce a finer tilth which is then rolled to consolidate the seedbed.

Permanent grassland

Perennial ryegrass is also a major component of permanent swards provided that they have received fertilizer inputs and are well managed. In practice, the distinction between sown and permanent grassland is often blurred, as older sown swards often revert to a botanical composition similar to agriculturally improved permanent swards. Permanent swards are generally grass-based (see Plate 6) and may have high contents of unsown species such as *Agrostis* spp, *Holcus lanatus*, *Poa trivialis,* as well as *Lolium perennne* and *Dactylis glomerata*. The better managed permanent swards often contain white clover, but with increased use in N fertilizer rate, the content of legumes in grassland has fallen; there is still much

grassland in which herbage production is limited because of a combination of low legume content and low input of N and other plant nutrients. Although older swards can be of lower productivity or herbage quality than recently sown swards, they also tend to receive lower inputs of fertilizers. Studies carried out in the UK have not provided a clear case for reseeding in many situations (Hopkins *et al.*, 1990). However, there has been recent progress in improving both yield and quality of grass and clover varieties (Humphreys, 2005) and reseeding provides opportunities for introducing these new varieties.

For classification purposes the term permanent grass may include all swards that are at least 5 years old, though a more strict ecological interpretation would limit the term to grassland of at least 10, or even 20, years old. The situations in which permanent grassland is important are mainly those where other agricultural land-use options are limited by physical conditions. These might include conditions that affect cultivation such as access, topography, soil (hydrology, depth, texture and stoniness), and climate. In the UK at least 50% of the grassland is over 20 years old and there is seldom any cultivation of land that receives more than 1 000 mm rainfall, and relatively little in the 800–1 000 mm zone.

Grazing is usually the most cost-effective method of utilisation of permanent grassland. As for sown grassland, the length of the growing season, and the period when there is adequate feed for grazing livestock is limited, typically to between 5 and 9 months each year. Utilisation of grazed permanent grassland is therefore usually integrated with that of forage (conserved as silage or hay) harvested from permanent meadows or sown grassland during periods of maximum production. Many older permanent swards have a relatively dense sward structure that enables them to withstand the trampling action of livestock during wet periods, when sown grassland would suffer sward damage from poaching. It is common practice for sheep, and sometimes cattle, to be kept outdoors during all or most of the year in some areas, including parts of the British Isles.

Forage conservation

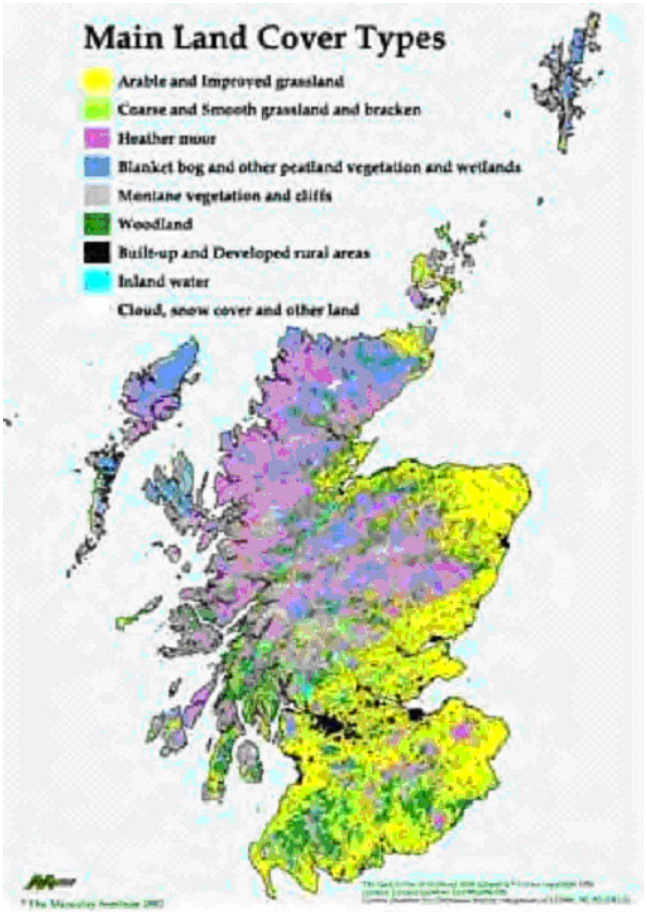
In the UK there is a need to conserve sufficient forage to supply livestock through the winter months when grazing opportunities are limited, and soil and weather conditions require livestock to be taken off the land. Traditionally this was as hay, usually of low feed value and subject to being damaged by summer rain. Winter feeding based on hay necessitates high levels of feed supplements especially for milking cows. Although silage making was practised on some farms from the late nineteenth century, hay making remained widespread for most of the twentieth century and silage only became widely adopted from the nineteen-seventies. The use of technologies based on wrapped bales has since greatly extended the opportunities for silage making to situations where hay would previously have been the usual form of forage conservation, including many small farms and grassland in marginal environments. Hay continues to be made for providing high dry matter feed to particular classes of stock, e.g. horses and young stock. It is also encouraged (through agri-environmental management agreements) as the preferred method to manage grasslands of high ecological value where the flora has evolved under a hay cutting regime and the combination of late cutting and turning of the mown swath are essential for natural reseeding of many flowering plants.

Rough grazing and common land

Rough grazing is the pasture resource that most closely corresponds to rangeland (the term rangeland is not widely used in the UK). For the purposes of definition rough grazing is classified as either in ‘sole rights/ sole ownership’ or as ‘common grazing’ but the situation is complex and both categories cover a range of vegetation types and types of utilisation.

In general terms rough grazing lands usually consist of grasses and related vegetation (e.g. dwarf shrub) that is agriculturally unimproved (or has undergone only minimal intervention) and that is of relatively low value in terms of the livestock numbers per hectare that can be supported. However, in terms of their area, rough grazings make an important contribution to the UK’s forage resources. Their strategic national agricultural importance lies in the fact that they provide grazing resources on land that has no other potential agricultural value, and in that they supply large numbers of lambs and also young cattle for fattening on better pastures elsewhere. Their value at a local scale arises from their association with improved land and thus the viability of farming structures within regions of marginal land. For example, in many upland and marginal areas, a typical livestock farm may consist of perhaps

20–50 ha of agriculturally improved grassland usually on the floor or lower sides of a valley (sometimes called in-bye land) which may be used for rearing spring lambs followed by mowing of forage for hay or silage. The utilisation of such land depends on the availability of additional grazing land for the remainder of the year, and an area of perhaps 100–200 ha of rough grazing on the same farm provides this resource, thus enabling a viable farming system to be maintained. In the more remote parts of the UK there are also entire farm holdings that consist wholly or mainly of rough grazing land. In some cases these can be relatively small, and in effect are part-time holdings, but are still of importance to the rural economy and to local agriculture. One category of note is that of crofting, a traditional form of land utilisation on poorer agricultural land in parts of Scotland (see www.scotland.gov.uk/Topics/Rural/Crofting/17096/7492).



The above figure shows vegetation land cover for Scotland. For similar information for the whole of the UK go to the countryside survey website (www.countrysidesurvey.org.uk/ and follow the links to www.countrysidesurvey.org.uk/land_cover_map.html).

Figure 6. Main land cover types in Scotland

Rough grazing vegetation communities

The types of vegetation that commonly occur on rough grazing land and their agricultural value depend on soil type, rainfall and management. Several broad types can be recognised (see Plate 7 and Figure 6), based on a dominance of *Agrostis* spp. and *Festuca ovina* on the better soils, *Nardus stricta* and *Molinia caerulea* on poorer wet acid soils, blanket bog (*Sphagnum* moss, *Deschampsia flexuosa, Juncus* spp. and *Eriophorum vaginatum*) on the poorest wet peaty sites, and heather (*Calluna vulgaris*) moorland on freely drained peaty podzols.

***Agrostis-Festuca* grazing land**. This is the most valuable rough grazing type and occurs on the better drained brown earth soils and is responsive to improvement measures such as liming. Utilisable pasture production can be up to 4 tonnes dry matter per ha and the feed value is also relatively good over 6–7 months of the year. In summer months a grazing stocking rate of 6–9 ewes/ha is possible. White clover and dicotyledons (herbs) can add to the feed value, though on wetter areas patches of rushes and sedges are common and reduce the overall feed value. Management problems include the potentially poisonous and highly invasive bracken fern (*Pteridium aquilinum*) which is a major weed of the better drained soils in both upland rough grazings and on lowland heaths.

Plate 7. Rough grazing land with mosaics of vegetation of poor agricultural quality, Scottish Highlands

***Nardus stricta* grazing land**. This type of pasture is found on podsolic soils and poorly drained gley soils. It tends to be tussocky

grassland with species such as *Deschampsia flexuosa* and *Festuca ovina*. Feed value and production can be reasonably good, but poorer than *Agrostis-Festuca*, and intake levels can be low especially when the proportion of *Nardus* is high (as tends to occur if grazing is by sheep only). A grazing stocking rate of 3–5 ewes per ha in the summer months is possible.

***Molinia* (purple moor-grass) grassland**. This type predominates on peaty gley soils that are not well drained. *Molinia caerulea* is a tussocky grass that produces valuable forage in summer but sheds its leaves in autumn, and can produce 2–3 tonnes/ha of forage. Overgrazing can result in its reversion to Nardus grassland, so summer stocking rates would be less than 4 ewes/ha or the equivalent in cattle (1/2.5 ha).

Blanket bog. This diverse type of grazing community occurs on deep peat in areas of high rainfall, e.g. in large areas of Scotland and upland areas of north Wales and northern England. The ground layer tends to be dominated by Sphagnum mosses with a range of species including *Molinia caerulea, Deschampsia flexuosa, Juncus* spp. and *Eriophorum vaginatum*. Net herbage production is low (<2.5 tonnes dry matter/ha) and the grazing value is highly sensitive to overgrazing, particularly by cattle which carry an increased risk of causing erosion. Blanket bog can provide autumn and winter maintenance grazing at about 1 ewe/ha, or year-round grazing at a lower stocking rate.

***Calluna vulgaris* (heather) moorland.** The most freely drained peaty podsols provide the conditions for heather moorland but its maintenance (with *Calluna* dominance, accompanied by patches or clumps of other heath species, grasses and herbs) is dependent on management by rotational burning and avoidance of sustained heavy grazing (particularly with cattle). Net herbage production is typically 2–3 tonnes dry matter/ha, mostly in summer but grazing deferred to the autumn and winter. A typical year-round equivalent stocking rate for heather moorland is 1 ewe/ha.

Areas of rough grazing land also have other functions in the rural economy notably through their landscape values and the associated opportunities for tourism, as well as water catchments and game shooting. The red grouse, *Lagopus lagopus scoticus*, is a game bird that is dependent on vegetation dominated by heather *Calluna vulgaris*, and the management of heather moorlands is often primarily carried out for grouse management (the main economic activity) with sheep grazing of secondary importance (see Plate 7 and Figure 6).

Common land

Common grazing presents a different situation to that of sole ownership. There are about 600 000 ha of common land in the UK (most of which is in England and Wales), and much of which can be regarded as consisting of rough grazing or marginal land (not always in the uplands). Commons are often associated with arrangements that have been in place for centuries and subject to legal complexities. Many commons have no known owners; others are in multiple ownership, or owned by trusts, charities or councils (For more details see www.defra.gov.uk/wildlife-countryside/issues/common/facts.htm).

A high proportion of common land is recognised as being of nature conservation value, and where it has Site of Special Scientific Interest designation there is a requirement that the management is compatible with the relevant ecological values. Over-grazing or under-grazing may be detrimental to both the agricultural value and ecological interest. Since 1997 there has been an initiative called the Grazing Animals Project (GAP). This is a UK-wide partnership network of practitioners and advisers from the nature conservation, agricultural and livestock sectors which aims to help improve the management of this type of pasture resource. (For more details see: www.grazinganimalsproject.org.uk/)

Herbage seed production

This is a small and specialized activity practised on about 10 000 ha in the UK. Herbage seed crops require adequate spring rainfall and a summer climate that has a dry sunny period in July and August for ripening and harvesting of seed. There is a need for free draining soils, and a need to comply with isolation requirements from other grass crops. For these reasons it is carried out primarily on arable farms that have harvesting equipment, located in southern and eastern England rather than in the main grass-growing areas (Marshall and Hides, 2000).

Integration of forage resource utilisation with environmental objectives and food quality issues

Since the late 1980s there has been a progressive shift in emphasis in the UK towards the integration of environmental requirements with agricultural land management. The types of extensive agriculture that existed up the mid-twentieth century enabled the co-existence of farming, and wildlife and farming was not considered environmentally damaging, e.g. through its potential to pollute water courses or aquifers. However, the loss of lowland species-rich permanent pastures through the combined activities of cultivation and reseeding, fertilizer applications and early cutting for silage rather than late-season hay, and more intensive stocking rates, have massively reduced the area of this type of grassland. There are now targets for increasing the areas of some types of grassland habitat including neutral hay meadows and wet grasslands. Agricultural improvement in the uplands has also led to losses of local landscape types, upland hay meadows, and resulted in overgrazing in some localities. It is widely recognised that in many areas the amenity value of grasslands is greater than the value of the food that is produced, but that the continued existence of productive agriculture, at a level of intensity compatible with protection of landscapes and biodiversity, is also essential for this amenity value. The UK introduced Environmentally Sensitive Areas in 1986 and extended this scheme, eventually replacing it with a national Environmental Stewardship (slightly different arrangements apply in the four constituent countries of the UK). Essentially, farmers can receive payments in return for managing their land in ways which deliver environmental benefits (such as maintaining or improving a particular habitat or landscape feature) in recognition that this might involve them with actual costs or time, or financial losses through reduced production. In addition, there are legally enforceable measures, notably in terms of pollution of ground water and surface waters by nitrates or farm effluents. The more recent reforms of the EU Common Agricultural Policy have strengthened this through the replacement of former subsidies which encouraged the keeping of large numbers of stock, by an area-based payment system and a shift towards payments for environmental benefits.

A second trend in recent years has been the growing interest in consumers in the links between food quality and production systems, with a particular emphasis on organic farming. Growth in both the dairy and red meat sectors has been strong as farmers have converted to organic systems in response to a growing market with premium prices. Many extensive grassland farms that rely on clovers for nitrogen fixation and recycling of manures, rather than on inorganic fertilizers, are well placed to take advantage of this development. Organic farming can also develop links with agri-environmental management. Thus, agricultural production is seen as a part of rural management for multi-functional purposes: food, landscapes, biodiversity, clean water, soil protection, carbon sequestration, leisure and tourism. This is particularly important when considering the potential for further improvements in the agricultural value of forage resources.

6. OPPORTUNITIES FOR IMPROVEMENT OF FORAGE RESOURCES

As outlined in the section above, efforts in recent years have focused on achieving a balanced management of the farm environment that protects biodiversity and wildlife, avoids pollution of air, water and soil, and helps maintain the amenity value of landscapes, while at the same time maintaining farming communities and encouraging the production of quality food. Within these constraints there are a number of issues where forage resources can be improved:

- There is considerable potential to increase output from grassland, should this be required in the future. Marked increases in productivity have occurred, with Wilkins (1991) estimating an improvement in utilized output per ha of 1.8% per year from 1950 to 1970 and 1.4% per year from 1970 to 1985. Many farms have not achieved these gains.
- Many of the environmental problems associated with fertilizers and nutrients (e.g. nitrates in water courses or in ground water) are partly the result of poor farm nutrient budgeting. There is

considerable scope to improve the efficiency of nutrient utilization at the farm level with financial benefits for farmers in terms of reduced costs or higher forage output.

- There is inadequate use of legume forages on most grassland farms in the UK. Research evidence gained in recent years has shown that legumes have the potential to replace many N-fertilized grass swards and help reduce the need for purchased protein-rich feed. Some expansion of legume use would be consistent with achieving goals of environmental policy and meeting consumer expectations (Peeters *et al.,* 2006).
- The quality of grassland feeds has emerged in relation to effects on product composition and human health. Dietary levels of conjugated linoleic acid (CLA) and the ratio of *n*-6 to *n*-3 polyunsaturated fatty acids (PUFA) have been associated with anti-carcinogenic effects and susceptibility to coronary heart disease, respectively. These observations open up possibilities for further exploitation of grassland in feeding systems and for new objectives in forage breeding and management (Scollan *et al.,* 2005).
- Further production potential improvement of cultivars is possible, and considerable opportunities exist for improvement in forage quality, including PUFAs, digestibility and protein quality. The application of new technological approaches such as introgression, gene mapping and marker-assisted selection provides the means to improve varieties for a range of nutritional and other targets such as rumen efficiency, lipid composition and drought tolerance (Pollock *et al*., 2005).
- There may be an increased role for many of the lesser used grassland species for particular environments and for contributing dietary components that lead to enhanced quality in meat or milk products, and for biodiverse swards that contribute to products of distinctive quality. This particularly applies in upland and other marginal environments where production costs prevent products from competing with those from lowland farms on an undifferentiated commodity basis.
- The effects of future climate change (consistent with the scenarios of the UN Intergovernmental Panel on Climate Change) suggest higher mean temperatures and changes in rainfall distribution (more summer droughts and heavier winter rain). Under these conditions the areas used for high-yielding forage crops, notably maize, whole-crop silages and for the growing of legume forages (grazing and conserved forage) might be expected to increase (Hopkins and Del Prado, 2007).

7. RESEARCH AND DEVELOPMENT ORGANIZATIONS AND PERSONNEL

In recent decades there has been a progressive reduction in the number of organizations involved in research and development on pastures and fodder crops. Further reorganizations were in progress at the time this profile was being compiled. At Aberystwyth in Wales the Aberystwyth University Institute of Biological, Environmental and Rural Sciences (IBERS) incorporates much of the work of the former Institute of Grassland and Environmental Research (IGER) on forage-related plant breeding, plant biology and genetics, animal science and nutrition. North Wyke Research, at Okehampton in south-west England, incorporates part of the former IGER research on grassland agro-ecology and soil science. In Scotland, the Macaulay Institute and the Scottish Agriculture College (SAC) are the leading research providers in Scotland on matters relating to agricultural land use. The Agri-food and Biosciences Institute (AFBINI) is the leading research and development centre for Northern Ireland. Additional forage and land use research, and research on animal production and animal health, is conducted by departments in a number of UK colleges and universities, as well as by private companies and in specialist institutes, such as the Institute of Animal Health. A feature of much of the research and development in the UK is that it is conducted by organizations that have a multi-disciplinary approach. The British Grassland Society is an organization that brings together grassland-related researchers, advisers, farmers and representatives from the agricultural business industries; it organizes conferences and its publications include the leading international journal Grass and Forage Science and a farm advisory publication Grass and Forage Farmer.

This list of organizations carrying out research (and in some cases associated teaching) is wide ranging but not necessarily representing all bodies that have a stake in forage-related research.

Organization and contact details	**Key personnel/ contacts/web**	**Research topic/responsibilities**
British Grassland Society Trent Lodge Stroud Road CIRENCESTER Gloucestershire GL7 6JN Telephone: 00 44 1285 885166	Ms Jessica Buss British Grassland Society Executive office@britishgrassland.com	Grassland publications Conferences Special interest groups Local societies
Institute of Biological, Environmental and Rural Sciences (IBERS) Plas Gogerddan Aberystwyth, Ceredigion, Wales SY23 3EB Telephone: 00 44 1970823000	Dr M Abberton Michael.abberton@bbsrc.ac.uk Prof Ian King Ian.king@bbsrc.ac.uk Prof N Scollan Nigel.scollan@bbsrc.ac.uk	Plant breeding and genetics Crop genomics Animal science
North Wyke Research Okehampton Devon EX20 2SB Telephone: 00 44 1837 883500	Prof. Les Firbank Prof. Les Firbank	Grassland Environment and Soil Systems Les.firbank@bbsrc.ac.uk Multi-functional landscapes Les. firbank@bbsrc.ac.uk
Macaulay Institute Craigiebuckler Aberdeen, Scotland, AB15 8QH Tel: 00 44 1224 498200	Dr Richard Aspinall Chief Executive enquiries@ macaulay.ac.uk	Integrated land use, catchment management, ecology, soils, socio-economics
Agri-food and Biosciences Institute, Hillsborough Co Down, Northern Ireland BT26 6DR Tel: 00442890255689	www.afbini.gov.uk/index/research.htm info@afbini.gov.uk	Crop and grass production, livestock production, animal health and welfare, economics and rural development
Royal Agricultural College Cirencester Stroud Road, Cirencester, GL7 6JS, UK, Tel 0044 01285 652531	www.royagcol.ac.uk/	Teaching, post-graduate study, research and consultancy include equine, sustainable agriculture, countryside and rural economy
Scottish Agriculture College (SAC) Campuses at Aberdeen, Ayr and Edinburgh. Communications Unit, SAC (Scottish Agricultural College) King's Buildings, West Mains Road, Edinburgh EH9 3JG Tel 00 44 131 535 4000	www.sac.ac.uk/	Teaching, post-graduate study and research on land economy and environment, climate change, sustainable livestock, animal health
University of Reading Centre for Agri-Environmental Research (CAER).Tel 0044 118 378 8938	www.rdg.ac.uk/caer/index.html	
University of Newcastle School of Agriculture, Food and Rural Development, Agriculture Building, Newcastle upon Tyne, NE1 7RU, UK Tel 0044 191 222 6900	http://www.ncl.ac.uk/afrd/ E-mail: afrd-enquiries@ncl.ac.uk	Integrated agricultural systems, rural economy, ecological farming, renewable energy from land. Teaching and post-graduate study and research
NIAB Huntingdon Road CAMBRIDGE CB3 0LE Tel: +44 (0)1223 342200	www.niab.com/	Plant science research, breeding and variety evaluation

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