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SOILS of Co. OFFALY

by R.F. Hammond and L.E.

Brennan

National Soil Survey of Ireland

Teagasc

AGRICULTURE AND FOOD DEVELOPMENT AUTHOHITY

"The quality of this soil is more generally, either a deep moor or a shallow gravelly loam, the moist season being most favourable to the produce it yields and the moors very productive in dry summers"

Charles Coote, 1801

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PREFACE

The survey of the soils of County Offaly began in the early 1970's and the fieldwork was completed in the late 1980's. The contribution of Dr. Pierce Ryan, then Head of the National Soil Survey of Ireland, who was instrumental in setting up the Survey is acknowledged. The reorganisation of An Foras Taliintais in 1987/88 and subsequent interregnum through re-deployment of staff to other duties effectively put soils report writing on hold for several years. However, with perseverance this publication, Soil Survey Bulletin No. 43, presents the findings of the Soil Survey of County Offaly, which is the twelfth county soil survey bulletin to be published.

Dr. Robert Hammond and Mr. L.E. Brennan were responsible for the field mapping which commenced in 1971. This type of survey is a joint effort between many interested parties. The contributions of Mr. Sean Diamond and Mr R Parle are acknowledged in the correlation and editing of the soils descriptions and the section on trace elements, respectively. Mr. T. Gleeson helped in the preparation and Mr. L.E. Brennan carried out the analyses in the section on soil physical characteristics and pollution susceptibility (Chapters 8 and 9). The late Mr. T.F. Finch carried out the stone counts for the different classes of soil parent materials and the late Dr. T Gately co-operated in the preparation of data for the malting barley survey in the 1970's. Dr. M.J. Conry was associated with the survey of the Hill and Mountain soils. Mr. Michael Bulfin contributed information on aspects of land use in relation to forestry.

The bulletin was compiled and word-processed in the main by Dr. R.F. Hammond. Dr. M.J. Conry (Teagasc) and Dr. J.F. Collins (NUI, Dublin) assisted in technical editing and overall editing was by Dr. Con O'Rourke. Acknowledgements are given to the secretarial members, Sharon McAuley, Jackie Smith and James Oberlander, of the Veterinary Epidemiology and Tuberculosis Investigation Unit, Faculty of Veterinary Medicine, NUI Dublin who carried out word processing in the intervening years.

Dr. R.F. Hammond, Dr. J.F. Collins and Dr. C. O'Rourke took the photographs that illustrate the bulletin.

Mr. J. Lynch and Mr. V. Staples prepared the Soil and Land Use Capability maps. The Quaternary Map prepared by Dr. W. Warren and Dr. R.F. Hammond was a joint cartographic effort between the Geological Survey of Ireland (Sarah-Jane Burns and Robbie Meehan) and the Geographical Information Technology section of the Veterinary Epidemiology and Tuberculosis Investigation Unit, NUI Dublin (Guy McGrath). Funding of this map by the Geological Survey of Ireland is also gratefully acknowledged.

The laboratory staff of the Soil Survey Laboratory, the Soil Fertility and Soil Chemistry Department and Plant Nutrition and Biochemistry Department, Johnstown Castle, provided the analytical data.

Acknowledgements are due to the Teagasc Advisory Staff, especially Michael Hassett (Chief Agricultural Officer (CAO), Co. Offaly) now retired and his staff during the field work and Mr. T. Collins, CAO, for his contribution to the chapter on Farming in County Offaly. The climatic data were provided by Met Eireann (The Meteorological Service).

The colour maps were printed by the Ordnance Survey, which was also the source of the base maps for the field mapping. The printed maps are based on the Ordnance Survey by permission of the Government.

Grateful acknowledgement is made to all those contributors mentioned here and to others who helped in various ways.

Dr. John Lee,
Head, Environmental Research Centre,
Teagasc,
Johnstown Castle,
Wexford.

2002

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DISCLAIMER

CHAPTER 1

GENERAL DESCRIPTION OF THE AREA

Location and Extent

County Offaly situated in central Ireland between 52° 52' and 53° 25' north latitude and 6° 58' and 8° 3' west longitude, occupies an area of 1,990.29 km^2 (199,029 hectares). The county is bounded by Counties Kildare, Laois, Tipperary, Galway, Roscommon, Westmeath and Meath (Fig. 1.1). A significant boundary is the River Shannon (Photo 1.1), which separates it from Counties Galway and Roscommon.

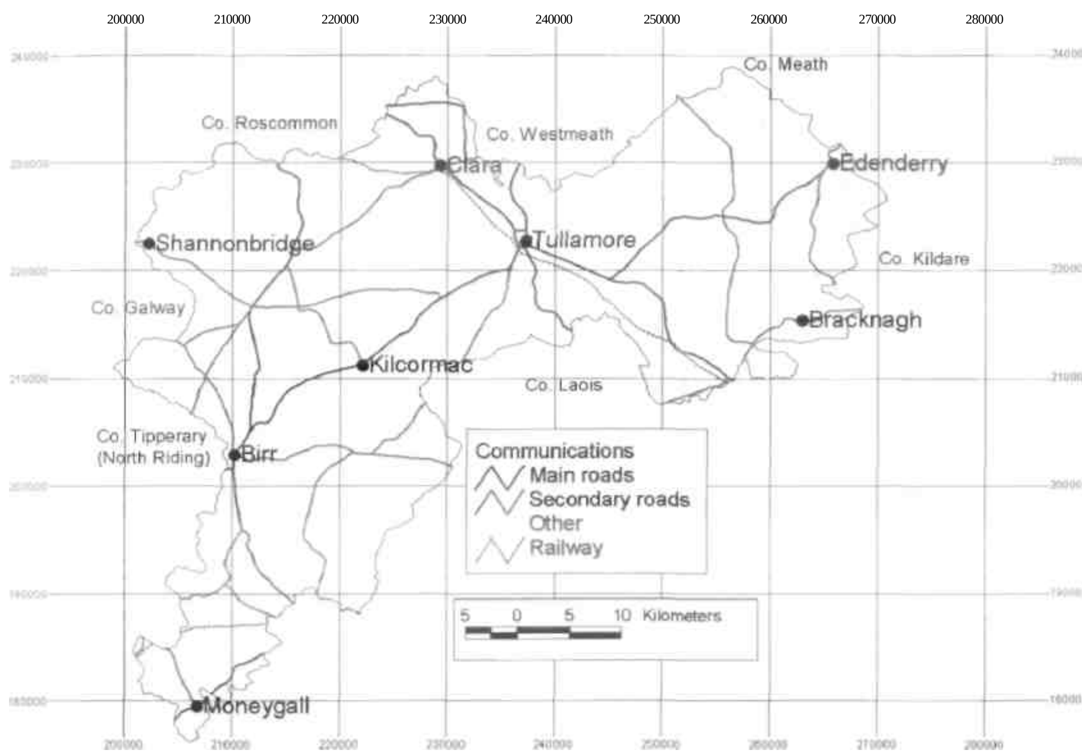


Figure 1.1. Major towns, villages and communications network in Co. Offaly.

Topographic Features

Topographically the county is quite varied. The mountainous region of the Slieve Bloom Mountains to the southwest (Photo 1.2) forms a common border with Co. Laois and contrasts with the flat floodplain of the River Shannon. In between these two extremes the topography of the county varies from rolling to gently undulating, the shape and form determined by the effects of Quaternary glaciations (Fig. 1.2).

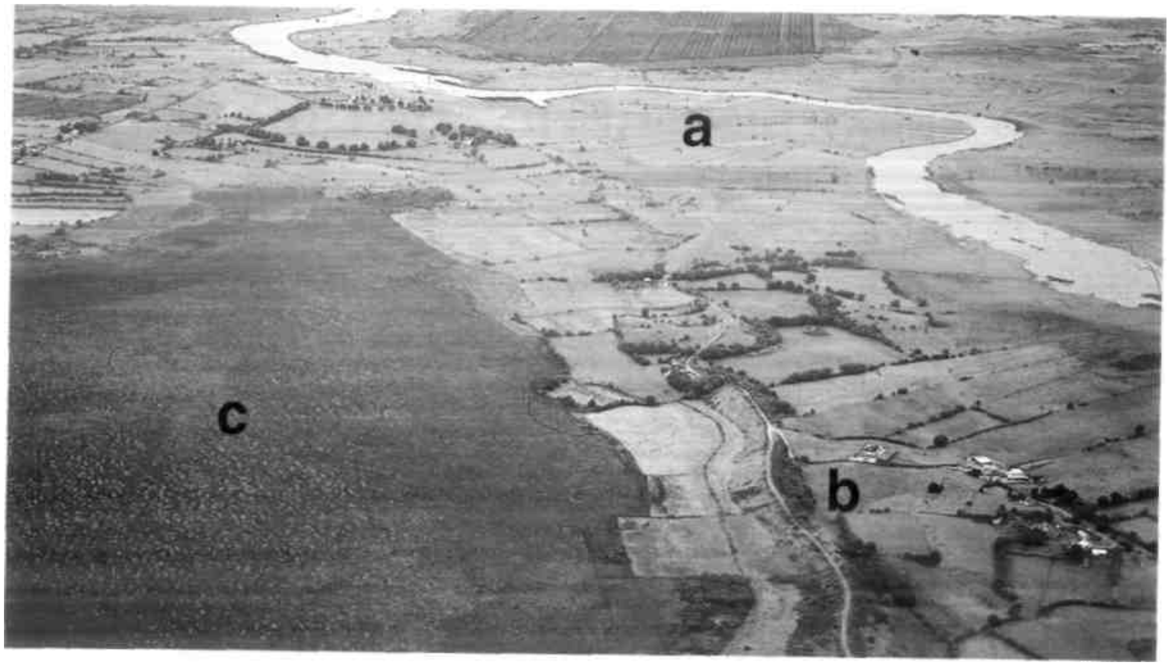


Photo 1,1: Clonmacnoise, Co. Offaly (looking south) showing a) Shannon callows (see page 81), b) Medieval Pilgrims' Way to Clonmacnoise along top of esker, and c) Mongan's Bog (now conserved). *(C. O 'Rourke)*

Photo 1.2: Slieve Bloom Mountains looking to the north-east. *(C. O 'Rourke)*

The Slieve Bloom Mountains, comprising Devonian Red Sandstone and Silurian Shales, range in elevation from 130-510 metres. The river valleys are deeply incised into the shale bedrock and crlacial gravels are piled up against the mountains in a number of locations.

A notable feature of the landscape to the north of the Slieve Bloom Mountains, near the Co. Westmeath/Offaly border, is the pre-Cenozoic Greenstone (Diorite) volcanic plug of Croghan Hill (see Croghan Series pi 16), rising to 210 metres, a place of religious pilgrimage in times past.

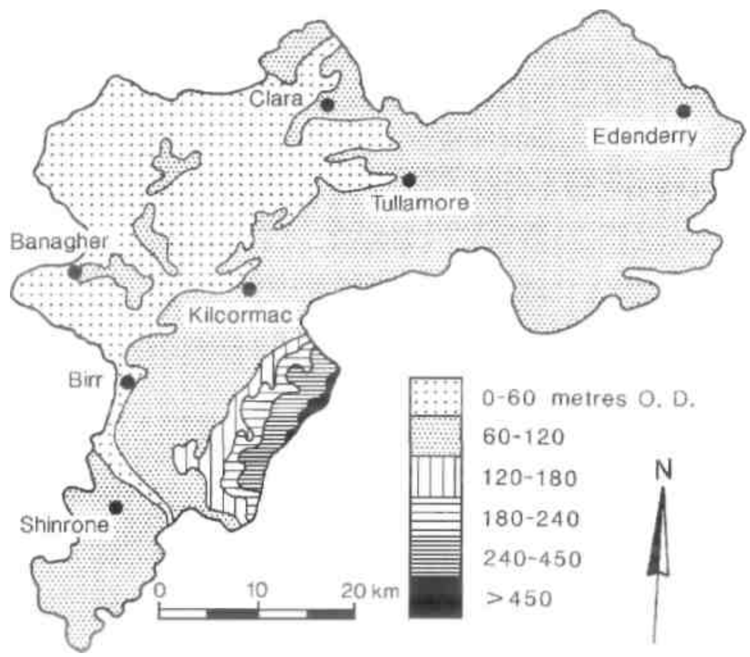


Figure 1.2: Relief map of Co. Offaly, showing locations of towns and villages.

Characteristic features of the gently undulating landscape are the sinuous eskers formed by glacial meltwaters. The historic Pilgrims' Way follows the east-west Esker Riada, connected the east of the country to the 12th- century Clonmacnoise religious seat of learning on the banks of the River Shannon (Photo 1.1). These formations, however, are being extensively excavated (Photo 1.3) to provide aggregates for the construction industry.

The raised bogs, a characteristic landscape feature of the Midlands are well represented in the county. The larger tracts have been developed for industrial peat extraction especially to the west of Tullamore and three of these unique landscape units with relatively undisturbed surface vegetation located at Clara (Photo 4.14), Clonmacnoise (Photo 1.1) and Raheenmore in Co. Offaly, have been conserved.

Photo 1.3: Gravel extraction from an esker north of T\illamore, Co. Offaly. *(C. O 'Rourke)*

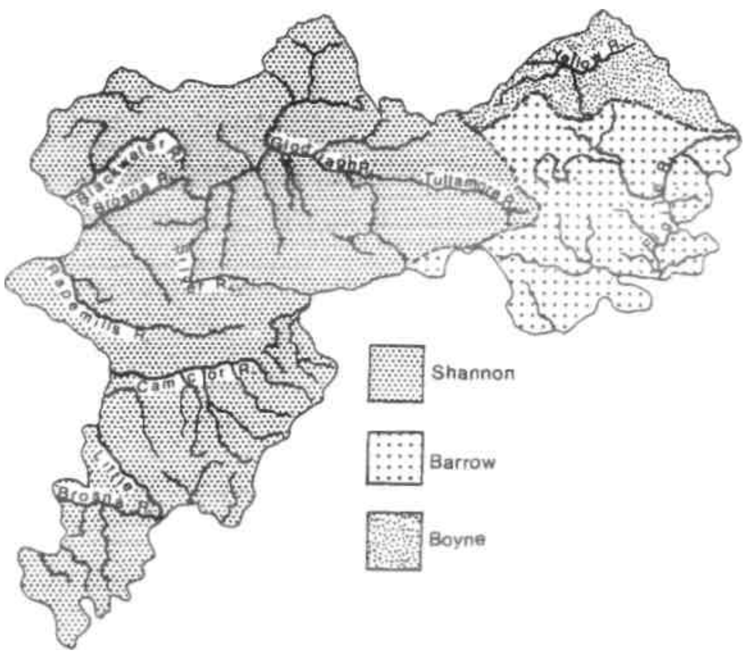


Figure 1.3: Catchment basins of the major rivers and associated tributaries, Co. Offaly.

Catchment Basins
Three major rivers, the Shannon, Barrow and Boyne and their tributaries, drain the county (Fig. 1.3). The tributary rivers Brosna, Little Brosna, Tullamore, Clodiagh and Silver River drain westwards and constitute part of the Shannon catchment. The Barrow rises within the county in the Slieve Bloom Mountains and is joined by the southerly flowing Cushaling, Figile and Philipstown rivers. The Yellow River to the north of the county drains to the northeast, forming part of the Boyne catchment.

Climate
Climatically Ireland falls into the broad category of Continental oceanic being strongly influenced by its mid-latitude oceanic position in the path of the moderating influence of the North Atlantic Drift (Gulf Stream). The prevailing winds are from the southwest and bring moisture-laden air from the Atlantic Ocean. In the eastern half of country there are on average two rain days per week >= 0.2 mm of precipitation.

Co. Offaly is centrally placed in the country and its climate is described from data collected at the Met Eireann synoptic weather station at Birr for the period 1955-1980. The synoptic data for the Birr station for the years 1955-1980 are presented in Table 1.1.

Precipitation
The average annual precipitation, 1955 - 1980, at Birr amounted to 819 mm. This can be compared to the rest of the country in Fig. 1.4; precipitation is relatively evenly distributed throughout the year.

However, precipitation recorded at stations in the county (Table 1.2) varies from 800 mm at Clonsast in the east to 1032 mm at Moneygall in the southwest. Annual rainfall amounts can be as high as 1500 mm at higher elevations in the Slieve Bloom Mountains (taken from Conry, 1987). Isohyets for the county are shown in Fig. 1.5. March to June are the driest months.

Table 1.1: Climatological data for Birr, 1955 - 1980, Lat. 53° 05'N Long. 7° 53'W, 70 metres above mean sea level

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Rainfall													
Mean rainfall amount (mm)	77	51	54	57	62	54	70	75	78	78	78	85	819
Greatest rainfall amount in a day[1]	27.8	23.5	18.4	30.8	17.5	24.2	31.1	36.3	31.6	33.8	30.2	44.2	44.2
Mean number of days with 0.2mm or more	18	15	17	16	17	16	17	17	18	18	18	20	207
Mean number of days with 1.0mm or more	14	11	12	11	13	11	11	13	13	13	13	14[3]	149
Wind													
Mean wind speed (knots)[2]	7.9	7.6	8.3	7.3	7.1	6.5	6.1	6.0	6.8	7.0	7.2	8.2	7.2
Highest wind speed in a gust (knots)	85	67	62	60	56	51	44	58	81	65	66	69	85
Highest mean wind speed over a period of 10 minutes (knots)[3]	51	42	36	36	31	30	27	35	39	40	39	43	51
Mean number of days with gales[3]	0.3	0.3	<0.1	<0.1	0.0	*0.0*	*0.0*	<0.1	<0.1	<0.1	0.2	0.2[3]	1.3
Other													
Mean number of days with snow or sleet	4.8	4.6	2.4	0.8	0.2	0.0	0.0	0.0	0.0	<0.1	0.7	2.4	15.9
Mean number of days with snow lying at 9hGMT	3.0	2.2	0.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	<0.1	0.6	6.8
Mean number of days with hail	0.6	0.9	2.3	1.6	1.2	0.4	<0.1	0.1	0.3	0.3	0.7	0.4[3]	8.8
Mean number of days with thunder	0.2	<0.1	0.2	0.2	0.8	0.8	1.1	1.1	0.4	0.2	0.1	<0.1	5.2
Mean number of days with fog at 9h GMT	1.2	1.0	0.8	0.4	<0.1	0.1	0.0	0.4	1.0	1.6	1.0	0.9	8.4
Mean number of days with fog (at any time)	4	2	2	3	1	2	2	4	4	5	3	3	35
Mean number of hours with fog	24	14	11	11	5	7	8	17	20	31	20	22	190
Mean number of days with air temperature less than 0.0 °C	10	12	8	4	1	<0.1	0.0	0.0	<0.2	1	3	8	48

[1] "Day" is taken as a period of 24 hours commencing at 06.00 GMT

[2] Based on periods of 10 minutes at each hour over the years 1955-1961 and mean hourly wind over the remainder of the period

[3] Mean wind speed 33.5 knots or more, for a period of at least 10 minutes

Table 1.1: (cont.)

Air Temperature (°C)	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Mean daily maximum	7.3	7.8	9.8	12.3	15.0	17.8	18.9	18.9	16.8	13.8	9.8	8.2	13.0[4]
Mean daily minimum	1.6	1.7	2.7	3.9	6.2	9.0	10.9	10.5	8.9	6.9	3.4	2.6	5.7[5]
Mean daily	4.5	4.8	6.3	8.1	10.6	13.4	14.9	14.7	12.9	10.4	6.6	5.4	9.4
Mean monthly maximum	12.0	12.2	14.6	17.5	20.6	23.7	24.3	23.4	21.5	18.2	14.5	12.8	25.8[4]
Mean monthly minimum	5.8	4.4	4.0	2.3	0.3	3.8	5.4	4.4	2.3	0.3	4.5	4.9	7.6[5]
Absolute maximum[4]	14.5	14.5	19.7	23.7	24.7	31.2	30.5	29.3	26.3	23.2	17.5	14.3	31.2[4]
Absolute minimum-"	-11.6	-10.5	-10.5	-4.6	-2.1	0.3	3.1	1.2	-0.8	-4.0	-7.2	-9.4	11.6[5]
Relative Humidity													
Av. Percentage at 00.00 GMT	90	89	88	88	88	88	89	91	90	90	90	90	89
Av. Percentage at 06.00 GMT	90	90	90	91	90	91	92	93	92	91	90	90	91
Av. Percentage at 12.00 GMT	85	81	74	69	67	68	71	71	74	79	83	86	76
Av. Percentage at 16.00 GMT	87	82	75	69	67	69	71	73	78	84	87	88	78
Sunshine													
Mean daily duration (h)	1.77	2.54	3.43	4.78	5.67	5.30	4.34	4.54	3.70	2.76	2.05	1.45	3.53
Mean duration (h)	55	72	106	143	176	159	134	141	111	86	62	45[4]	1290
Greatest duration in a day	7.5	9.2	11.7	13.8	15.2	15.8	15.2	13.8	11.5	10.0	8.0	6.7[4]	15.8
Mean number of days with no sun	12	6	5	3	2	2	3	2	4	6	9	10[4]	64

[4] Mean of highest each year
[5] Mean of lowest each year

Table 1.2: Mean monthly and annual rainfall (mm) for recording stations in County Offaly, 1961-1990

	Grid Ref.	Elevation (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
BANAGHER (CANAL HSE.)	N004160	37	80	59	65	54	60	62	58	84	75	85	79	82	842
BIRR	N074044	73	76	54	61	53	61	56	59	78	71	84	74	78	804
BLACKWATER (BORD NA MONA)	N002253	49	86	61	68	55	63	62	62	87	81	92	82	87	885
BOORA	N180197	58	81	58	64	53	60	61	59	80	72	82	76	82	829
CLONSAST (BORD NA MONA)	N535160	73	78	59	60	54	58	59	55	76	69	79	72	81	800
DAINGEAN G.S.*	N472271	78	84	60	61	56	63	60	61	79	76	81	74	83	838
DERR1NLOUGH (BORD NA MONA)	N082146	61	81	58	64	55	61	62	59	82	76	87	80	84	849
DERRYGREENAGH	N493382	90	88	62	67	57	65	62	58	79	80	86	82	89	873
EDENDERRY (THE TUNNEL)	N6443J3	81	82	59	64	55	64	64	58	79	76	87	79	85	853
EDENDERRY G.S.	N627325	85	82	59	63	56	64	63	58	78	73	83	77	84	838
FERBANE G.S.	Nl 13244	47	86	60	65	56	63	65	64	86	77	89	82	87	879
KILCORMAC G.S.	N182139	64	85	60	65	56	62	64	60	81	76	85	80	88	860
KINNITTY CASTLE	N203058	143	105	76	77	68	76	68	70	91	87	101	89	104	1012
LEMANAGHAN (BORD NA MONA)	N152259	55	80	60	63	54	60	64	63	87	78	88	80	84	862
MEELICK (VICTORIA LOCK)	M946129	39	87	63	70	58	64	62	62	88	77	91	84	87	893
MONEYGALL G.S.	S032811	125	116	84	84	66	75	63	62	85	86	106	93	112	1032
RHODE G.S.	N536336	94	87	62	66	56	64	63	59	78	78	87	80	88	867
SHINRONE G.S.	S045925	70	91	66	67	57	68	58	59	80	75	92	82	91	885
TULLAMORE G.S.	N337251	58	81	59	61	55	63	59	57	76	72	83	74	83	823
Co. Kildare															
LULLYMORE (AGR.RES.STN.)	N695262	77	81	58	62	56	63	63	55	79	73	83	77	85	834
LULLYMORE (BORD NA MONA)	N7U289	84	79	54	60	54	61	63	57	78	71	80	76	83	813

* *G.S.* Garda Station

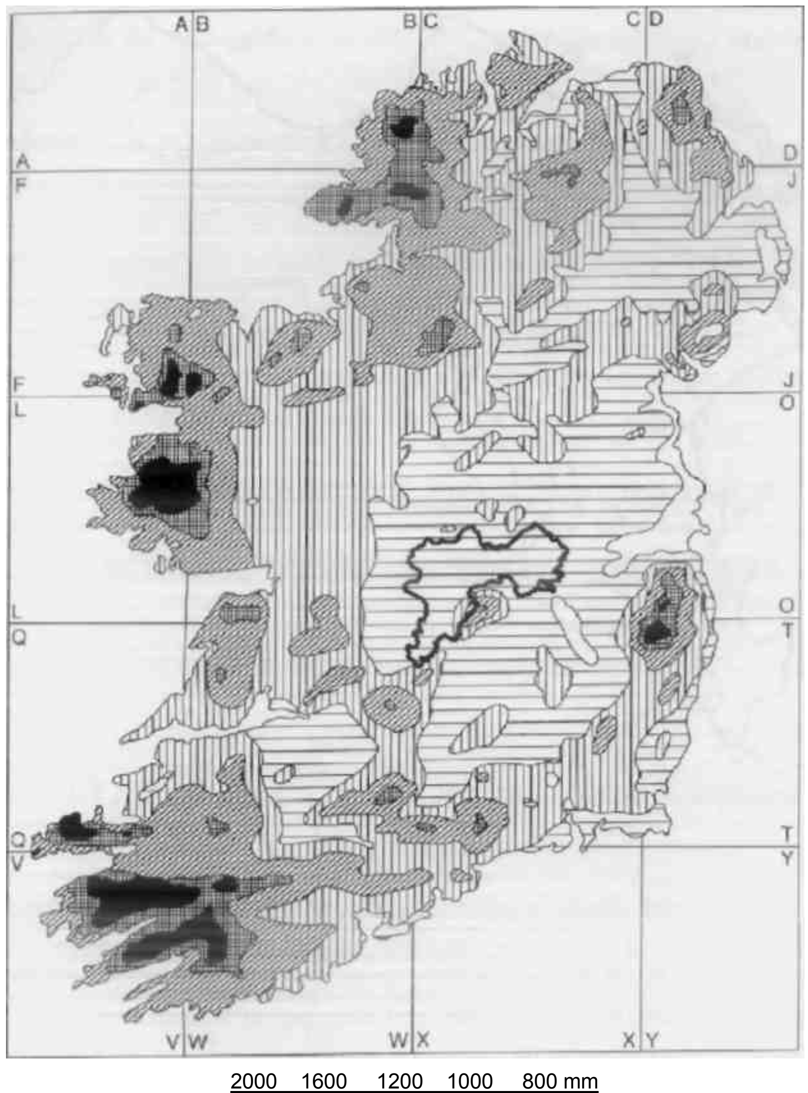


Figure 1.4: Mean annual precipitation, 1951-1980 (Met Eireann data). Co. Offaly shown in bold outline.

Temperature

Mean air temperatures vary from a mean minimum of 5.7°C to a mean maximum of 13.0°C. Absolute maximum and minimum recorded in the period 1955-1980 were 31.2 °C and -11.6°C respectively.

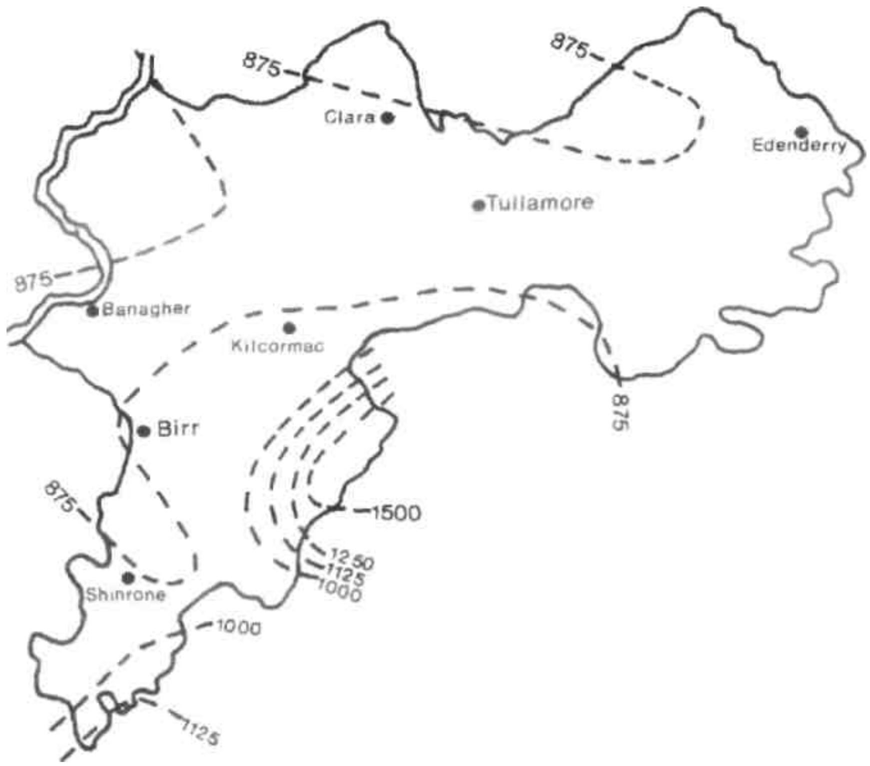


Figure 1.5: Precipitation isohyets (mm per annum), Co. Offaly (Met Eireann data).

Sunshine

Sunshine in the year totals 1290 hours with a daily average of 3.5 hours. These values compare to 1500 hours on the east coast and a mean daily average of 4.0 hours. Overall in the county it is calculated that sunshine levels in December and May are 19% and 37% of maximum possible amount respectively. Relative humidity values range from 67-93% in the summer and 85-90% in the winter. The Agroclimatic Atlas (Collins and Cummins, 1996) quotes an annual mean value of 75-85% with a general decrease inland in the summer when inland temperatures increase.

Crop growing season

The full potential for crop growth is achieved through a long growing season, no soil moisture deficits, adequate temperature, radiation and crop nutrition. Crop growth effectively ceases when air and soil temperatures drop to 5°C and 6°C, respectively (Brereton *et al.* 1985). Average daily temperatures drop below 5°C in January and February and only marginally over this value in December (Fig. 1.6.). Accumulated temperatures expressed as "degree days" and/or "heat units" are parameters used to calculate the time taken for a crop to reach maturity. Base temperatures, which are statistical concepts (Burke, 1968) vary from crop to crop but range from 4°C for spring wheat to 7.0°C for potatoes with orass, oats and peas intermediate to these values. Degree-days per month calculated for the Birr Synoptic Station based on the base temperature (4°C, 1967-1986) are as follows Mar. 39, Apr. 93, May 173, June 252, July 297, Aug. 300, Sept. 235, Oct. 165, Nov. 48 and Dec. 12.4.

Overall there is potential for growth for about 270 days in the year (Fig. 1.7). Approximately 70 per cent of County Offaly is under grassland management and it is extremely important to maximise production levels through the efficient application of fertiliser nitrogen. The base temperature for grass suggests that fertiliser applications on well-drained soils could be applied in most years in early March depending on local conditions. Grass utilization early and late in the season is made difficult by soil conditions especially on the finer-textured, peaty and organic soils in the county. However, organic soils, due to their low plasticity values are easily tilled within a few days in comparison to finer-textured mineral soils.

Peatland covers 34% of the county. Where peat soils have been reclaimed and developed for agriculture, there is an increased incidence of frost. This arises from the low-lying topography, leading to cold air drainage and the nett effect of black body radiation. Organic soils are considered to have a 6-month grazing period. The data in Table 1.3 from the meteorological station at the Peatland Experimental Centre, Lullymore, Co. Kildare for 1963-1985 show that July is the only frost-free month.

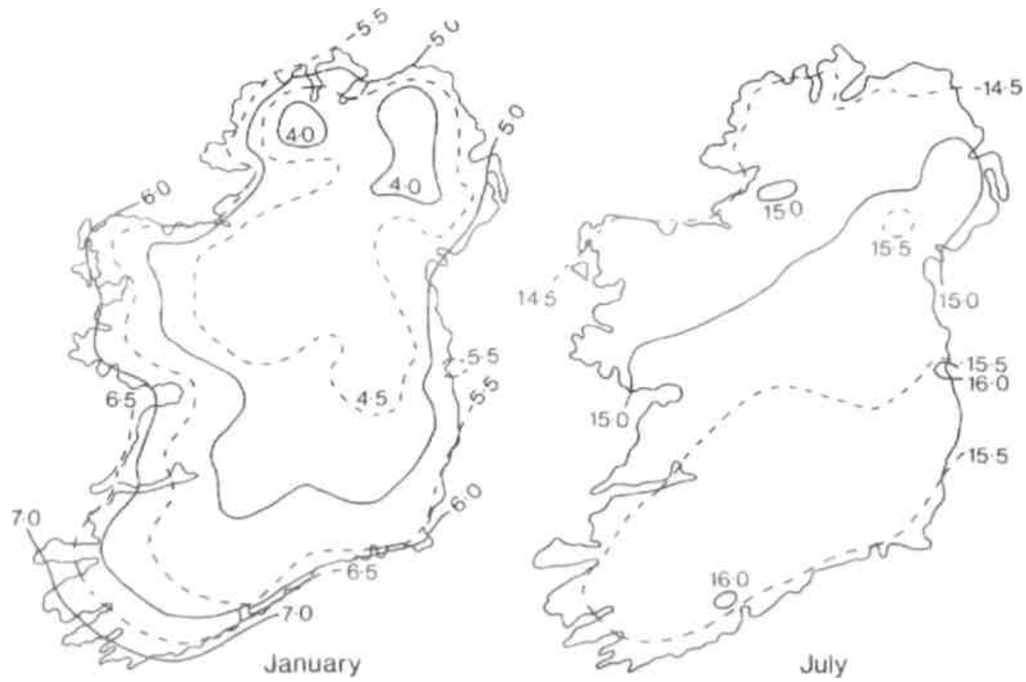


Figure 1.6: Mean daily air temperature (°C) Ireland, January and July, 1931-1960, reduced to mean sea level (Met Eireann data).

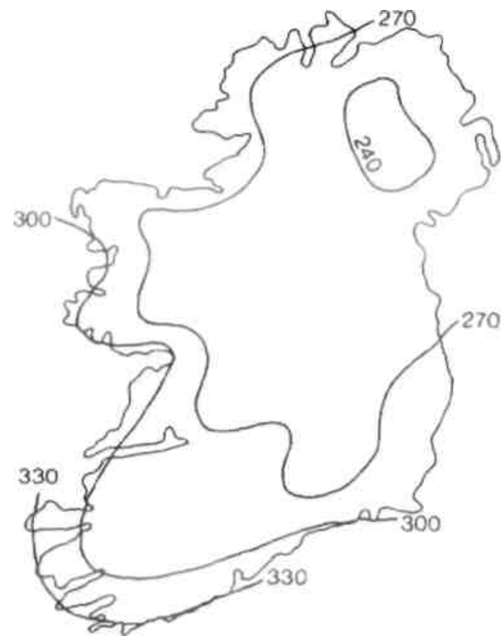


Figure 1.7: Median length (days) of grass growing season (1954-1968) (Met Eireann data).

Soil moisture deficits

Optimum crop growth is strongly correlated with adequate levels of soil moisture throughout the growing season. Soil moisture retention/supply in turn is strongly influenced by the texture and depth of the soil in any particular series. Fig. 1.8 shows the monthly relationship between the average calculated Penman evapo-transpiration (Etp) values in mm (Stanhill, 1958) for inland synoptic stations and the average monthly rainfall for Birr for the 1958-1982 period.

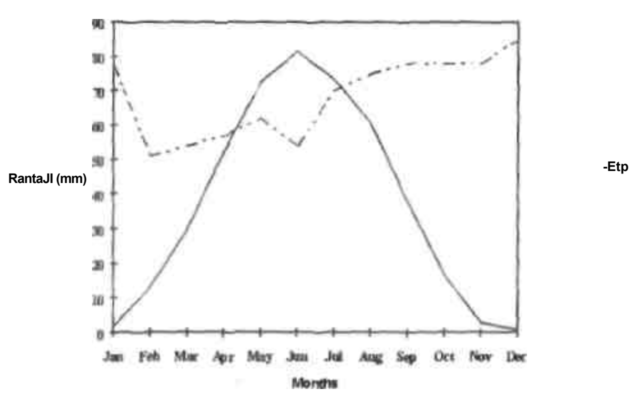


Figure 1.8: Evapo-transpiration (Etp) and rainfall amounts showing the months for potential moisture deficit.

Soil moisture deficits can be expected in any given year to occur in the months April to August. The Agroclimatic Atlas (Collins and Cummins, 1996) indicates a mean accumulated potential moisture deficit of approximately 25 mm for the months May to August (1958-1965). This figure is in line with the data in Fig. 1.8. Soils most prone to moisture deficits occur on the lighter, sandy/gravelly parent materials, e.g. Graceswood and Baggotstown, whereas the deeper more heavy-textured soils such as Elton and Mortarstown are less prone to moisture deficits. Whereas peat soils have disadvantages to being frost-prone they have excellent soil moisture characteristics and are generally able to supply moisture throughout the growing season except in exceptionally long droughts.

Table 1.3: Monthly temperatures, sunshine and rainfall, Lullymore, Co. Kildare, 1963-1985

Month	**Mean temp. (°C)**	**Max. temp. (°C)**	**Min. temp. (°C)**	**Mean daily sunshine (h)**	**Max daily sunshine (h)**	**Rainfall (mm)**
Jan	**4.0**	**13.2**	**-18.8**	**1.3**	**7.1**	**81**
Feb	**4.0**	**14.0**	**-12.9**	**1.9**	**9.4**	**58**
Mar	**5.5**	**19.0**	**-10.1**	**2.7**	**11.5**	**62**
Apr	**7.2**	**22.0**	**-5.0**	**4.3**	**13.4**	**56**
May	**9.8**	**25.2**	**-4.0**	**4.5**	**15.3**	**63**
Jun	**13.0**	**28.3**	**-1.0**	**4.3**	**15.9**	**63**
Jul	**14.6**	**30.4**	**0.6**	**3.8**	**15.0**	**55**
Aug	**14.4**	**29.7**	**-0.1**	**3.7**	**14.1**	**79**
Sep	**12.4**	**23.9**	**-2.4**	**3.0**	**11.5**	**73**
Oct	**9.8**	**21.5**	**-4.1**	**2.3**	**9.1**	**83**
Nov	**6.0**	**17.4**	**-6.5**	**1.7**	**8.8**	**77**
Dec	**4.7**	**14.5**	**-11.5**	**1.0**	**6.9**	**85**

CHAPTER 2

BEDROCK AND PLEISTOCENE GEOLOGY OF COUNTY OFFALY

D. Daly and W. Warren
(Geological Survey of Ireland)

BEDROCK

Introduction

The bedrock in most of Offaly is masked by the Quaternary deposits - peat, sand, and gravel and till - which form many of the lower irregular topographic features.

The rocks are folded with the axes of the folds trending NE-SW. The older sandstone rocks are present in the anticlines of the Slieve Bloom Mountains, and at Moneygall, the Cloghan-Ferbane-Lemanaghan area and near Clonmacnoise. The remainder of Offaly consists of a variety of limestones with a small area of volcanic rocks forming Croghan Hill. Two sets of faults are present; the dominant set trends NE-SW and the subsidiary set trends NW-SE.

A bedrock geology map is given in Figure 2.1. It is a simplified map compiled from several sources (see references section).

Silurian rocks

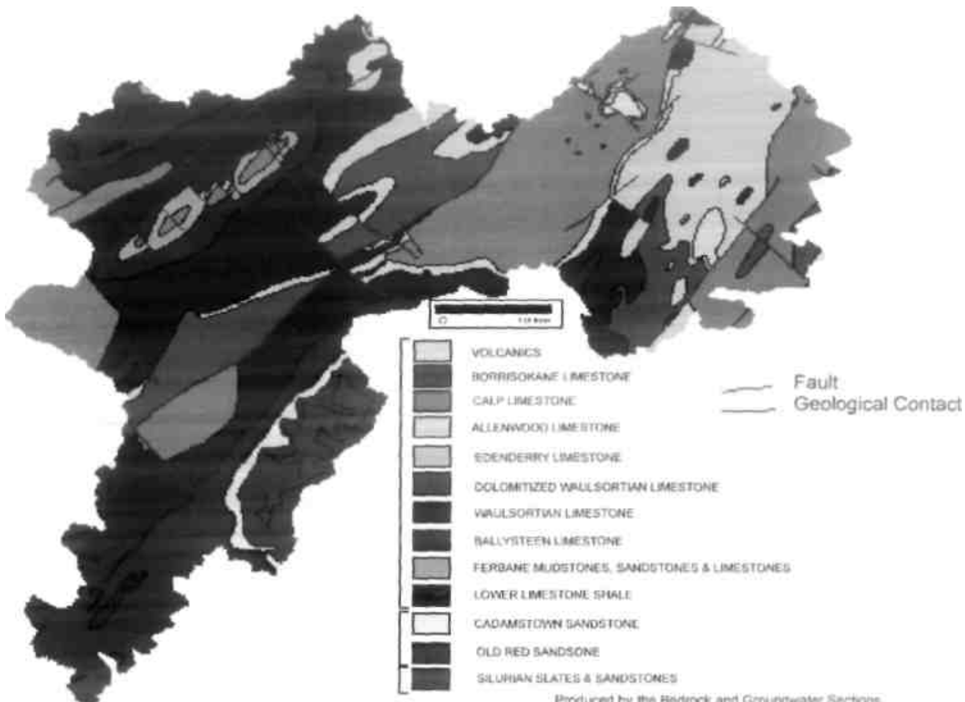
These rocks, the oldest in County Offaly, are present in the core of the Slieve Bloom Mountains and near Moneygall. They consist of grey and grey-green clayey sandstones and slates (locally called 'shlig'). They were slightly metamorphosed by a phase of folding at the end of the Silurian Period.

Devonian rocks

Overlying the Silurian rocks in the Slieve Bloom Mountains are a mixed sequence of red sandstones, siltstones, mudstones (Photo 2.1) and occasional conglomerates, which were deposited on the Devonian land mass by meandering rivers. These in turn are overlain by coarse-grained pale grey or yellow sandstones. These sandstones, called the Basal Sandstone, are also present in the Cloghan-Ferbane-Lemanaghan area and north of Clonmacnoise, although they are seldom exposed at the surface.

Carboniferous sediments

At the beginning of the Carboniferous Period, a sea gradually spread northwards and inundated the basin now occupied by Offaly. All the remaining rocks - mainly limestones - were deposited as sediments under a range of marine environments caused by variations in sea depth and the amount of deposited mud.



Geological Survey of Ireland. 1997

Figure 2.1: Solid geology of Co. Offaly.

The onset of marine conditions caused the deposition of an alternating sequence of limestone, sandstones and mudstones which now occur in the Cloghan-Ferbane-Lemanaghan area and near Clonmacnoise. These are overlain by dark muddy limestones, which also surround the Slieve Bloom Mountains and stretch southwards to Moneygall.

The "reef limestone is the most abundant rock type in Co. Offaly, stretching as three broad bands across the county in a NE-SW direction. It is a light to medium grey, fine-grained, poorly bedded limestone containing many fossils. It was deposited as mounds of fine organic, probably mainly algal, material in a pure sea when the sediment input form the land was minimal. The area of "reef in the east of the county also includes overlying pale, poorly bedded, pure limestones and oolites called the Allenwood Beds. However, there are insufficient data to allow them to be delineated on the map. Dolomite is also common in this area (Dolomitisation is caused when magnesium (Mg) is introduced into limestone ($CaC0_3$), forming dolomite ($CaC0_3$, $MgC0_3$). This results in a theoretical reduction in volume of the rock, which frequently leaves it soft and friable.

Throughout most of Co. Offaly the Reef Limestone is overlain by a dark grey or black, well bedded, muddy limestone called the Calp Limestone. It is rarely fossiliferous and often contains chert. However, north-east of Clara and between Clara and Tullamore, a pure limestone, which is mainly fine grained and fossiliferous, with thin chert horizons and nodules in the lower part, is present.

The youngest limestone forms the spine of the county, stretching from Birr north-eastwards through Kilcormac and Tullamore to the border with Westmeath. It is a pure, pale, thick-bedded, coarse-grained limestone, which is locally dolomitised. A small area of similar limestone, although within shale bands, is present in the south east of the county at Bracknagh.

Carboniferous volcanics

The highest hill in east Offaly - Croghan Hill - is formed from a volcanic plug, a remnant of a volcano that was active in Carboniferous times. It consists of dark grey or black basalt and dark green volcanic ash.

Pleistocene geology

Morphology

The topography of the central midlands, including counties Offaly and Kildare, is dominated by glaciofluvial landforms relating to the final deglaciation (Fenitian) of the area. The most prominent features are the extensive esker chains Photo 1.3) extending across the two counties to the Shannon and continuing westward into the heart of County Galway. Apart from the eskers, there are large spreads of glaciofluvial outwash gravels and glaciolacustrine sands and gravels (Photo 2.2). The Curragh of Kildare is composed of a complex suite of glaciofluvial, glaciolacustrine and glacial sediments in excess of 60 m thick. Its present surface expression, a rolling plateau standing less than 30m above the surrounding topography was probably formed by inwashing of glacial and glaciofluvial debris into a dead ice, or interlobate, basin during deglaciation.

Natural sections or exposures are rare in the glacigenic sediments and the reliance geologists are forced to place on man made sections, particularly in gravel pits, may give the impression of more sand/gravel than in reality exists. Reconnaissance work in County Offaly shows that many of the sand/gravel units are small and are interbedded with diamictons and in places it is not possible to map out separately the sand/gravel and diamicton units. This has led to the term "Till with gravel" being employed to categorise the sediments over extensive areas. This situation is not unusual in sedimentary suites deposited in a deglacial environment where both the environment and the sediment associations have often been termed chaotic. As well as gravel and "till with gravel" large spreads of diamicton (interpreted as till) are common.

Apart from the esker chains, the surface form of the sediments is rarely expressed in easily identified morphological units; exceptions include 1) moraines associated with eskers near I Tullamore (Farrington and Synge, 1970), 2) a thick band of hummocky "morainic" terrain along the western flanks of the Slieve Bloom Mountains, 3) a washboard moraine sequence south of the Tullamore esker in Offaly, and 4) some discontinuous moraine ridges in west Kildare. None of j these features can be easily extended beyond the immediate localities in which they have been [a] identified. On a broader scale the surface morphology as reflected in the drainage pattern is expressed north of the Slieve Bloom Mountains in a series of east-west trending low ridges and valleys. The drainage pattern to the west and southwest of the Slieve Bloom Mountains is similarly expressed by low ridges, running from northwest to southwest. As the raised bogs occupy the lower ground the Quaternary sediment map picks out this alignment. More significantly, the map also reflects the pattern of esker alignment and, west of the Slieve Bloom Mountains, the striae orientation. Regardless of whether this topography is an expression of ice moulding/streamlining or glaciofluvial outwash systems it reflects the pattern of ice movement during deglaciation.

Petrography of the deposits

The glacigenic deposits in the Midlands are derived largely from the underlying Carboniferous limestone. Where they directly overly limestone in County Offaly the total limestone and chert content of the glacigenic deposits averages 80-90% with small amounts of Devonian sandstone, Silurian shale and Carboniferous shale. Galway granite is a common glacial erratic, particularly in the flanks of the Slieve Bloom Mountains where as much as 1.0% of phenoclasts (in a count of 400 stones), in the 5.6-11.2 mm size range, have been recorded as granites. Such erratics have been recorded in till, glaciofluvial gravels and morainic gravels and in south Offaly are commonly found as surface boulders. They have been found as far north as Clara (in the Clara esker) and extend south of Shinrone.

Petrographic analysis of the phenoclasts in the glacigenic deposits shows that limestone and chert have been carried over the Devonian sandstones and Silurian shale of the Slieve Bloom Mountains as the dominant petrographic type for a distance of about 3 km. After this distance the limestone proportion begins to drop suddenly and within 5-6 km it has disappeared entirely from the 5.6-11.2 mm phenoclast size range. This is very similar to the situation that obtains on the northern flanks of the Galty Mountains in south-east Limerick (Synge, 1970). It is clear that two interdependent factors contributed to the rapid disappearance of the limestone component: 1) an exponential distance decay in carry-over, and 2) a rapid decalcification of the sediments after the calcareous component has fallen to a critical level. Further complications in these mechanisms are outlined below. Generally speaking the glacigenic deposits and the periglacial slope deposits of the Slieve Bloom Mountains above about 250 m are dominated by Devonian sandstone and/or Silurian shale and are non-calcareous.

Stratigraphy
Outside the deep glens of the Slieve Bloom Mountains it is difficult to view the stratigraphy of the glacigenic deposits of County Offaly. There are no properly logged borehole records and no clear stratigraphic record. Within the Slieve Bloom Mountain glens, coarse, often poorly sorted, gravels are often seen to overly strongly compacted diamictons. The diamicton varies from a grey silty limestone-rich till to a red sandstone-dominated till. These tills are generally over-consolidated, colour banded and sub-horizontally jointed. They are almost certainly basal deposits and the colour banding suggests they may be melt-out deposits, although there is in places evidence of shearing and phenoclast lodgement. It is likely that both lodgement and melt-out facies occur. Fabric analyses and erratic transport indicate an ice movement from the west.

The overlying coarse gravels have similar petrographic composition to the underlying tills. The sedimentary structures in these gravels, which are often as much as 20 m thick, have not been examined in detail. They are interpreted as proximal glaciofluvial (possibly in part glaciolacustrine) gravels deposited during the down-wasting of the ice sheet. In places they are morainic, contain diamicton lenses and are clearly ice-marginal deposits. There is no evidence that they are associated with any specific glacial halt stage or readvance. It is more likely that they simply accumulated in a convenient topographic position between the mountains and the ice during general deglaciation and it need not be expected that there is an equivalent "moraine" on the lower ground to the north or to the south. Thus there is no evidence of any more than one glacial event in County Offaly.

The deposits of west Kildare offer a little more insight into the glacial history of the area. A reverse circulation borehole at the Curragh Camp showed 63 m of Quaternary sediments. These included three diamicton units separated by sand and gravel units. Persistent Wicklow granite in one of the gravel units suggests a fluvial or glaciofluvial input from the east after initial glaciation but before final deglaciation of the area. Thus, there must have been either an early ice advance from the east into west Kildare or a period between two glacial events during which river gravels were deposited by a river flowing west from the Wicklow Mountains.

Pattern of glaciation and deglaciation
All the evidence points to a strong ice movement from the west across north Offaly and into Kildare. This ice overtopped the Slieve Bloom Mountains but was partly deflected by them to flow south-westward across southern Offaly. The pattern of the esker chains and the Galway granite erratic distribution indicates that during deglaciation the ice-front retreated westward to Galway. There is no evidence of any significant readvance of the ice-front or change in direction of ice-movement during deglaciation.

There is evidence of considerable ponding of melt-water during deglaciation in the clays that drape the tops of many of the eskers and the large deltaic deposits associated with many of them. It is possible that many of the diamictons in the low-lying areas are subaqueous deposits although it should be noted that no clear evidence of drop stones has been observed.

After the ice had melted, periglacial conditions obtained for some time, shown by involutions in the esker gravels at Geashill. At this time also it is likely that the diamictons on the steep slopes of the Slieve Bloom Mountains were reworked by gelifluction. This is evident from recent road sections.

In the postglacial period, extensive alluvial deposits accumulated in the flat river valleys. Shell marls also accumulated and peat began to develop on the poorly-drained low-lying areas.

The eskers

Eskers (derived from the Gaelic term 'eiscir') are typically long sinuous sand/gravel ridges. They are composed of glaciofluvial sediments that accumulated in subglacial or englacial tunnels or, in part, close to the glacier snout in ice-walled channels. They reflect the chief meltwater routes taking water from the glacier system to its margins and usually parallel the most recent direction of ice movement. They commonly contain a variety of sediment types ranging from very coarse boulder gravels to lacustrine silts and clays. The coarsest sediments reflect very high energy environments consistent with subglacial tunnels while the finer deposits may react to subglacial or ice-marginal ponding. The sediments are often faulted towards the sides in response to the removal of a supporting ice-wall. More complex faulting also occurs, reflecting ice-melt under the deposit at ice-push of one form or another.

The eskers of the Midlands are among the finest in the world, although Charlesworth (1928) mistakenly regarded many of them as moraines. He gave the term esker to the scientific literature and it has a pedigree in Irish literature that extends back to Old and Middle Gaelic sources. Following an ancient tradition, many roads across the Midlands have been built on the eskers which provide an excellent foundation through otherwise boggy or difficult terrain (Photo. 1.1).

The eskers of the Irish midlands may be regarded as the original or proto-type eskers. They are known and visited by geologists from many parts of the world. It is unfortunate that so many of them are being systematically (and often haphazardly) destroyed for the purpose of sand/gravel extraction (Photo 1.3). It is hoped that the recent raising of awareness of the amenity value of midland bogs will be accompanied by an equal awareness of the essential contribution which the eskers make to the Midland landscape and to our aesthetic and scientific enjoyment.

Photo 2.1: Sandstone section in the Slieve Bloom Mountains. *(R.F. Hammond)*

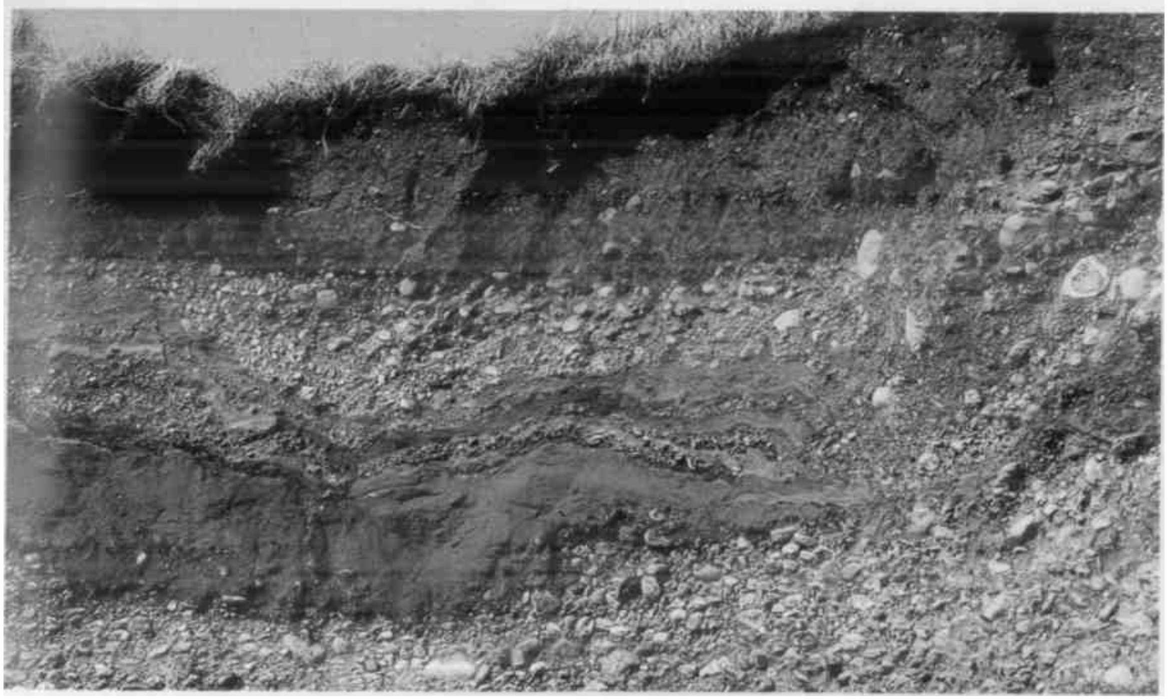


Photo 2.2: Section through gravel deposit showing irregular bedding and discontinuity in size fractions. *(R.F. Hammond)*

CHAPTER 3

CONSIDERATIONS IN SOIL SURVEY

Introduction

Soil is the natural medium for the growth of land plants. Although the soil mantle of the earth is far from uniform, all soils have certain factors in common. Every soil consists of mineral and organic matter, living organisms, water and air. The relative proportions of these components vary between soils. As a small segment of the earth's surface, every soil extends downwards as well as laterally and must, therefore, be regarded as being three-dimensional, having length, breadth and depth.

The soil profile

The soil profile refers to a vertical section of the soil down to, and including, the geological parent material. The nature of the soil profile is important in many aspects of plant growth, including root development, moisture storage and nutrient supply. The profile is, therefore, the basic unit of study in assessing the true character of a soil. It usually displays a succession of layers that may differ in properties* such as colour, texture, structure, consistence, porosity, chemical constitution, organic matter content and biological composition. They are known scientifically as **soil horizons.**

Soil horizons

Most soil profiles include three main or master horizons that are usually identified by the letters A, B and C (Fig. 3.1). The combined A and B horizons constitute the so-called solum or "true soil" whilst C refers to the assumed parent material. Certain soils lack a B horizon and are said to have AC profiles. In some soils also organic layers (O horizons) overlie the mineral horizons. An E master horizon is also recognised, while hard rock, within reach of biological activity is labelled R.

Some soils may have a relatively uniform profile with A and C horizons whilst others are so complex that they possess not only O, A, B, E and C horizons, but also several sub-horizons. Where a vertical sub-division is necessitated on the basis of minor differences, for example within a C horizon successive layers could be CI, C2, C3, and so on. These conventions apply whatever the purpose of the sub-division. Where morphological differences are apparent within a horizon such as texture (t), gleying (g), colour (w), divisions are numbered consecutively. The numbering starts at 1 at whatever level in the profile any element of the letter symbol changes. Thus Btl-Bt2-Btgl-Btg2. The various horizons in a soil and their character reflect the processes of soil formation

Texture, structure and porosity are defined and discussed in Appendix 1 that have been operative, and present a picture of the true nature and salient characteristics of a soil which are important in its use and management.

The A horizon

This horizon is the uppermost layer in mineral soils and corresponds closely with the so-called "surface soil". It is that part of the soil in which living matter, e.g. plant roots, bacteria, fungi, earthworms, and small animals is most abundant, and in which organic matter is usually most plentiful. Being closest to the surface, this horizon is the first to be reached by rainfall and is, therefore, more leached than underlying horizons. The A horizons in most Irish soils have been depleted of soluble chemical substances and, in certain cases also, of some of their very fine clay particles. In cases where the soils have been strongly leached they may be depleted of iron and aluminium oxides and of other constituents.

Two sub-divisions of the A horizon are commonly made, namely Al and A2. Either the A1 or both may be represented in a profile. The Al is a surface mineral horizon that usually contains a higher

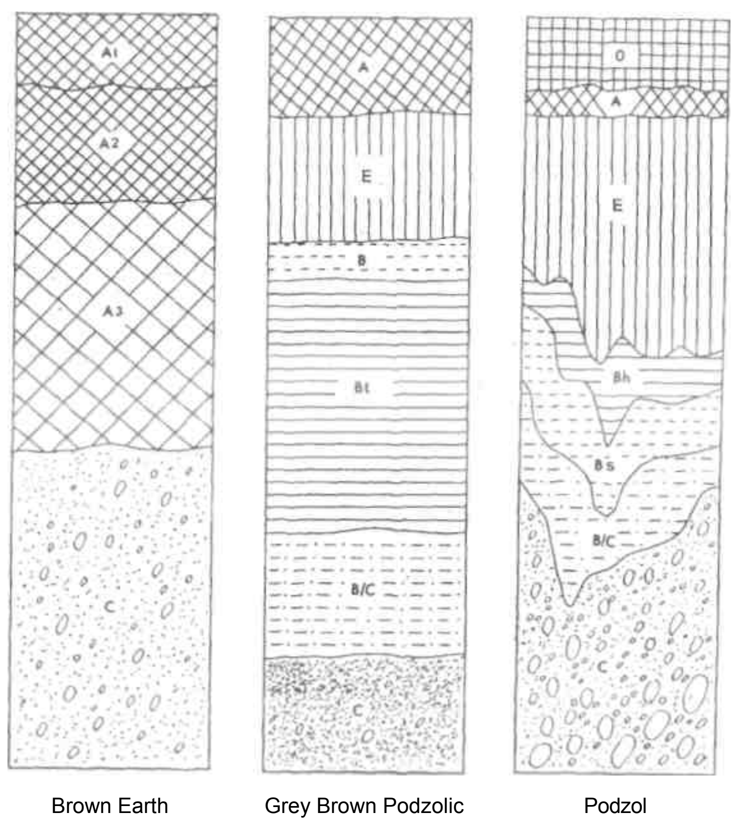


Figure 3.1: Diagrammatic representation of three common soil profiles.

proportion of organic matter, incorporated with the mineral matter, than any of the underlying horizons. In cultivated soils this horizon corresponds to the plough layer and may be designated Ap. The A2 is usually underneath the Al and has less organic matter. A3 signifies a transition zone or horizon between the A and B horizons or A and E horizons.

The E horizon

This horizon is comparatively light-coloured and frequently has a bleached appearance. These characteristics reflect the partial removal of colouring constituents, principally iron.

The B horizon

This horizon occupies a position beneath the A or E horizons and corresponds closely to the so-called "subsoil". Lying between the A and C horizons, it possesses some of the properties of both. Living organisms are fewer than in the A but more abundant than in the C horizon. Compared with the A horizon, the B horizon is generally one of accumulation and usually has a relatively high content of iron and aluminium oxides, humus or clay that, in part at least, have been leached from the overlying horizons. A more pronounced blocky or prismatic structure is found where this horizon is clay-enriched. Stronger colours are apparent in the B horizon, especially when the accumulation products are iron oxides or humus or both.

Depending on the degree and pattern of accumulation of constituents within the B horizon, symbols such as Bt, Bs and Bh are used to denote different kinds of B horizon such as significant accumulations of clay, iron and humus respectively. If the B horizon is without any appreciable accumulation of leached products but has distinctive colour or structure characteristics, it is usually referred to as a Bw horizon. Transitional or mixed horizons are denoted by using both letters, e.g. BC. B/C.

The C horizon

This horizon refers to the geological material beneath the A and B horizons (solum). It consists of the upper part of the loose and partly decayed rock or other geological material, such as glacial drift, similar to that from which the soil has developed. It may have accumulated locally by the breakdown of the native rock or it may have been transported by ice, water or wind. The C horizon is less weathered, generally has less organic matter and is usually lighter in colour than overlying horizons. It may be modified by gleying (Cg), indurated (Cm) or fragipan characteristics (Cx).

The O horizon

A surface layer of raw or partly decomposed organic matter, more usually associated with very poorly drained mineral soils or organic (peat) soils. Where little or no decomposition has taken place the symbol 01 is used; 02 denotes more advanced decomposition. Where the anthropomorphic factor has altered the surface horizon the symbol Oap is used. The organic matter content of O horizons is commonly several times greater than that of the underlying mineral horizons or of surface A horizons. Where organic accumulations form peat the horizonation or stratigraphy is defined by the symbols Oi, Oe and Oa; denoting high, medium and low fibre contents respectively.

The R horizon
Consolidated bedrock underlying the profile.

Factors of soil formation
The character of every soil can be attributed largely to the interaction of five major factors of soil formation: 1) parent material, 2) climate, 3) living organisms, 4) topography, and 5) time. These factors control the rate of weathering of rocks, the constitution and composition of the resultant soils, and subsequent gains, losses and alterations within the profile. The relative influence of these factors is responsible for many of the differences in our soils. Man's interference with the natural development processes may be regarded as a sixth factor influencing the modification of the soils.

1) Parent material
Parent material may be either solid rock, which has weathered, or some superficial deposit such as glacial drift or alluvium that has been derived from weathered rocks and transposed. Rocks vary greatly in composition, and such variation is reflected in the soils derived from them. For example, quartzite is highly resistant to weathering and during its slow weathering process little clay is formed and release of mineral nutrients is poor. Besides being inherently poor, soils on such materials degrade easily as the leaching process outpaces the rate of weathering. Fortunately, most rocks are mixtures of many minerals, few of which are able to withstand weathering as well as quartz. Glacial drift, the most common parent material of Irish soils, varies considerably in constitution and in geological composition, giving rise to many different soils.

2) Climate
Even on uniform geological parent material, soils may vary widely due to environmental factors that influence them in their genesis, formation and development. One of the most active agents in this regard is climate. It is now recognised that our post-glacial climate showed distinct variations over time, and current climate varies widely from season to season and from region to region. The main element of our climate influencing soil development is the rainfall-evaporation regime. With the ratio balanced well in favour of rainfall, most of our soils tend to be leached to varying degrees, being strongly podzolised in more extreme cases. Apart from leaching, the humid climate is also partially responsible for the extensive areas of wet gley soils and for much of the peat formation in the country.

3) Living organisms
Living organisms in the soil include plants, animals, insects, fungi, bacteria and other biological

forms. These play an important role in soil development, such as determining the kind and amount of organic matter that is incorporated in the soil under natural conditions. They also govern the manner in which organic matter is added, whether as leaves and twigs on the surface or as fibrous roots within the profile. The rate of organic matter decomposition is strongly influenced by the type and activity of organisms present. Plants can reverse the leaching process in part: the roots take up calcium, potassium, phosphorus and other elements from the lower horizons and, on the decay of leaves, roots and other plant remains, return them to the surface.

The nature of the vegetative cover itself is known to have a decided influence on soil development. Other factors being equal, a forest cover promotes a different soil-forming process than either grass or cultivated crops. Trees also differ in their influence on soil development; in general, conifers are more conducive than broad-leaved trees to soil degradation and podzol formation, particularly on acid parent materials. Certain forms of ground cover, e.g. heath, also promote podzol formation. Most Irish soils and most of those in Co. Offaly developed under deciduous forest cover throughout the Holocene Epoch *(ca.* last 10,000 years).

Earthworms, insects, and microorganisms, e.g. fungi, and bacteria perform many functions in the soil and strongly affect soil character and behaviour.

4) Topography

Since topography governs the position of a soil on the landscape, it is important in many respects, especially in its effect on water runoff and drainage. The amount of water that moves through a soil is less on steep than on gently slopes, low-lying or flat areas. This accounts, to some extent, for the preponderance of poorly-drained soils in low-lying areas. Soils of poor drainage, however, may be found on moderate slopes where the lower soil horizons or parent material is of low permeability, leading to retardation of water movement.

Elevation, with its attendant climatic, erosion and vegetation characteristics, strongly influences the soil development pattern. Other features such as slope shape and length and those related to aspect are also important topographical features. Apart from its influence on soil formation, topography can be an important factor in deciding the use of soils.

5) Time

Considerable time is needed for the accumulation of soil parent material and for the development of horizons in the soil profile. The degree of maturity of a soil depends to a large extent on age, and also on the parent material and other factors. Soils developed on young deposits, such as alluvium, show less distinct horizons, in general, than those developed on old materials over a longer period. As pointed out above, virtually all Co. Offaly soils are derived from Quaternary and Holocene deposits.

Differences and similarities among soils

None of the above five factors of soil formation is universally uniform. There are many kinds of rocks, many types of climate, and many combinations of living organisms, great variation in topography and in age of different land surfaces. As a result there are innumerable combinations of the factors of soil formation, giving a multitude of different soils.

Differences among soils are both local and regional. Most farms consist of local kinds of soil, of importance to management and productivity, whilst over the whole country there are also many different soils. Although it is true that great variability exists, the distribution is not so haphazard as might be expected. Each soil reflects the environment in which it has formed, occupies a definite geographic area and occurs in certain patterns with other soils. By recognising the main factors of soil formation and by distinguishing the reflected characteristics in the soils themselves, we can identify different soils (Soil Series) and segregate them into geographic units. Thus similarities and differences among soils can be recognised, and the various soils can be classified and their distribution depicted on maps.

Soil Series

It is principally on the basis of profile character, as expressed by the nature of the various horizons, that soils are classified and mapped. Although each profile has its individual character, some have so many important features in common that they can be placed together in a single primary category. The primary category used in mapping is the **Soil Series,** which comprises soils with similar type and arrangement of horizons, and developed from similar parent material. The Soil Series is also a basic category in a soil classification system.

A major problem in mapping soils is the delineation of boundaries between different Series. Typical profiles of two different Soil Series may differ widely but, where the Series are contiguous, it is usual for them to merge, sometimes over a considerable distance. Consequently, a line on the map very often defines the merging zone between soils rather than a sharp change in the soil character.

A Soil Series is named usually after the location in which the particular soils were first identified and classified, and are best expressed or occur most widely.

Soil variants

Variants are really separate Soil Series that are too small in extent to be shown at the scale of mapping adopted. A soil which is recognised and defined as a variant in one survey, however, may be designated as a separate Series later in another area, depending on its extent.

Other soil units

Soils within a series may be further sub-divided into **soil types** on the basis of textural differences in the surface soil. Different **soil phases** may also be mapped, covering variations in features, such as slope, depth or stoniness, that are important in soil behaviour and land use. Segregation at these levels requires more detailed survey than that employed in County Offaly.

Soil Associations

To relate soils to their environment and, in particular, to their geological parent materials, two or more series may be grouped into larger mapping units, or **Soil Associations.** A Soil Association is a grouping of series developed on similar parent materials but varying in profile character as a result of differences in other soil-forming factors. Soils within the same Association, therefore, although they may fall into a number of series on the basis of profile differences, have important physical and chemical properties in common, which have been inherited from the same parent material. The Association unit has not been employed generally in County Offaly, but the Soil Series of the county are grouped in this manner in Chapter 11.

Scale of mapping

Field mapping was carried out using base maps at a scale of 6 inches to 1 mile (1:10,560) but this detail is reduced to a scale of 1/2 inch to 1 mile (1:126,720) for publication. Since one 6-inch sheet covers an area of 24 square miles, to publish on this scale would necessitate, in the case of County Offaly, 47 individual map sheets. Considerations such as the cost of colour printing, ease of handling and general use of the map warranted the reduction to the smaller scale.

This reduction, however, introduces certain difficulties. It has been found necessary to consolidate and, in some cases, delete some of the least extensive soil separations shown on the large scale. The minimum area that can be represented on a soil map printed to a scale of 1:126,720 is 12 ha. The consolidation of intricate distribution patterns of mapped Soil Series in preparation of the soil map, results in soil units of less than 12 ha in extent being combined into a **soil complex** mapping unit. The component Series within the complex are named and, where possible, their relative proportions are given.

To accommodate those who are interested in more detail for special purposes, the field sheets (at a scale of 1:10,560) showing the entire field survey records are retained for consultation at Teagasc, Johnstown Castle, Wexford.

Description of soil profiles

During the survey of Co. Offaly, profiles typical of each soil were selected for special study. Fresh profile pits were opened for this purpose. The depth of pit varied according to soil depth but was usually about 1.3 - 1.6 m. Each profile is thoroughly examined and described and a record made of its salient characteristics.

Soil profiles were described by first noting certain features of the soil's environment, followed by details of its general characteristics. The characteristics of the site include relief, slope, aspect, elevation and vegetation. Drainage conditions and the pattern of horizon development within the profile are considered next and, finally, properties of the individual soil horizons such as texture, structure, consistence, colour, mottling, amount of organic matter, stoniness, presence of hardpans and root development are described.

A bulk 1-2 kg sample was taken from each soil horizon and forwarded for physical and chemical analyses at the Soils Laboratory, Johnstown Castle. The analytical data supplement many of the field observations and provide a more complete picture of the true soil character. The results of these analyses for representative profiles of each Soil Series are given in the body of the text.

In the course of describing the soil's morphology, and bulk sampling the different horizons, profile drawings were also made. These were executed by draping clear acetate sheet over the cleaned profile face and a number of different features outlined with contrasting colour markers.

The locations of the soil profiles described and sampled in the course of the soil survey of Co. Offaly are shown in Fig. 3.2.

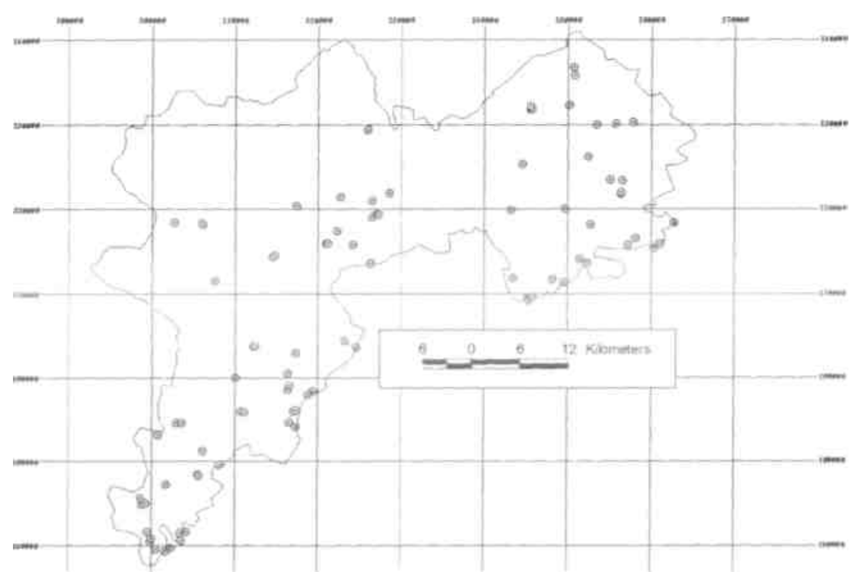


Figure 3.2: Sampling locations of soil profile pits, Co. Offaly.

CHAPTER 4

THE SOILS AND THEIR USE RANGE

Fifty seven soil mapping units, comprising 31 Soil Series, nine phases and 17 soil complexes were differentiated in County Offaly. The Soil Series, the basic mapping unit, was assigned a name according to the locality where the Soil Series was first identified and classified, e.g. Patrickswell Series first identified and mapped in Co. Limerick. In the course of the mapping programme five new Series were defined; the remaining Series had all been mapped in previous surveys conducted in the counties neighbouring Co. Offaly. This is to be expected due to the similar climatic regime and the nature of the soil parent materials from which these soils are formed.

The soils can be grouped into two quite distinct physiographic units: 1) Lowland, and 2) Hill and Mountain. The descriptions of the various Soil Series are arranged according to Great Soil Groups within each physiographic unit; soils derived from alluvial and peat deposits and complexes are treated separately.

LOWLAND SOILS

The topography of the lowlands of Co. Offaly extending from the Shannon Basin in the west of the county to the Kildare border in the east is gently undulating. The soils pattern is influenced by the thickness and variability of the mantle of glacial drift (Chapter 2), which covers the underlying bedrock formations. The drift materials vary from rather compact tills to the characteristic esker gravels. On the higher parts of the topography Grey Brown Podzolic and Brown Earth Soils dominate whilst, at lower levels, Gleys, Peats and Alluvial soils predominate.

Rendzina Group

Rendzinas are shallow soils less than 50 cm deep, derived from parent material containing over 40% carbonates. The surface horizon is dark coloured with a well-developed structure and neutral or alkaline reaction. A calcareous B-horizon may be present but generally the A horizon directly overlies the calcareous parent material. Two Series were recognised, Burren and Crush.

Burren Series

This Series, first mapped in Co. Clare, is found in the northwest of the county. It is of very limited extent, occupying only 146 ha (0.05%) of the county. It usually occurs intimately associated with outcropping bedrock and with the Ballincurra Series. The relief, in general, is undulating and the elevation is about 60 m. The profile (see below) is characterised by a dark-brown A horizon, with moderate crumb structure, overlying limestone bedrock which outcrops frequently. Roots are abundant. The soil is generally less than 25 cm thick. The analyses (Table 4.1) shows that the profile has a slightly peaty to organic clay loam texture and with slightly acid pH, higher than average organic carbon levels which are reflected in high cation exchange capacity values.

Soil suitability: These soils have a very limited use-range; due to shallow soil depth and frequent rock outcrops, tillage on a conventional basis is not practicable. The agricultural use is confined to grazing but output is restricted by low available water content. It is poorly suited to forestry.

Representative profile description: Burren Series

Location:	Rineanna North townland, Co. Clare, Grid Ref. 135033 159799
Relief:	Level
Slope of site:	1°
Elevation:	lOmO.D.
Vegetation and land use:	Not classified
Drainage:	Well drained
Parent material:	Limestone bedrock with some drift
Great Soil Group:	Rendzina

Horizon	Depth (cm)	Description
Al	0-3	Slightly peaty clay loam; dark brown (10YR3/3); moderate, fine crumb structure; moist, slightly plastic; abundant roots, forming a root mat; clear, smooth boundary.
A2	3-7	Organic clay loam; brown to dark brown (10YR4/3); moderate, fine to medium crumb structure: friable; plentiful roots; abrupt. smooth boundary.
R	Below 7	Limestone bedrock.

Table 4.1: Profile Analyses - Burren Series

Horizon	Al	A2	R
Depth (cm)	0-3	3-7	7+
Particle size distribution analysis (%)			
Coarse sand	12	15	
Fine sand	12	15	
Silt	45	41	
Clay	31	29	
PH	6.0	6.5	
CEC, mEq/100 g	59.2	52.4	
TEB, mEq/lOOg			
Base saturation, %			

Table 4.1: Profile Analyses - Burren Series (cont.)

Carbon, %	12.8	10.0	-
Nitrogen, %	1.25	1.05	
C/N ratio	10.2	9.5	
Free iron, %	2.3	2.2	-
TNV, %			

Crush Series

The Crush Series differs from the Burren Series in being developed in calcareous gravels rather than in weathered limestone rock, is of limited extent and confined to the crests of eskers and to a component of the Baggotstown-Crush complex. Profiles are very shallow with humic, gravelly, loamy-sand texture and moderately developed granular structure in the surface. The sub-surface horizon has gravelly coarse sand texture, single grain structure and loose consistence. The profiles are generally very calcareous throughout. This soil is prone to drought, even after short dry periods, due to rapid permeability and poor water-holding capacity. Land use is also restricted due to its position on the crests of eskers. The soil generally supports vegetation of poor pasture grasses, mixed herbs and scrub. The representative profile described below has three horizons even though analytical data are only available for the A and C horizons (Table 4.2). It has a higher pH and lower organic carbon and free iron content than the Burren Series.

Representative profile description: Crush Series

Location:	Ashfield townland, Co. Offaly, Grid Ref. 227850 230600
Relief:	Steeply sloping esker
Elevation:	65 m O.D.
Slope of site:	5°
Vegetation and land use:	Scrub and poor grasses
Drainage:	Excessively drained
Parent material:	Glacio-fluvial gravels and sands
Great Soil Group:	Rendzina

Horizon	Depth (cm)	Description
Al	0-14/17	Gravelly loamy sand; very dark brown (10YR2/2), dark grey (10YR4/1) dry; moderately developed fine to medium granular structure; moist friable; common fibrous roots and few coarse fleshy bracken root stocks; very calcareous; sharp, slightly wavy boundary.
	14/17-18/21	Gravelly medium and fine sands; dark greyish brown (2.5Y4/2), light brownish grey (2.5Y6/2) dry; single grain structure; compact very weakly cemented *in situ;* moist loose; few fine fibrous roots; very calcareous; slightly wavy boundary.
2C	18/21 +	Sand; very dark grey (2.5YN3/0), dark grey (5YN4/0) dry; single grain structure; moist loose; very calcareous.

Table 4.2: Profile Analyses - Crush Series
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Horizon Depth (cm)	Al 0- 14	C 14-21	2C 21+
Particle size distribution analysis (%)			
Coarse sand	55	69	
Fine sand	8	18	
Silt	18	11	
Clay	19	2	
pH	6.8	8.7	-
CEC, mEq/100 g	-	-	-
TEB, mEq/100 g	-	-	-
Base saturation, %	-	-	-
Carbon, %	8.0	-	-
Nitrogen, %	0.73	-	-
C/N ratio	11	-	-
Free iron, %	0.9	0.2	-
TNV, %	-	47.0	-

Brown Earth Group

The Brown Earth Group are well-drained soils possessing rather uniform profiles with little differentiation into horizons. They have not been extensively leached or degraded with the result that there are no obvious signs in the profile of removal and deposition of materials such as iron oxides, humus or clay. However, in many cases a certain degree of leaching has taken place, resulting in the translocation of soluble constituents notably calcium and magnesium. Two Series, already mapped and described in other counties, were identified, namely Baggotstown and Ballineurra.

Baggotstown Series

The Series is widespread in west Offaly, occupying 4061 ha (2.0%) of the county. The Baggotstown Series was first mapped in Co. Limerick. In Co. Offaly it occurs on gently undulating terrain associated with outwash fans, eskers and kame-and-kettle topography. It is derived from sand and gravel materials of predominantly limestone origin (Photo 4.1, Figs. 4.1, 4.2) with occasional inclusions of sandstone or shale depending on the provenance of the glacial drift. The combination of coarse texture and topographical position results in free drainage. Solum depth is shallow to moderately shallow (30 - 45 cm); in certain instances it may be as deep as 70 cm. Roots are well distributed in the A and B horizons but decrease sharply in the C horizon. Three profiles, presented below, were sampled and described to represent the Series location in different areas. The analyses are presented in Tables 4.3,4.4 and 4.5. All three profiles are alkaline in reaction with the exception of the surface horizon in Profile 1, which is very slightly acid, high in base saturation, and relatively low in organic carbon content. Clay content of the profiles is on average 16_19%; there is, however, a clay "bulge" in the B/C horizon of Profile 1 which can be considered as being inherited from the parent material.

Soil suitability: These soils have a moderately wide use range and are limited only by shallowness, drought risk, and in places, by slope. They are easily cultivated, maintaining continuous tillage and suited to malting barley. Due to good soil structure and drainage, Baggotstown soils can be grazed early and late in the grazing season without serious risk of poaching.

Representative profile description: Baggotstown Series 1

Location:	Clynoe townland, Co. Offaly, Grid Ref. 201111 180646
Relief:	Gently undulating moraine, top of knoll
Slope of site:	Simple 2°
Elevation:	125mO.D.
Vegetation and land use:	Barley
Drainage:	Well to excessively well drained
Parent material:	Fluvio-glacial gravels
Great Soil Group:	Brown Earth

Horizon	Depth (cm)	Description
Al	0-17	Gravelly loam; very dark greyish brown (10YR3/2) dry br (10YR5/3); weakly developed fine to very fine granular structure; moist friable; dry soft; abundant very fine fibrous roots; clear, smooth boundary.
A2	17-29	Gravelly loam; dark greyish brown (10YR4/2) to brown (10YR4/3) dry pale brown (10YR6/3); weakly developed granular structure; moist friable dry soft; many very fine fibrous roots; slightly wavy, gradual boundary.
Bw	29-40	Gravelly loam; brown (10YR4/3) dry pale brown (10YR6/3); weakly developed granular structure; moist friable dry soft to slightly hard; locally many fine fibrous roots following in filled voids; slightly wavy with irregular tongues, clear boundary.
B/C	40-54	Gravelly loam; dark greyish brown yellowish brown (10YR4/2); to brown (10YR4/3) dry yellowish brown (10YR5/4); massive structure; moist friable; dry soft; abrupt, wavy boundary.
	54+	Stony gravelly sand loam; very dark grey (5Y3/1) dry light grey 5Y7/1; massive loose structure; friable; calcareous.

Table 4.3: Profile Analyses - Baggotstown Series 1

Horizon Depth (cm)	A1 0-17	A2 17-29	Bw 29-40	B/C 40-54	C 54+
Particle size distribution analysis (%)					
Coarse sand	30	32	36	30	56
Fine sand	18	17	15	11	9
Silt	32	32	34	33	23
Clay	20	19	15	26	12
pH	6.5	7.0	6.9	7.7	8.4
CEC, mEq/100g	19.0	8.4	11.6	15.2	3.0
TEB, mEq/100g	9.36	3.85	7.44	10.35	3.48
Base saturation, %	49	46	64	68	Sat
Carbon, %	2.4	1.7	0.2	0.4	0.1
Nitrogen, %	0.24	0.11			
C/N ratio	10.0	15.4			
Free iron, %	1.9	1.8	1.7	2.8	0.9
TNV, %			0.5	0.5	45.8

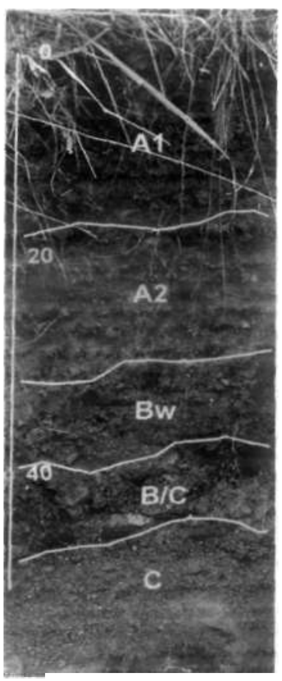

Photo 4.1: Profile of Baggotstown soil.
(R.F. Hammond)

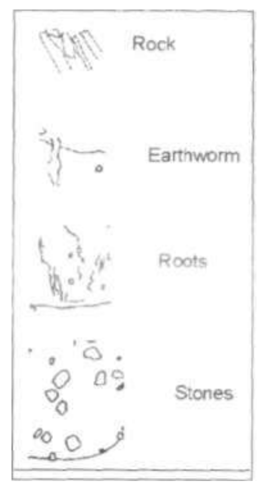

Figure 4.2: Legend for soil profile drawings, Figs. 4.1 and 4.6.

Figure 4.1: Line drawing of Baggotstown soil illustrating gravelly, stony sub-soil.

Representative profile description: Baggotstown Series 2

Location:	Screggan townland, Co. Offaly, Grid Ref. 284500 222500
Relief:	Gently undulating moraine, on top of knoll
Slope of site:	Simple 2°
Elevation:	82 m O.D.
Vegetation and land use:	Barley
Drainage:	Well to excessively well drained
Parent material:	Fluvio-glacial sands and gravels
Great Soil Group:	Brown Earth

Horizon	Depth (cm)	Description
Ap	0-15	Dark brown (7.5YR3/2); greyish brown (10YR5/2); dry; loam; weak fine to fine granular structure; dry loose; many fine and very fine roots; clear, smooth boundary.
Bw	15-29	Dark brown (7.5YR4/2); light brownish grey (10YR6/2) dry fine gravelly loam; weak fine sub-angular blocky, breaking to simple grain in places; dry loose; common fine and very fine roots; abrupt, irregular boundary.
B/C	29-42/45	Dark greyish brown (2.5YR4/2); sandy loam; weak structure; dry loose; common roots; calcareous; abrupt, irregular boundary.
	42/52	Olive grey (5YR4/2); sands fine to medium gravels; structureless; loose single grain; dry loose; roots common; highly calcareous.

Table 4.4: Profile Analyses - Baggotstown Series 2

Horizon	Ap	Bw	B/C	C
Depth (cm)	0-15	15-29	29-42	42/45+
Particle size distribution analysis (%)				
Coarse sand	35	19	28	28
Fine sand	31	19	32	18
Silt	40	14	29	17
Clay	61	12	17	10
pH	7.5	7.8	8.0	8.2
CEC, mEq/100 g	29.8	17.6	12.2	4.0
TEB, mEq/lOOg	24.0	13.4	9.6	5.4
Base saturation, %	80	76	79	Sat
Carbon, %	3.3	0.8	0.3	0.5
Nitrogen, %	0.35	-	-	-
C/N ratio	9.4	-	-	-
Free iron, %	1.3	1.3	1.0	0.4
TNV, %	3.3	6.1	35.1	67.8

Representative profile description: Baggotstown Series 3

Location:	Killooly townland, Co. Offaly, Grid Ref. 227800 216900
Relief:	Undulating terrain
Slope of site:	l°-2° slight concave
Elevation:	84 m O.D.
Vegetation and land use:	Mixed farming
Drainage:	Well to excessively well drained
Parent material:	Calcareous glacial drift, predominantly of fluvio-glacial origin
Great Soil Group	Brown Earth

Horizon	Depth (cm)	Description
Ap	0-16	Dark brown (10YR3/3) light brownish grey (10YR6/2) dry; loam; very weak structure breaking to fine medium angular clods; moist friable; dry soft; many fine and very fine roots; weak effervescence; clear, smooth boundary.
Bw	16-25	Dark yellowish brown (10YR4/4); loam; weak, fine sub-angular bloeky structure; common macro-pores; common very fine roots; moderate effervescence; abrupt, wavy boundary.
	25+	Greyish brown (2.5Y5/2); to light olive brown (2.5Y5/4) with dark yellowish brown patches (10YR4/4) fine gravelly loam; massive structure; when dry cemented in places; compact *in situ;* moist friable firm; many macropores; common, very fine roots; vigorous effervescence.

Table 4.5: Profile Analyses - Baggotstown Series 3

Horizon	Ap	Bw	C
Depth (cm)	0-16	16-25	25+
Particle size distribution analysis (%)			
Coarse sand	23	22	1
Fine sand	27	24	23
Silt	32	34	41
Clay	18	20	18
pH	7.6	7.8	8.
CEC, mEq/100 g	32.0	19.0	4.
TEB, mEq/100 g	16.9	12.4	5.
Base saturation, %	53	65	Sa
Carbon, %	3.9	0.9	0.1
Nitrogen, %	0.24	0.12	
C/N ratio	16.3	7.5	
Free iron, %	1.1	1.1	0.5
TNV, %	1.2	1.7	9.4

Ballincurra Series

This Series was, similarly, first mapped in Co. Limerick. It is of very limited extent occupying 461 ha (0.23%) of the county. These soils are shallow and well to excessively well drained. The profile displays a very dark greyish brown surface horizon overlying a pale brown sub-soil resting on bedrock. Soil consistence is friable and structure is very weak apart from the surface horizon where it is moderately developed. Roots are abundant in the surface but decrease in content with depth. The analytical data (Table 4.6) show that this soil has high pH reflected in the total neutralising values, saturated base status, and moderately high organic carbon content.

Soil suitability: These soils are unsuitable for arable cropping due to shallowness and proximity to bedrock. However, in some locations the soil depth is satisfactory and suited to arable cropping. Low moisture holding capacity is a severe limitation for both arable crops and grass production.

Representative profile description: Ballincurra Series

Location:	Newpark townland, Co. Clare, Grid Ref. 146338 1638
Relief:	Rolling
Slope of site:	6°
Elevation:	60 m O.D.
Vegetation and land use:	Old pasture
Drainage:	Well to excessively drained
Parent material::	Drift of limestone composition (with a little sandstone and shale)
Great Soil Group:	Brown Earth

Horizon	Depth (cm)	Description
AI	0-5	Gravelly loam; very dark greyish-brown (10YR3/2); moderate, medium crumb structure; friable; abundant rooting; gradual, smooth boundary.
A2	5-9	Gravelly loam; very dark greyish-brown (10YR 3/2); weak, fine sub-angular blocky to weak, medium crumb structure; friable; plentiful rooting; clear, smooth boundary.
Bw	9-12	Gravelly silt loam; pale-brown (10YR6/3); weak, fine crumb structure; friable; few roots; abrupt, irregular boundary.
R*	Below 12	Limestone rock.

* R refers to consolidated bedrock underlying the profile.

Table 4.6: Profile Analyses - Ballincurra Series

Horizon	Al	A2	Bw	R
Depth (cm)	0-5	5-9	9-12	12+
Particle size distribution analysis (%)				
Coarse sand	19	19	11	
Fine sand	26	25	19	
Silt	34	34	34	
Clay	21	22	12	
pH	7.7	8.0	8.0	
CEC, mEq/100 g	30.0	17.5	8.3	
TEB, mEq/100 g				
Base saturation, %				Sat
Carbon, %	6.9	3.2	1.5	
Nitrogen, %	0.63	0.30	0.16	
C/N ratio	11.0	10.7	9.4	
Free iron, %	1.3	0.9	0.6	
TNV, %	11.4	19.1	41.4	

Grey Brown Podzolic Group

Grey Brown Podzolic soils have a significant increase in clay in the B horizon relative to the horizon above, which is believed to have been translocated from the overlying horizons. They usually have light-coloured A horizons and medium or high base status. A sub-surface E horizon, with light colour and low organic matter or iron content, may form between the A and B horizons. The Series are generally developed on calcareous or base-rich parent materials. Four Soil Series were recognised one of which, Patrickswell Series, included three phases; the others are Elton, Mortarstown and Knock.

Elton Series

The Elton Series occurs mainly in the east of the county. It occupies 10,082 ha (5.06%) of the county and also occurs in complexes with Patrickswell and Baggotstown Series. The soil has been mapped at elevations of between 90 and 200 m O.D. on undulating topography. The parent materials are calcareous, consisting of limestone-dominated tills with an admixture of sandstone and shale and a total neutralising value (TNV) of 20 -30%. The content of the sandstone and shale depends on the proximity to the Devonian/Silurian bedrock formations. In the south west of the county sandstone contents tend to be greater due to carry-over by localised ice flow from the Slieve Bloom Mountains and other formations to the northwest. The descriptions of two Elton profiles are given below, representative of its occurrence in the east and southwest of the county, respectively.

The main characteristics of the Series are a relatively deep profile development and a relatively modest increase in clay content in the Bt horizon compared to the horizon above. The well-drained friable solum always exceeds 75 cm in depth. The surface horizon is a dark greyish brown loam overlying a brown or dark brown Bt horizon with loam to clay loam texture. Soil structure is generally weak but roots are abundant in the surface horizon and extend down to the bottom of the solum at 75 cm or more. Table 4.7 shows the soil of high pH and base status, moderately high organic carbon content and a B/E clay ratio of 1.3 with an accompanying increase in free iron in the Bt horizon. In contrast Table 4.8 shows a soil of moderate acidity with medium base saturation, a B/E clay ratio of 1.5 and an increased free iron content in the Bt horizon.

Soil suitability: The deep Elton soils with their good moisture holding capacity are some of the most productive soils in the county and have a wide use range (Photo 4.2). Elton soils have a very high potential for grass production and normally can be grazed over a long season. However, these soils with weak structure and somewhat heavier textures in the surface horizons can be prone to poaching and surface compaction if stocked during wet periods. High yields of arable crops, especially winter cereals can be obtained but weak structure and consistence limit their suitability for spring crops.

Representative profile description: Elton Series 1

Location:	Ballina townland, Co. Offaly, Grid Ref. 258300.231300
Relief:	Gently undulating moraine
Slope of site:	2° straight simple
Elevation:	94 m O.D.
Vegetation and land use:	Cocksfoot, Tall Fescue, Ryegrass ley
Drainage:	Well drained
Parent material:	Calcareous stony boulder till
Great Soil Group:	Grey Brown Podzolic

Horizon	Depth (cm)	Description
Ap	0-10	Loam; dark brown (10YR3/3); weak sub-angular blocky to granular structure; moist friable; moderate permeability; many roots; clear smooth boundary.
A2	10-36	Loam; (10YR3/3); weak sub-angular blocky to granular structure; moist friable; moderate permeability: many roots; clear smooth boundary.
B1	36-48	Clay loam; dark brown to dark yellowish brown (10YR3/3-3/4); medium very angular peds; very compact *in situ;* moist firm to friable; rolls to moderately strong wire; moderate to slow permeability; sparse rooting; clear, smooth boundary.

B2	48-60	Loam; dark brown (10YR3/3); weak medium angular structure; decrease in porosity; moist friable to firm; rolls moderately strong wire; few roots; moderate to slow permeability; diffuse, smooth boundary.
Bt	60-76	Clay loam; dark brown (10YR3/3); weak medium angular blocky to fine prismatic with many fine pores; moist friable to firm; rolls moderately strong wire; moderately permeable; clear, smooth boundary.
B/C	76/81 -100	Clay loam; brown to dark brown (10YR5/3-4/3) with black (2.5YN/0) weathered shale; weak medium subangular blocky structure with many fine pores; moist firm to friable; moderately strong wire; very sparse rooting; clear, irregular boundary.
C	100+	Loam; greyish brown to brown (10YR5/2-5/3); massive structure; compact *in situ;* moist friable; moderate permeability; calcareous.

Table 4.7: Profile Analyses - Elton Series 1

Horizon	Ap	A2	Bl	B2	Bt	BC	C
Depth (cm)	0-10	10-36	36-48	48-60	60-76	76-100	100+
Particle size distribution analysis (%)							
Coarse sand	20	19	19	20	19	18	30
Fine sand	16	15	13	17	12	12	19
Silt	42	41	41	40	39	43	39
Clay	22	25	27	23	30	27	12
pH	6.9	7.7	7.9	7.8	7.9	7.8	8.3
CEC, mEq/100 g	32.0	22.6	16.8	21.4	18.2	22.6	3.8
TEB, mEq/lOOg	21.6	15.9	11.1	12.1	12.3	11.4	5.1
Base saturation, %	68	70	66	57	68	51	Sat
Carbon, %	6.4	3.5	-	-	-	-	-
Nitrogen, %	0.36	0.19	-	-	-	-	-
C/N ratio	17.8	18.4	-	-	-	-	-
Free iron, %	2.6	2.7	3.0	2.5	2.0	3.3	1.2
TNV, %	-	3.4	0.9	2.3	3.7	2.6	30.2

Representative profile description: Elton Series 2

Location	Galbally townland, Co. Offaly, Grid
Relief:	Ref. 204305 194948
Slope of site:	Undulating to rolling moraine
Elevation:	2-3°
Vegetation and land use:	81 mO.D.
Drainage:	Arable
Parent material:	Well to moderately well drained
	Calcareous glacial drift predominantly
Great Soil Group:	limestone
	with sandstone and shale
	Grey Brown Podzolic

Horizon	Depth (cm)	Description
Ap	0-17	Loam; dark greyish brown to greyish brown (10YR4/2-5/2) light brownish grey (10YR6/2) dry; common fine to very fine distinct clear yellowish red (5YR4/6) root mottles; massive *in situ* breaking randomly to sub-angular blocky to granular elements; moist friable dry soft; many fine fibrous roots; clear, smooth boundary.
El	17-33	Loam; 5% stones; dark brown (10YR4/3); light brownish grey (10YR6/2) dry; massive structure *in situ* breaking to sub-angular blocky to medium granular structure; moist firm to friable dry soft; common roots; gradual, smooth boundary.
E2	33-48/53	Loam; 2-5% stones weathered sandstone and shale; brown (10YR5/3) to dark greyish brown (10YR4/2) and inclusions dark brown (7.5YR4/4) very pale brown (10YR7/3) dry; massive structure compact *in situ;* moist firm to friable dry soft; few fine fibrous roots; clear wavy boundary.
Btl	48/55-60	Clay loam; 10-15% weathered stones (sandstone and shale); dark brown (7.5YR4/4) pale brown (10YR6/3) dry; massive structure; moist firm deformable; few very fine fibrous roots; clear, wavy boundary.
Bt2	60-70/73	Stony clay loam; 50% stones; brown (10YR5/3) pale brown (10YR6/3) dry; massive structure; moist deformable; few very fine fibrous roots; clear, wavy boundary.
C	70/73+	Very stony loam; light brownish grey to pale brown (10YR6/3); massive structure; wet deformable; calcareous.

Table 4.8: Profile Analyses - - Elton Series 2

Horizon	Ap	El	E2	Btl	Bt2	C
Depth (cm)	0-17	17-33	33-48	48-60	60-73	73+
Particle size distribution analysis (%)						
Coarse sand	23	24	28	22	24	23
Fine sand	21	21	19	17	16	19
Silt	37	37	35	32	34	36
Clay	19	18	18	29	26	22
pH	5.5	5.1	5.6	7.3	7.8	8.2
CEC, mEq/100 g	21.4	14.2	7.6	12.0	11.2	6.4
TEB, mEq/lOOg	8.1	2.1	1.7	7.2	8.7	7.2
Base saturation, %	38	15	22	60	78	Sat
Carbon, %	3.5	0.7	0.6	0.4	0.2	0.1
Nitrogen, %	0.36	-	-	-	-	-
C/N ratio	9.7	-	-	-	-	-
Free iron, %	1.3	1.5	1.4	2.5	2.1	1.0
TNV, %	-	-	-	1.4	2.5	21.0

Patrickswell Series

Patrickswell is one of the most extensive soils in the county; the Series occupies 29,520 ha (15.05%) of the county. It also occurs in complexes with Elton, Baggotstown and some gley soils. It occurs on undulating topography and parent material consists of medium textured till derived predominantly from limestone and has a total neutralising value of 24 - 63%.

These soils are very similar to Elton but they are less than 75 cm deep. Clay content increases with depth; texture varies from loam in the surface horizon to loam/clay loam in the Bt horizon. Structure is weak to moderate in the surface A horizon, weak in both B horizons and massive in the C horizon (Photo 4.4.). Roots are usually abundant in the surface under grassland, and decrease with depth in the solum; thistle roots frequently extend into the C horizon. Profile data (Tables 4.9, 4.10) show that the surface horizons thickness ranges from 15-22 cm and that of the Bt horizons from 11 - 14 cm The variation in the B/A clay ratio, 1.38 to 1.65, reflects the degree of Bt horizon development. All horizons show moderately high to high base saturation and are slightly alkaline to alkaline in reaction. The differences in per cent organic carbon contents in the topsoils of Profiles 1 and 2 reflect land-use practices, the former under tillage and the latter a result of profound modification by anthropogenic activity.

Soil suitability: The Patrickswell Series has a wide use range. With their medium texture and good structure and consistence topsoils are easily tilled. When properly fertilised, excellent yields of cereals, sugar beet, potatoes, swedes and other root and vegetable crops are obtained. They are very suitable for grass production. Where the Baggotstown Series occurs closely associated with the Patrickswell Series, yield potential is lower due to coarser textures leading to drought.

Representative profile description: Patrickswell Series 1

Location:	Walshe Island townland, Co. Offaly, Grid Ref. 252265 221560
Relief:	Undulating
Slope of site:	3°
Elevation:	90 m O.D.
Vegetation and land use:	Malting barley, mixed farming
Drainage:	Well drained
Parent material:	Compact calcareous bouldery till
Great Soil Group:	Grey Brown Podzolic

Horizon	Depth (cm)	Description
Ap	0-15	Loam; brown to dark brown (10YR4/3); moderate to weak medium fine granular structure; moist friable, dry soft to slightly hard; many roots; clear, smooth boundary.
A2	15-22	Loam; brown to dark brown (10YR4/3); weak medium fine sub-angular blocky structure; moist friable common roots; clear, smooth boundary.
	22-32	Loam; dark yellowish brown (10YR4/4); weak to moderate fine sub-angular blocky structure; common macropores; somewhat compacted *in situ*, moist friable, dry slightly hard; few roots; distinct, smooth boundary.
Bt2	32-43	Clay loam; brown to dark brown (10YR4/3); very weakly developed almost apedal structure; many macropores; moist friable; many roots; distinct, slightly wavy boundary.
C	43+	Loam; greyish brown to light brownish grey (2.5Y5.5/2); massive structure; compact *in situ* moist friable; localised common roots thistle roots penetrating deep into this horizon; highy calcareous: large boulders or bedrock at 75 - 100 cm.

Table 4.9: Profile Analyses - Patrickswell Series 1

Horizon	Ap	A2	Bl	Bt2	C
Depth (cm)	0-15	15-22	22-32	32-43	43+
Particle size distribution analysis (%)					
Coarse sand	20	20	21	14	15
Fine sand	26	24	23	19	22
Silt	34	35	35	38	41
Clay	20	21	21	29	22
pH	7.6	7.3	7.9	8.0	8.0
CEC, mEq/lOOg	23.8	24.0	17.6	20.4	8.0

Table 4.9: Profile Analyses -	**- Patrickswell Series 1 (cont.)**				
TEB, mEq/100 g	15.81	15.67	10.30	12.45	7.15
Base saturation, %	66	65	59	61	89
Carbon, %	2.0	2.1	0.8	0.5	0.1
Nitrogen, %	0.25	0.24	0.12	-	-
C/N ratio	8.0	8.8	6.7	-	-
Free iron, %	1.7	1.6	1.3	2.0	1.9
TNV, %	1.1	0.6	1.2	1.7	47.2

Representative profile description: Patrickswell Series 2

Location:	Corraclevin townland, Co. Offaly, Grid Ref. 202992 187509
Relief:	Undulating
Slope of site:	**6°**
Elevation:	lOOmO.D.
Vegetation and land use:	Permanent pasture
Drainage:	Well drained
Parent material:	Calcareous glacial drift
Great Soil Group:	Grey Brown Podzolic

Horizon	Depth (cm)	Description
Ap	0-22	Loam, very dark brown (10YR2/2) moist, grey (10YR4/1) dry; fine granular to single grain structure; dry soft; abundant roots; artefact (plough point); slight effervescence; clear, smooth boundary.
A2	23-40	Sandy loam to loam, very dark greyish brown (10YR3/2), very fine granular to single grain structure; moist friable dry soft; good rooting; slight effervescence; clear, wavy boundary.
Bl	40-47	Loam; brown (7.5YR5/4) moist; light brown (7.5YR6/4) dry; weak fine granular tending to apedal structure; moist friable dry slightly hard; infilled pedotubules; fine roots; clear, wavy boundary.
Bt2	47-58	Clay loam; dark brown (7.5YR4/4) moist reddish yellow (7.5YR6/6); fine sub-angular blocky breaking to medium fine granular; moist firm to friable dry slightly hard; good rooting; slight effervescence; clear, wavy boundary.
	58+	Sandy loam; grey (2.5YR7/0) massive structure; compact *in situ;* vigorous effervescence.

Table 4.10: Profile Analyses - • Patrickswell Series 2

Horizon	Ap	A2	Bl	Bt2	CI
Depth (cm)	0-22	22-40	40-47	47-58	58+
Particle size distribution analysis (%)					
Coarse sand	24	29	23	19	27
Fine sand	20	20	23	16	24
Silt	36	31	36	32	35
Clay	20	20	18	33	14
pH	7.3	7.5	7.6	7.5	8.3
CEC, mEq/100 g	64.0	37.4	26.4	28.6	-
TEB, mEq/100 g	48.6	29.9	16.2	18.4	-
Base saturation, %	76	80	61	64	-
Carbon, %	9.0	3.6	1.6	1.1	-
Nitrogen, %	0.79	0.27	0.14	0.13	-
C/N ratio	11.4	13.3	11.1	8.5	-
Free iron, %	1.0	1.5	2.1	2.7	-
TNV, %	6.4	15.6	4.4	3.4	63.2

Patrickswell Series - Rolling phase
The rolling phase occurs in the south-west of the county. It is similar to the normal phase except that slopes are 8°-12°.

Soil suitability: The slopes present a moderate limitation for tillage and silage operations.

Patrickswell Series - Lithic phase
The lithic phase occurs in the southwest of the county, comprising 447 ha (0.22%) of the county. It occurs on the reef knolls of the limestone formations on undulating topography. It is derived from thin limestone drift and directly overlies limestone bedrock at depths generally less than 50 cm. A profile description is given below. Table 4.11 shows the soil to be slightly alkaline in the surface, increasing to alkaline with depth; however, base saturation does not exceed 80%. The B/A clay ratio of 1.2 reflects a weaker development of the Bt horizon in this situation. The organic carbon content in the surface is somewhat lower than usual for a grassland soil.

Soil suitability: Grass yields similar to the normal phase can be obtained but risk of damage to machinery limits their suitability for cultivation.

Patrickswell Series - Bouldery phase
The bouldery phase occurs in the north and southwest of the county in small pockets and occupies 707 ha (0.35% of the county). Soil depth is generally about 40 cm. It is similar to the normal phase except for the presence of many large boulders that may be 1 - 2 m in diameter. Description and analyses are not presented.

Soil suitability: This phase is suited to grazing but unsuited to tillage and great care would be required for mechanised harvesting of grass. Moisture availability can be a limiting factor in dry years.

Representative profile description: Patrickswell Series - Lithic Phase

Location: Cloncreen townland, Co. Offaly, Grid Ref. 258916 224401
Relief: Gently undulating
Slope of site: Straight 2° slope
Elevation: 76 m O.D.
Vegetation and land use: Grassland
Drainage: Well drained
Parent material: Metamorphic dolomite
Great Soil Group: Grey Brown Podzolic

Horizon	Depth (cm)	Description
Ap	0-19	Loam; dark greyish brown (10YR4/2); medium sub-angular blocky with fine granular to single grain; moist friable; abundant roots; diffuse, smooth boundary.
B2	29-40	Gritty loam; dark yellowish brown (10YR4/4); weak fine granular breaking to single grain; moist friable; common rooting; diffuse boundary.
B3	40-50	Gritty loam; dark yellowish brown (10YR4/4); weak sub-angular blocky structure; moist friable; common rooting; abrupt, clear boundary.
R	50+	Dolomitic metamorphic calcareous bedrock.

Table 4.11: Profile Analyses - Patrickswell Series - Lithic Phase

Horizon	Ap	Bl	B2	B3	R
Depth (cm)	0-19	19-29	29-40	40-50	50+
Particle size distribution analysis (%)					
Coarse sand	18	17	17	12	-
Fine sand	16	16	15	15	-
Silt	45	46	44	47	-
Clay	21	21	24	26	-
pH	7.2	7.6	7.7	7.8	-
CEC, mEq/lOOg	33.0	21.4	19.0	15.2	-
TEB, mEq/lOOg	21.12	14.52	13.86	12.19	-
Base saturation, %	64	68	73	80	-
Carbon, %	2.7	1.8	1.1	0.7	-
Nitrogen, %	0.33	0.16	0.13	-	-
C/N ratio	8.18	11.2	8.46		-
Free iron, %	2.3	2.4	2.6	2.3	-
TNV, %	2.3	5.4	4.4	23.3	-

Mortarstown Series

The Mortarstown Series occupies 3126 ha (1.57%) of the county and is developed in a stone-free loamy to clayey material ("drape material" Chapter 2) that formed during deglaciation at the end of the Midlandian period (Photo. 4.3). These are well-drained soils with loam texture in the surface horizon and clay loam in the B horizons. The profile description shows an abrupt lithological transition from the Bt2 horizon to the calcareous C horizon which comprises fluvio-glacial sands and gravels. Surface structure is moderate or weak depending on land use history. The Btl horizon has a well-developed prismatic structure with a very high proportion of pores as well as large wormholes thus ensuring easy infiltration of air and water. Clay films on ped faces in the Btl horizon indicate clay illuviation from the horizons above. Table 4.12 shows the surface horizon to have moderate to low organic carbon levels and moderate acidity but pH changes to alkaline with depth. The B/E clay ratio of 1:73 indicates a well-developed textural B horizon. Grass roots are abundant in the surface A horizon, decreasing with depth to few roots throughout the Bt horizons.

Soil suitability: Mortarstown soils have a wide use range. Potential stocking rates are high; however, the heavier textures of these soils require the best management practices as a high stocking density in periods of prolonged wet weather can cause poaching. A wide range of arable crops, including cereals and root crops, can be grown successfully. Tillage operations can be difficult in the wetter seasons, especially seedbed preparation and autumn harvesting.

Representative profile description: Mortarstown Series

Location:	Ballydownan townland, Co. Offaly, Grid Ref. 246640 219980
Relief:	Esker
Slope of site:	10°
Elevation:	90 m O.D.
Vegetation and land use:	Pasture
Drainage:	Well drained
Parent material:	Drape material, over esker sand and gravel
Great Soil Group:	Grey Brown Podzolic

Horizon	Depth (cm)	Description
Al	0-15	Dark greyish brown to dark brown (10YR4/2-4/3); loam; moderate medium crumb structure; friable; some washed sand grains; abundant diffuse rooting; common faint, small mottles of yellowish-red (5YR4/6) colour associated with surface organic mat; non-calcareous: gradual smooth lower boundary.
A2	15-33	Dark greyish brown to dark brown (10YR4/2-4/3); loam; moderate, medium, crumb structure; friable; some washed sand grains; less diffuse rooting than above; fairly clear, non-calcareous, smooth lower boundary.

E	33-46	Modified E; pale brown (10YR6/3) and yellowish-brown (10 YR5/4); silt loam; structure ill defined but tending towards coarse platy; compact *in situ;* friable *ex situ;* few washed sand grains; sparse vertical rooting; non-calcareous; clear, slightly wavy lower boundary.
Btl	46-62	Dark brown to brown (7.5YR3/2-4/2); clay loam; moderate, medium prismatic structure: compact *in situ;* friable *ex situ;* sparse vertical rooting; evidence of clay skins on vertical ped faces and in crevices; slightly calcareous; clear, slightly wavy lower boundary.
Bt2	62-84	Very dark brown (10YR2/2) and dark brown (10YR3/3); gravelly clay loam with humus; very weak, subangular blocky structure; friable; abundant evidence of extensive biological activity; very diffuse rooting; calcareous; clear, wavy lower boundary.
C	Below 84	Rounded stones and gravels with sands; highly calcareous.

Table 4.12: Profile Analyses - Mortarstown Series

Horizon	Al	A2	E	Btl	Bt2	C
Depth (cm)	0-15	15-33	33-46	46-62	62-84	84+
Particle size distribution analysis (%)						
Coarse sand	11	11	12	15	21	-
Fine sand	14	16	17	17	13	-
Silt	44	30	51	34	34	-
Clay	23	24	19	33	31	-
pH	5.8	6.7	6.9	7.2	7.2	7.8
CEC, mEq/lOOg	15.0	11.7	6.0	10.9	11.5	2.5
TEB, mEq/lOOg	-	-	-	-	-	-
Base saturation, %	-	-	75	92	Sat	Sat
Carbon, %	3.73	1.68	0.48	0.36	0.84	-
Nitrogen, %	0.35	0.19	0.07	0.08	0.12	-
C/N ratio	10.7	8.8	6.9	4.5	7.0	-
Free iron, %	2.06	1.93	1.23	1.76	1.81	-
TNV, %	-	-	-	-	6.3	36.5

Knock Series

The Knock Series, not previously mapped, occupies 397 ha (0.19%) of the county (Photo 4.5). It occurs on rolling topography in the south west of the county at Elevations between 90-120 m O.D. The parent material, a calcareous till composed predominantly of limestone with some sandstone, has a higher clay content than the Patrickswell Series. The soil is characterised by clay loam textures, with clay contents greater than 30% throughout the solum. The profile description shows that soil structure is weakly developed in all horizons, with few roots throughout the profile. Field tests suggested that the sub-soils had more clay in a subsurface horizon compared with horizons above and below. However, the subsequent analysis for this profile (Table 4.13) shows that the B/A clay ratio does not meet the requirement for a Bt horizon designation. The soil is slightly acid in the surface, increasing to alkaline with depth; the base saturation values reflect this trend. The low organic carbon content relates to the land use of continuous tillage.

Soil suitability: Potential stocking rates are high; however, due to the 30%-plus clay contents and weak structure there is a risk of poaching in wet weather. Seedbed preparation and harvesting of arable crops are also limited by the weak structure and fine textures.

Representative profile description: Knock Series

Location:	Knock townland, Co. Offaly, Grid Ref. 212200 196400
Relief:	Undulating
Slope of site:	Simple 2°
Elevation:	108 m O.D.
Vegetation and land use:	Tillage
Drainage:	Well drained
Parent material:	Limestone-dominated glacial drift
Great Soil Group:	Grey Brown Podzolic

Horizon	Depth (cm)	Description
Ap	0-23	Clay loam; dark greyish brown to brown (10YR4/2 - 4/3); pale brown (10YR7.3) dry; very weak almost apedal structure breaking to random angular elements; moist firm dry hard; few roots; clear, smooth boundary.
Bl	23-48	Clay loam; dark brown (7.5YR4/4), yellowish brown (10YR5/4) dry; weak fine angular blocky structure; moist firm deformable dry slightly hard; some evidence of biological mixing; few roots; gradual in places irregular, sharp boundary.
B2t	48-84	Clay loam; greyish brown (10YR5/2), light grey (10YR7/2) dry; weakly developed almost massive structure breaking randomly to medium coarse granular elements; moist firm deformable dry slightly hard; few locally common fine fibrous roots; sharp boundary.
	84+	Loam; greyish brown (2.5Y5/2), light grey (10YR7/1) dry; massive structure; moist firm dry slightly hard; calcareous with weathered sandstone.

Table 4.13: Profile Analyses - Knock Series

Horizon	Ap	Bw	B2t	C
Depth (cm)	0-23	23-48	48-84	84+
Particle size distribution analysis *t(%)*				
Coarse sand	16	16	13	16
Fine sand	11	15	10	13
Silt	42	38	45	45
Clay	31	31	32	26
pH	6.7	6.7	7.5	8.3
CEC, mEq/lOOg	20.0	13.8	18.6	8.4
TEB, mEq/lOOg	10.6	5.9	12.4	7.9
Base saturation, %	35	43	67	94
Carbon, %	1.6	0.7	0.7	0.2
Nitrogen, %	0.21	-	-	-
C/N ratio	7.6	-	-	-
Free iron, %	2.3	2.8	1.8	1.1
TNV, %	-	-	2.5	40.4

Podzol-Grey Brown Podzolic Group

Graceswood Series

The Graceswood Series occurs in a limited area in the southeast of the county in the vicinity of Portarlington. It also occurs in other areas as isolated pockets, which are often too small to map. An area of 566 ha (0.28%) of the county has been mapped as this Series. These soils occur on undulating kame topography interspersed with raised bogs and fen and are developed from a mantle of outwash sands originating from meltwater from a mass of dead ice north of Portarlington (Frank Mitchell, *pers. comm.).* Two profiles describe the Series.

The distinguishing features of these soils are coarse texture, bleached eluvial E horizon and iron/or humus-enriched argillic horizons. Although podzolised they frequently contain small amounts of carbonates in the solum. Secondary carbonates are common in the C layers. On the upper slopes of the kames the soils have a dark greyish brown surface A horizon and iron-enriched spodic horizon, whereas on the lower slopes the surface A horizon is invariably black and the spodic horizon is enriched with humus.

The surface horizons have strong structure, abundant fine fibrous roots and friable consistence. The underlying B horizon is slightly firmer with massive structure and few roots and the C layers have single grain structure with very few or no roots. Tables 4.14 and 4.15 show that the soil profiles are alkaline and base saturated. The B/E clay ratios are 4.6 and 2.0 for Profiles 1 and 2 respectively. Profile 1 has a substantially higher organic carbon content than Profile 2.

Soil suitability: These soils with their light texture, strong structure and friable consistence are easily tilled even after periods of heavy rain. The Series is highly suitable for grass production. With proper fertilising, high levels of production can be attained, especially on new leys. Poaching is not normally a problem on these soils but drought can limit production in very dry periods.

Representative profile description: Graceswood Series 1

Location:	Cushina townland, Co. Offaly, Grid Ref. 255944 214303
Relief:	Undulating
Slope of site:	2°
Elevation:	70 m O.D.
Vegetation and land use:	Permanent pasture (mainly Couch grass *Agropyron repens),* cocksfoot *(Dactylis glomerata)*
Drainage:	Excessively well drained
Parent material:	Calcareous glacial outwash sands
Great Soil Group:	Podzolised Grey Brown Podzolic

Horizon	Depth (cm)	Description
Al	0-20	Fine sandy loam; few large sub-angular stones (limestone); moist dark greyish brown (10YR4/2); weak medium coarse crumb structure; very friable; some washed and corroded sand grains; very extensive and diffuse rooting; calcareous; gradual, smooth boundary.
A2	20-30	Loamy sand to fine sandy loam; dark brown (10YR4/3 - 10YR5/3); weak medium crumb structure; moist very friable; some washed and corroded sand grains; rooting sparse and vertical; calcareous; fairly.clear, smooth lower boundary.
El	30-43	Fine sandy loam; brown to pale brown (10YR4/3 - 10YR5/3); single grain structure; friable to loose; abundant washed and corroded sand grains; rooting sparse and vertical; calcareous; fairly clear, slightly wavy boundary.
E2	43-51	Fine sandy loam; brown (10YR5/3 - 10YR6/3); single grain structure; loose; numerous washed and corroded sand grains; very sparse rooting; slightly calcareous; clear, wavy boundary.
Bt	51-60	Sandy clay loam; brown to dark brown (7.5YR4/4); coarse sub-angular blocky structure; moist friable, dry firm; coated sand grains; clay skins in crevices; sparse diffuse rooting; slightly calcareous; strongly wavy lower boundary.
	60+	Mainly fine sands with gravels.

Table 4.14: Profile Analyses - Graceswood Series 1

Horizon	Al 0-20	A2 20-	El 30-	E2	Bt 51-	C
Depth (cm)		30	43	43-51	60	60+
Particle size distribution analysis (%)						
Coarse sand	23	28	26	22	13	27
Fine sand	39	30	40	45	36	37
Silt	21	19	195	22	21	14
Clay	5	4	5	6	28	4
pH	7.5 15.0		7.5	7.2	8.0 10.4	8.0
CEC, mEq/100 g			5.6	3.7		1.0
TEB, mEq/lOOg	Sat	7.6			Sat	
Base saturation, %		11.1		Sat		Sat
		Sat	Sat			
Carbon, %	4.6	2.6	1.3	0.6	0.5	-
Nitrogen, %	0.34	0.17	0.08	0.04	0.05	
C/N ratio	13.7	15.5	16.5	15.0	9.6	
Free iron, %	1.09	0.86	0.81	0.96	1.99	0.79
TNV, %	18.5	18.6	12.1	7.8	7.8	40.9

Representative profile description Graceswood Series 2

Location: Derryvilla Hill, Co. Offaly, Grid Ref. 254720 214528
Relief: Convex top of kame structure
Slope of site: 2-3°
Elevation: 88 m O.D.
Vegetation and land use: Poor pasture and hawthorn scrub
Drainage: Well drained to excessive
Parent material: Calcareous outwash sands
Great Soil Group: Podzolised Grey Brown Podzolic

Horizon	Depth (cm)	Description
Al	0-20	Loamy sand; dark greyish brown (10YR4/2); very weakly developed crumb structure; moist friable; high in organic matter; abundant fine fibrous roots; abrupt, smooth boundary.
El	20-30	Loamy sand; very pale brown (10YR3/); weak fine to very fine crumb structure; moist friable; few medium coarse gravels; abundant very fine fibrous roots; gradual smooth boundary.
E2	30-45	Loamy sand; brown (10YR5/6); massive structure; moist friable; distinct wavy boundary.

gl	30-104	Sandy loam; reddish yellow (7.5YR6/6); massive structure; moist friable; few fine fibrous roots; abrupt, irregular broken boundary:
g_t	104-145	Loamy sand; yellowish red (5YR4/6); massive structure; moist friable; very few roots; abrupt, irregular boundary.
Q	45-145	Coarse sand; grey (2.5Y6/2); single grain structure; moist friable to loose; very few fine fibrous roots; calcareous; abrupt, smooth boundary.
Ck/Bs	145-148	Fine sand; light brownish grey (2.5Y7/2); single grain structure; moist friable (slightly indurated *in situ)* within horizon inclusion of sandy loam; strong brown (7.5YR5/8) with secondary carbonates white (10YR8/1); massive structure; moist firm; highly calcareous; abrupt, smooth boundary.
C2	148-177	Coarse sand; light grey (2.5Y6/2) to light brownish grey (2.5Y6/2); single grain structure; moist friable; gradual, smooth boundary.
C3	177-200	Fine and coarse bedded sands; light brownish grey (2.5Y6/2); single grain structure; moist friable dry loose; clear, smooth boundary.
Ck4	200-208	Fine sand; light brownish grey (2.5Y6/2) with white (10YR8/2) secondary carbonates; moist friable (indurated *in situ);* very calcareous; abrupt, smooth boundary.
C5	208+	As described previously for C2.

Table 4.15: Profile Analyses - Graceswood Series 2

Horizon	Al	El	E2	Bl	Bt	CI	Ck/Bs	C2	C3	Ck4
Depth (cm)	0-20	20-30	30-45	30-104	104-145	45-145	145-148	148-177	177-200	200-204
Particle size distribution analysis (%)										
Coarse sand	63	61	65	56	79	82	71	83	47	9
Fine sand	20	22	19	31	6	11	21	9	30	41
Silt	12	12	10	6	5	2	4	4	18	44
Clay	5	5	6	7	10	5	4	4	5	6
pH	8.1	-	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3
CEC, mEq/lOOg	16.5	11.8	6.3	5.0	7.2	1.3	2.0	1.1	1.6	3.0
TEB, mEq/lOOg	15.1	10.9	7.3	4.9	7.7	2.4	3.6	2.9	3.2	2.4
Base saturation, %	93	93	Sat	93	Sat	Sat	Sat	Sat	Sat	Sat
Carbon, %	2.1	1.2	0.2	0.1	0.2	0.7	0.1	0.1	0.1	0.1
Nitrogen, %	0.15	0.09	0.04	0.06	-	-	-	-	-	-
&; C/N ratio	14.0	13.0	5.0	2.0	-	-	-	-	-	-
Free iron, %	0.5	0.6	0.5	0.7	1.1	0.2	0.3	0.2	0.3	0.3
TNV, %	4.2	nd	10.4	1.2	1.0	31.6	32.4	30.0	30.4	30.4

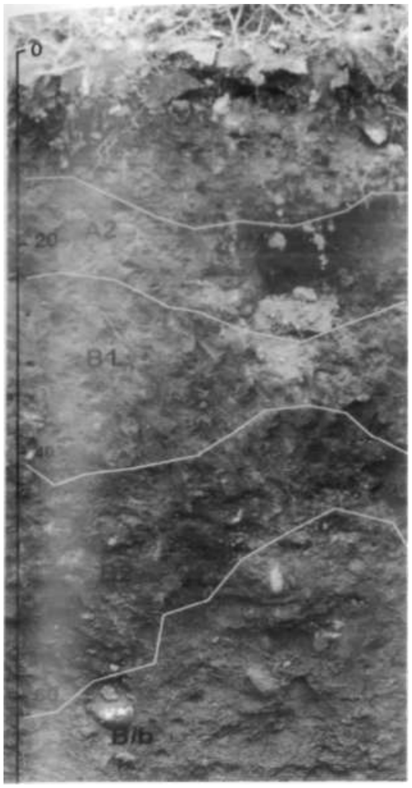

Photo 4.2: Profile of Elton soil.
(R.F. Hammond)

Photo 4.3: Profile of Mortarstown soil.
(J.F. Collins)

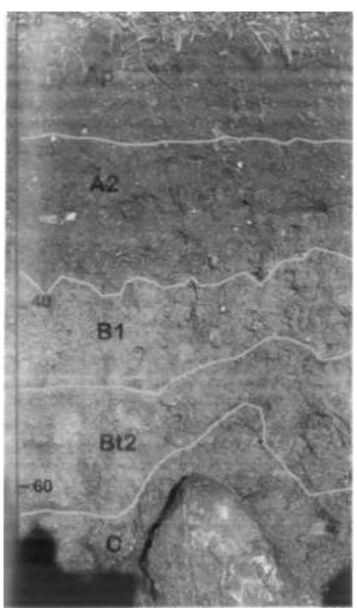

Photo 4.4: Profile of Patrickswell soil.
(R.F. Hammond)

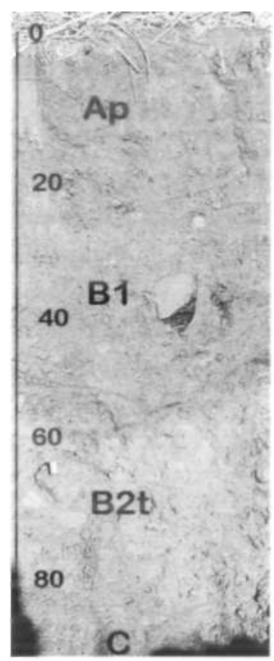

Photo 4.5: Profile of Knock soil.
(R.F. Hammond)

Gley Group

Gleys are soils in which the effects of permanent or intermittent waterlogging dominate. The waterlogging of the soil may be due to a high watertable, to a 'perched' watertable caused by the impervious nature of the soil itself, or to seepage or run-off from slopes. Where gley conditions are the result of high watertable, the soil is referred to as a groundwater gley. Where gleisation is due to a 'perched' watertable, the soil is referred to as a 'surface-water gley'. Gley soils have poor physical properties, which make them unsuitable for cultivation or for intensive grassland farming. Their productive capacity is also affected by restricted growth in spring and autumn. Peaty gley soils have an organic horizon up to 30 cm thick. The presence of this horizon generally indicates wetter conditions than for mineral Gley soils. Seven Series were identified in Co. Offaly.

Howardstown Series

The Howardstown Series occupies 3720 ha (1.86%) of the county and is widespread in lowland areas underlain by Carboniferous limestone. The Series, first mapped in Co. Limerick is generally found in low-lying positions bounding the Elton Series on gently undulating topography. It has also been mapped as a complex in association with the Patrickswell and Bagottstown Series. The soils of this Series are derived from medium to moderately fine-textured calcareous glacial till. They are moderately deep with loam to clay loam textures in the surface A horizon, increasing to clay loam in the Bg horizons. Structure is weakly developed in the surface horizon and is generally massive in the B horizon. Mottling is common to abundant in the sub-surface horizons, indicating periodic waterlogging. Rooting is common to abundant in the surface few centimetres but decreases markedly below this level. Analyses in Table 4.16 show the B/A clay ratio varies between 1.3-1.7 in the B horizons. The soil is slightly acidic in the surface, increasing to alkaline with depth reflected in the high base saturation values. Organic carbon values indicate the impeded drainage of this soil.

Soil suitability. This soil has a limited use range. Its main limitations are weak structure, slow permeability and poor drainage. It is suited mainly to pasture. Susceptibility to poaching is a problem, and good management is necessary to sustain maximum production. It can be successfully drained where there is a suitable outfall.

Drainage works associated with industrial peat development has lowered the groundwater table in the immediate environs. In these situations the agricultural potential of the Howardstown Series has improved considerably.

Representative profile description: Howardstown Series

Location:	Leitrim townland, Co. Offaly, Grid Ref. 255900 231200
Relief:	Very gently undulating moraine
Slope of site:	0° flat slight depression
Elevation:	81 mO.D.
Vegetation and land use:	Poor pasture
Drainage:	Poorly drained
Parent material:	Calcareous - stiff tenacious glacial till
Great Soil Group:	Gley
Sub-group	Mineral

Horizon	Depth (cm)	Description
Al	0-22	Humose silt loam; dark greyish brown (10YR4/2) with reddish brown (5YR4/4) abundant fine distinct root mottles; weak to massive structure breaking to fine granular; moist friable; roots common; slow permeability; distinct, wavy boundary.
El	22-42 42-	Silt loam to fine sandy clay loam; dark grey (2.5Y4/0); massive structure; moist friable; roots sparse to few; slow permeability; distinct, wavy boundary.
E2g	78	Gravelly clay loam; grey (5Y 5/1); with many fine distinct yellowish brown (10YR5/8) mottles; massive structure; roots few; slow permeability; calcareous around weathered stones; distinct, irregular boundary.
Big	78-98	Coarse gravelly sand loam to sandy clay loam; greyish brown (2.5Y5/2), with common diffuse yellowish brown mottles (10YR5/8); massive structure; moist firm; slow permeability; calcareous; clear, irregular boundary.
B2g	98-110/115	Clay loam; light olive brown (2.5Y5/6) with grey (2.5Y6/0) patches; massive structure; wet sticky, strong wire; fossil roots; slow permeability; calcareous; clear, wavy boundary.
cig	110/115-150	Clay loam; wet sticky, greyish brown and grey (2.5YR5/2 and 6/0) with fine distinct dark brown (7.5YR4/4) mottles; massive structure breaks to random angle apedal elements; moist firm; slow permeability; calcareous.
C2g	150-175	Silty clay loam; grey (5Y5/1), massive structure; wet slightly sticky rolls to a weak wire; slow permeability; calcareous.
C3g	175+	

Table 4.16: Profile Analyses - Howardstown Series

Horizon	Al	El	E2g	B1g	B2g	Clg	C2g	C3g
Depth (cm)	0-22	22-42	42-78	78-98	98-115	115-150	150-175	175+
Particle size distribution analysis (%)								
Coarse sand	22	29	33	30	14	17	10	4
Fine sand	17	20	15	14	10	10	8	6
Silt	38	34	36	35	48	48	64	73
Clay	23	17	16	21	28	25	18	17
pH	6.5	7.3	7.7	8.1	8.1	8.1	8.2	8.1
CEC, mEq/100 g	29.4	12.8	13.6	7.2	13.2	13.6	5.8	-
TEB, mEq/lOOg	11.71	6.61	9.32	8.40	11.24	7.97	6.75	-
Base saturation %	40	52	69	Sat	85	59	Sat	-
Carbon, %	3.54	0.41	0.28	0.10	0.17	0.10	0.13	-
Nitrogen, %	0.44	0.07	0.05	0.02	0.03	0.02	0.01	-
C/N ratio	8.0	5.9	5.6	5.0	5.7	5.0	13.0	-
Free iron, %	2.5	0.6	1.2	2.0	2.8	4.2	3.0	-
TNV, %	-	-	8.9	30.6	17.9	31.9	34.1	-

Kilpatrick Series

The Kilpatrick Series (Soil profile, Photo 4.6) occupies 278 ha (0.13%) of the county. It is an imperfectly drained podzolic Gley and was first mapped in Co. Kildare (Conry *et al*, 1970). It occurs on undulating to flattish topography at a more low-lying position in the landscape than its well-drained counterpart, Patrickswell Series, and at slightly more elevated position than the poorly-drained Mylerstown Series. Parent material is medium-textured till derived predominantly from limestone.

The AI horizon is dark greyish brown with moderately good structure and consistence. The sub-surface horizon is a thin, bleached mottled E horizon (formerly designated A2), which in turn overlies a thin, undulating strongly mottled textural B horizon. Textures are loam throughout the solum but in the B horizon there is marked increase in clay content. Structure is weak to moderate in the A horizon, weak in the B horizon and massive in the C horizon. The B/A clay ratio of 1.7 (Table 4.17) indicates a sharp increase in clay content in the B horizon. The slightly acid A reflects the low total exchangeable bases and base saturation. However, soil reaction and base saturation increase with depth.

The soil is naturally imperfectly drained as a result of a high watertable. Drainage works associated with industrial peat development has improved the internal drainage properties to such an extent that the soils now behave as moderately well-drained but they still retain the colour and structure characteristics associated with impeded drainage.

Soil suitability: These improved soils have a fairly wide use range. Although the drainage oroperties have been improved, some limitations still persist. In favourable seasons the Kilpatrick Series has no disadvantages compared to its well-drained associate, the Patrickswell Series, but in unfavourable seasons it is much more difficult to produce a desirable tilth so that spring sowing is often delayed. Similarly there is also a greater risk of poaching damage by grazing stock in wet periods so that a greater proportion of the grass produced should be conserved for winter feeding off the land.

Representative profile description: Kilpatrick Series

Location:	Kilpatrick townland, Lullymore, Co. Kildare, Grid Ref. 270930 228908
Relief:	Undulating ground moraine
Slope of site:	1 -2°
Elevation:	90 m O.D.
Vegetation and land use:	Pasture
Drainage:	Imperfectly drained
Parent material:	Stony, compact, but non-tenaceous glacial till composed mainly of limestone
Great Soil Group: Sub-group	Gley Mineral

Horizon	Depth (cm)	Description
Al	0-18	Loam; dark greyish brown (10YR4/2) with reddish brown (5 YR4/4) root mottles; moderate medium angular blocky structure; moist friable; clear boundary.
A2	18-25/28	Loam; light brownish grey (2.5 Y 6/2) with many medium and fine strong brown (7.5 YR 5/6) mottles; moderate medium angular blocky structure; clear, wavy boundary.
B2t	28-36/41	Loam to clay loam; yellowish brown (10 YR5/4) with many distinct medium and fine strong brown (7.5YR5/4) mottles; weak angular blocky structure; clay skins distinct; abrupt, tonguing boundary.
Cg	36+	Silt loam; light grey (10 YR6/1) with many distinct yellowish brown (10YR5/6) mottles; structureless; moist hard *in situ;* no roots; calcareous.

Table 4.17: Profile Analyses - Kilpatrick Series

Horizon Depth (cm)	Al 0-18	A2 18-28	B2t 28-41	Cg 41+
Particle size distribution analysis (%)				
Coarse sand	19	16	9	10
Fine sand	22	25	20	13
Silt	44	44	46	62
Clay	15	15	25	15
pH	6.4	6.5	7.5	8.2
CEC, mEq/100 g	18.9	6.7	12.4	4.0
TEB, mEq/100 g	5.7	3.7	11.8	8.3
Base saturation, %	30	55	95	Sat
Carbon, %	3.4	0.6	0.5	0.3
Nitrogen, %	0.3	-	-	-
C/N ratio	11.3	-	-	-
Free iron, %	0.77	0.57	1.74	0.34
TNV, %	-	-	-	36.9

Mylerstown Series

The Mylerstown Series (Soil profile, Photo 4.7) occupies 8405 ha (4.22%) of the county and is distributed widely throughout it. The soil, a low humic or mineral gley, is derived from a moderately coarse-to-medium textured calcareous glacial drift and occurs at the lower positions in the gently undulating topography. It is shallow and has sandy loam textures in the surface with sandy-loam to loam textures in the sub-surface horizons. The lack of clay illuviation distinguishes this Series from the Kilpatrick Series. Table 4.18 shows this soil to be alkaline throughout with trace amounts of carbonates to the surface. The texture, free iron and per cent organic carbon (below the surface Ap) show little variation between horizons.

Structures are weakly developed throughout with abundant rooting in the surface, declining rapidly with depth. Mottling is common in the sub-surface horizons, indicating a history of fluctuating watertables. However, in locations where raised bogs have been developed for fuel production this Series has benefited from the overall drainage improvement.

Soil suitability: The Mylerstown soils are mainly restricted to grassland use but where artificial drainage has been effective for a number of years the deeper watertable enables a wider land-use range. In general a high winter watertable and low drainage gradients restricts grazing management at the spring turnout and also influences the extension of grazing into the autumn. Types of animal and stocking levels have to be controlled if poaching is not to be a problem.

Permanent pastures of variable quality predominate but where land reclamation has been carried out and good management is practiced, high-yielding swards are attainable.

Representative profile description: Mylerstown Series

Location:	Bracknagh townland, Co.Offaly, Grid Ref. 260889 217353
Relief:	Level
Slope of site:	1-2°
Elevation:	66 m O.D.
Drainage:	Moderately well drained
Vegetation and land use:	Mixed farming
Parent material:	Calcareous compact gravelly till
Great Soil Group:	Gley
Sub-group	Mineral

Horizon	Depth (cm)	Description
Ap	0-20	Dark greyish brown (10YR4/2) moist; greyish brown (10YR5/2); loam; weak to moderate medium and fine granular structure; sparse in ped macropores; moist friable; dry slightly hard to hard; common fine roots; slight effervescence; distinct, smooth boundary.
A2	20-29	Brown (10YR4/3) moist pale brown (10YR6/3); dry; loam; weak fine sub-angular blocky structure; common inped macropores; moist friable; vigorous effervescence; clear, smooth boundary.
Bwg	20-29	Yellowish brown (10YR5/4) loam; fine distinct manganese mottles very weak fine sub-angular blocky structure; common inped macropores; moist friable; few fine roots; distinct, wavy boundary.
Cgl	43-54	Pale brown to light brownish grey (10YR6/2.5) sandy loam; few distinct mottles; massive structure; moist friable; vigorous effervescence; dry hard; few fine roots; distinct, wavy boundary.
Cg2	54+	Light brownish grey (2.5Y 6/2); sandy loam; common distinct mottles; massive structure; compact *in situ;* moist friable; secondary carbonates around stones; cemented in spots; strongly calcareous.

Table 4.18: Profile Analyses - Mylerstown Series

Horizon	Ap	A2	Bwg	Cgl	Cg2
Depth (cm)	0-20	20-29	29-43	43-54	54+
Particle size distribution analysis (%)					
Coarse sand	23	25	21	18	25
Fine sand	35	30	32	28	30
Silt	26	25	28	35	33
Clay	16	19	19	19	12
pH	7.7	8.0	8.0	8.3	8.4
CEC, mEq/lOOg	31.2	20.0	16.0	6.8	3.4
TEB, mEq/100 g	19.4	14.0	12.5	6.6	5.1
Base saturation, %	62	70	78	97	Sat
Carbon, %	2.1	0.9	0.6	0.2	0.1
Nitrogen, %	0.20	0.11	-	-	-
C/N ratio	10.5	8.2	-	-	-
Free iron, %	1.1	1.3	1.0	0.6	1.3
TNV, %	3.1	4.3	4.1	42.1	47.5

Ballyshear Series

The Ballyshear Series (Soil profile Photo 4.8) covers 4350 ha (0.19%) of the county. The concept of this soil, as originally defined, is a gley developed on gravelly tills derived from limestone drift in low lying positions in the terrain. In the surveys of Co. Meath (Finch *et at,* 1983) and Co. Laois (Conry, 1987) it has been defined as in a catenary sequence with no specific reference to the type of parent materials in which it developed.

The profile description shows Ballyshear to have a loam, very dark greyish brown humose surface ' layer with friable granular structure overlying a dark grey, friable E horizon. The Bwg horizon consists of a very dark grey, gravelly sandy loam with massive structure overlying calcareous parent material at 54 cm. Analyses presented in Table 4.19 show little texture variation between horizons. Whilst reaction is slightly acid in the surface it is highly calcareous in the sub-surface horizons, confirmed by high free carbonates of 36 - 51 %. As with many gleys the per cent organic carbon reflects the impeded drainage of the soil.

Soil suitability: These soils have a limited use-range due mainly to their low-lying position and consequent poor drainage. They are suited mainly to grass production, which, because of the poor drainage, requires good management for optimum utilization.

Representative profile des(:ription: Ballyshear Series

Location:	Dromoyle townland, Co. Offaly, Grid Ref. 211604 200547
Relief:	Gently undulating
Slope of site:	0-1°
Elevation:	88 m O.D.
Vegetation and land use:	Pasture
Drainage:	Poor
Parent material:	Calcareous gravelly glacial drift (limestone with sandstone)
Great Soil Group:	Gley
Sub-group	Mineral

Horizon	Depth (cm)	Description
Al	0-26	Loam, very dark greyish brown (10YR3/2), dry greyish brown (10YR5/2); weakly developed medium fine granular; moist friable dry soft; medium macro pores; very fine, many fibrous root; abrupt, smooth boundary.
A2	26-41/46	Sandy loam; dark grey (2.5Y4/0), dry light grey (10YR7/1); massive structure; moist very friable dry soft compact *in situ;* occasional coarse bio-pore; very fine few fibrous roots; clear, slightly wavy boundary.
Bwg	41/46-60	Stony sandy loam; dark grey (2.5Y4/0), dry white (10YR8/1); yellowish red (10YR5/6) weathered sandstone fragments with light olive brown (2.5Y5/6); common coarse distinct diffuse mottles, massive structure; compact *in situ* moist friable dry slightly hard; gradual, smooth boundary.
Cg	54+	Stony sand loam; dark grey (2.5Y4/0), dry light grey (10YR7/2); massive structure; compact *in situ;* moist friable dry slightly hard; calcareous.

Table 4.19: Profile Analyses - - Ballyshear Series

Horizon	Al	A2	Bwg	Cg
Depth (cm)	0-26	26-46	46-60	60+
Particle size distribution analysis (%)				
Coarse sand	20	32	25	24
Fine sand	20	29	25	24
Silt	41	28	34	36
Clay	19	11	16	16
pH	6.5	8.5	7.6	8.6
CEC, mEq/100 g	35.2	3.8	2.0	3.2
TEB, mEq/lOOg	19.90	3.63	4.12	3.46
Base saturation, %	57	96	Sat	Sat
Carbon, %	4.0	0.3	0.2	0.1
Nitrogen, %	0.46	-	-	:
C/N ratio	8.7	-	-	
Free iron, %	0.5	0.3	0.4	
TNV, %	-	36.1	52.6	51.4

Ballintemple Series

The Ballintemple Series occupies 4304 ha (2.16%) of the county. This soil (Photo 4.9), a peaty gley, is widespread throughout the county occurring on flat to very gently undulating topography bordering the peat landscape units, raised bog and fen. The Series corresponds with the farmers' definition of "moory" soils on many midland farms. The soil has a variable depth of highly humified amorphous peaty material with a high ash content reflecting the historical application of marling materials (corn gravels) to the surface and long periods of agricultural utilisation. These organic surface horizons exhibit weak to moderately well developed granular structure and good root distribution within the horizon. However at higher moisture contents they have low bearing capacity. The surface O horizon can occasionally be underlain by a weakly expressed E horizon to a strongly mottled, highly calcareous Bg horizon with gravelly stony sandy clay loam textures, massive structure and few roots. The high cation exchange capacity and total exchangeable bases (Table 4.20) in the surface horizon reflect the high (11%) organic carbon value. In contrast the Bwg and *Cg* horizons are calcareous, with low cation exchange capacities and very high base saturation. The slightly acid surface and strongly alkaline sub-surface horizons confirm the application of marling material and the calcareous nature of the underlying horizons, respectively.

Sett suitability: Land use is restricted to grassland. Where the watertables are deeper than 50/60 cm and good management is practiced, these soils are capable of producing grass yields for moderate stocking rates. Given the inherent nature of these soils it is prudent to stock only between April and October/November, as dictated by seasonal weather conditions.

Representative profile description: Ballintemple Series

Location:	Rossamine townland, Co. Offaly, Grid Ref. 202000 193500
Relief:	Valley position in ground moraine, undulating
Slope of site:	0°
Elevation:	87mO.D.
Vegetation and land use:	Rush *(Juncus* spp.) infested permanent pasture
Drainage:	Poor
Parent material:	Calcareous glacial drift of mixed origin but predominantly limestone
Great Soil Group:	Gley
Sub-group	Peaty

Horizon	Depth (cm)	Description
Oap	30-0	Peat; black (10YR2/1); very slightly stony, medium sized sub-rounded stones of sandstone origin; moderately developed fine medium granular structure; moist well humified slightly greasy; semi-deformable; dry; common fibrous roots; smooth, sharp boundary.
Bwg	0-27	Sandy loam to sandy clay loam; grey (2.5Y5/0) with many medium distinct diffuse olive yellow (2.5Y5/6) mottles with pale yellow (5Y7/4) and pinkish grey (7.5YR6/2) weathered sandstones and olive (5Y5/6) shales; massive structure; many large sub-angular highly weathered stones; wet deformable slightly plastic; clear, smooth boundary.
Cg	27+	Sandy clay loam to loam; grey (5Y2/1); abundant medium sub-angular stones of sandstone origin; massive structure; compact *in situ;* moist moderately firm brittle; calcareous.

Table 4.20: Profile Analyses - Ballintemple Series

Horizon	Oap 30-	Bwg	Cg
Depth (cm)	0	0-27	27+
Particle size distribution analysis (%)			
Coarse sand	32	33	22
Fine sand Silt	19	22	22
Clay	41	26	33
PH	8	19	22
CEC, mEq/lOOg	6.4	8.3	8.
TEB, mEq/lOOg	124.8	5.4	4.
Base saturation, %	62.7	4.8	4.
	50	89	98

Table 4.20: Profile Analyses - Ballintemple Series (cont.)

Carbon, %	11.0	0.4	0.4
Nitrogen, %	0.99		
C/N ratio	IL1	-	-
Free iron, %	1.7	0.7	0.6
TNV, %	-	11.6	40.9

Clonlisk Series

The Clonlisk Series (Soil profile Photo 4.10) has not been previously mapped in adjoining counties. It occupies 3172 ha (1.59%) in the county, mostly in the southwest. It occurs on almost level to very gently undulating topography between better-drained soils on the upland and peaty flats contiguous to the raised bog landscape units. Like the Mylerstown and Ballyshear Series, it is shallow but is developed on clayey glacial till and physically resembles the Howardstown Series. Whilst occurring in a topographical position similar to the Ballintemple Series the Clonlisk Series has a lower organic matter content in the surface horizon. As with the Ballintemple and Mylerstown Series, structures are weakly developed with common rooting in the surface but declining rapidly with depth. Mottling is common throughout the profile and the grey colours of the C horizon indicate that a fluctuating water table in this horizon is a feature of this Series. Table 4.21 shows a uniform pattern of sand and silt and whilst field mapping detected an increase in texture with depth, the clay B/A ratio is only 1.26. The soil is slightly acid in the surface and organic carbon values reflect impeded drainage. Although cation exchange capacity and total exchangeable bases data are not available the pH and total neutralising values suggest that these values would be high throughout the profile.

Soil suitability: These soils are wet due to fine textures, topographical position and poorly developed structures and are restricted to grassland use. Permanent pastures predominate. Land reclamation improves production but a good level of management, with the provision of over-wintering facilities to prevent early spring and late autumn poaching to maximize production.

Representative profile description: Clonlisk Series

Location:	Clonbrennan townland, Co. Offaly, Grid Ref. 206962 188558
Relief:	Flat periphery of ground moraine, smooth to very gently undulating
Slope of site:	0°
Elevation:	90 m O.D.
Vegetation and land use:	Permanent poor pasture
Drainage:	Poorly drained
Parent material:	Calcareous glacial drift
Great Soil Group:	Gley
Sub-group	Mineral

Horizon	Depth (cm)	Description
^1	0-10	Loam; very dark greyish brown (10YR3/2) to dark greyish brown (10YR4/2); light brownish grey (10YR6/2) dry; extremely fine, common distinct, sharp yellowish red (5YR4/6) root mottles; very weakly developed to almost massive structure; wet deformable dry soft; many fine fibrous roots; smooth, gradual boundary.
A2	10-24	Loam; very dark greyish brown (10YR3/2), light brownish grey (10YR6/2) dry; few root mottles as for Al; very weakly developed medium sub-angular blocky structure; wet deformable dry soft; common to few fine fibrous roots; distinct, smooth boundary.
Bte	24-39/59	Clay loam; light brownish grey (10YR6/2), dry very pale brown (10YR8/3); very many (50 - 75%) coarse, prominent, diffuse yellowish brown (10YR5/6) mottles; massive structure breaking to medium coarse angular fragments; wet deformable; 2 - 5% stones along junction A2; few fine fibrous roots; distinct, irregular boundary.
Cg	39/59+	Loam; light grey (2.5Y7/0); with common, fine, distinct clear light olive brown (2.5Y5/5) mottles; massive compact structure; wet non-deformable; occasional very fine fibrous root; 40% stones all limestone origin; calcareous.

Table 4.21: Profile Analyses - Clonlisk Series

Horizon	Al	A2	Btg	Cg
Depth (cm)	0-10	10-24	24-39	39+
Particle size distribution analysis (%)				
Coarse sand	22	28	19	15
Fine sand	14	12	13	15
Silt	39	37	39	43
Clay	25	23	29	27
PH	6.5	6.6	7.5	8.3
CEC, mEq/100 g	-	-	-	-
TEB, mEq/100 g	-	-	-	-
Base saturation, %	-	-	-	-
Carbon, %	4.03	2.30	0.45	0.35
Nitrogen, %	0.36	0.19	0.03	0.01
C/N ratio	11.2	12.0	15.0	35.0
Free iron, %	1.6	1.8	2.6	0.8
TNV, %	-	-	-	58.1

Drombanny Series

Occupying 2161 ha (1.08%) of the county, the Drombanny Series is widespread, occurring in old lakebeds (Table 4.22, Photo 4.11) and river floodplains. The soils are poorly drained, with a peaty surface, very high base status and have been classified as Peaty Gleys at sub-group level. Marl of variable thickness is evident at 20 cm from the ground surface. Beneath the marl layer the effeci of the high watertable is shown by the dominance of drab grey colours and diffuse mottling. The structure, weak to moderate in the surface horizon, becomes massive below the marl layer. Rooting forms a dense mat above the marl but thereafter is very sparse.

Soil suitability: These soils are mainly used for extensive summer grazing. The poor permanent pasture vegetation is dominated by wetland species such as sedges *(Carex* spp.), soft rush *(Juncus effusus)* and meadow-sweet *(Filipendula ulmaria).* If well managed they are capable of good grass production, especially so in the drier seasons where the peaty nature of the topsoil maintains a higher level of available moisture. These soils have a tendency to be copper deficient and at high pH can cause molybdenosis in cattle if grazed for extended periods.

Representative profile description: Drombanny Series

Location:	Frankfort townland, Co. Offaly, Grid Ref. 205452 187432
Relief:	Flat
Slope of site:	0°
Elevation:	88mO.D.
Vegetation and land use:	Poor rush-infested *(Juncus* spp.) permanent pasture
Drainage:	Very poor
Parent material:	Peat over limnic marl
Great Soil Group:	Gley
Sub-group	Peaty

Horizon	Depth (cm)	Description
Oap	0-20	Peat; very dark brown to very dark greyish brown (10YR2/2 well developed medium fine crumb to granular structure; wet s deformable; many fine fibrous roots abrupt, smooth boundary
C	20+	Marl.

Table 4.22: Profile Analyses - Drombanny Series

Horizon	Oap	C
DeptMcm)	0-20	20+
Particle size distribution analysis (%)		
Coarse sand		
Fine sand		
Silt		
Clay		
piT	6.9	8.5
CEC, mEq/100 g		
TEB, mEq/lOOg		
Base saturation, %		
Carbon, %	45.3	1.7
Nitrogen, %	-	0.1
C/N ratio	-	17.0
Free iron, %	-	-
TNV, %	-	88.8

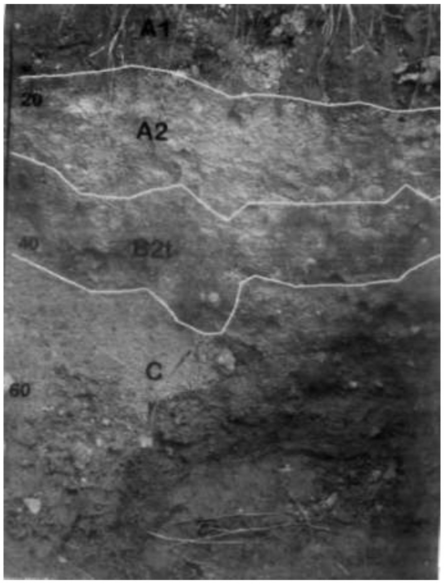

Photo 4.6: Profile of Kilpatrick soil.
(R.F. Hammond)

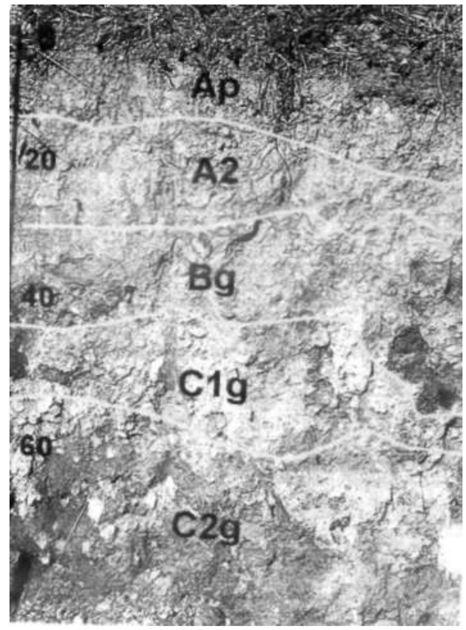

Photo 4.7: Profile of Mylerstown soil.
(R.F. Hammond)

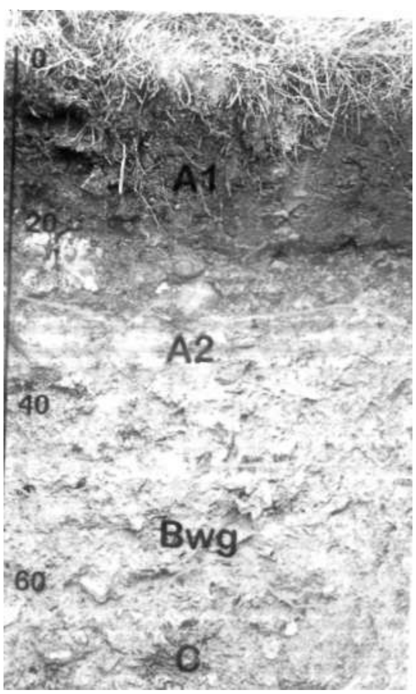

Photo 4.8: Profile of Ballyshear soil.
(R.F. Hammond)

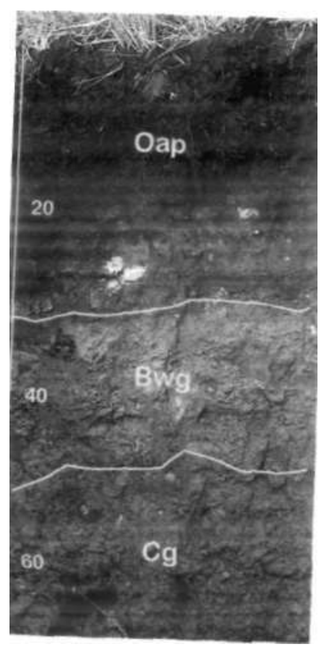

Photo 4.9: Profile of Ballintemple soil.
(R.F. Hammond)

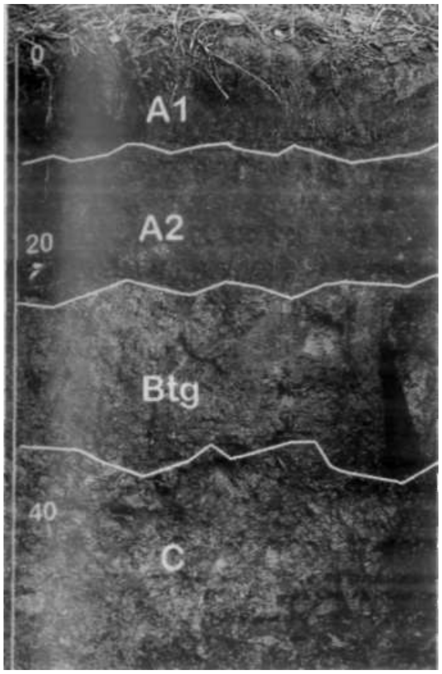

Photo 4.10: Profile of Clonlisk soil.
(R.F. Hammond)

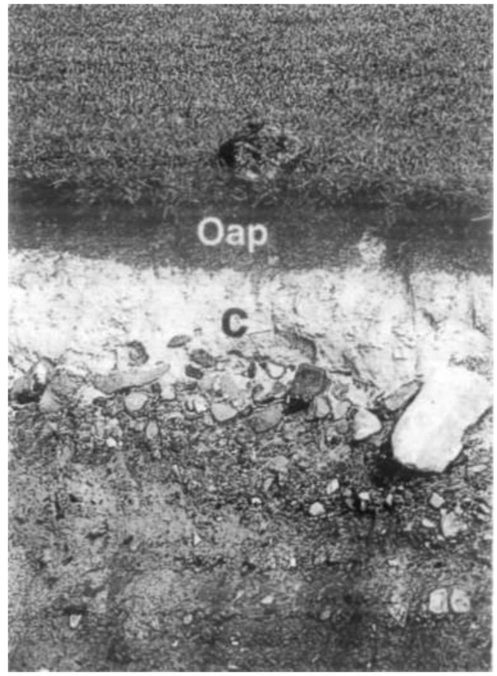

Photo 4.11: Profile of Drombanny soil.
(R.F. Hammond)

Regosol Group

Regosols are very immature soils and show little or no profile development. The A horizon directly overlies the C horizon. They are usually differentiated on the basis of such factors as origin and composition of parent material, texture, drainage and base status.

Alluvium

Alluvial soils are found in all the major river and stream catchments occupying 10,692 ha (5.37% of the county). Whilst separations into lake and river alluvium had been made in previous county surveys it was decided, in line with the survey of County Laois (Conry, 1987), to designate all the alluvial soils as Alluvium.

The soils can show a wide range of physical characteristics both within and between profiles depending on the mode of deposition. In general these alluvial deposits can be of variable thickness overlying the glacial drift. However, in certain areas bordering the rivers Boyne and Shannon alluvium of much younger age can be found overlying peat. Throughout the Holocene, drainage conditions can have a strong influence on the degree of organic matter accumulation giving rise to humic or even peaty surface horizons. Descriptions and analytical data are given for two sample profiles from the southwest and east of the county.

Textures of these alluvial soils vary from silty clay loams to fine loamy sands. The surface horizon varies from humose to peaty in texture with well developed granular to crumb structures and abundant rooting. The subsurface horizons are usually massive in structure with a sharp decrease in rooting and biological activity generally. Watertables vary in depth depending on drainage management of the stream and/or river in the vicinity.

The analytical data presented show the variability that occurs within the Alluvium mapping unit. The profile data in Table 4.23 show the Alluvial Soil 1 to have variable clay contents between horizons with a surface horizon that is slightly acid and near neutral to very slightly alkaline to depth, which is reflected in the total neutralizing values. A consequence of high cation exchange capacity values and only moderate levels of total exchangeable bases results in relatively low base saturation. The analytical data in Table 4.24 also show a high clay content but with little variation between horizons in Soil 2. This profile is alkaline throughout with high base saturation. The 18% organic carbon in the surface of Alluvial Soil 2 contrasts sharply with the 3.0% value in Alluvial Soil 1. This is a reflection of the topographical position of the two profiles, the former in a "backswamp" location and the latter located on a levee position.

Soil suitability: Through their topographical position and generally heavy texture profiles these soils are restricted to grassland management. They are generally used for extensive summer grazing but where a high level of management is practiced excellent production is possible for both conserved hay and grazing.

Representative profile description: Alluvial Soil 1

Location	Breaghmore townland, Co. Offaly, Grid Ref. 213718 204431
Relief	Level river flat
Elevation	68 m O.D.
Slope of site	0°
Vegetation and land use	Permanent pasture
Drainage	Poorly drained
Parent material	River alluvium
Great Soil Group	Gley
Sub-group	Mineral

Horizon	Depth (cm)	Description
Al	0-19/23	Silt loam; very dark greyish brown (10YR3/2), dry light gre[1] (10YR7/2); common very fine distinct clear yellowish brown (10YR5/6) mottles; moderately developed fine granular structure; moist firm semi-deformable, wet slightly plastic dry slightly hard; occasional bio-pore; many fine fibrous roots; sharp, slightly wavy boundary.

Eg	19/23-70	Sand; greyish brown (2.5Y5/2), dry light grey (10YR7/1); few medium prominent sharp black (5YR2/1) and yellowish red (5YR5/8) mottles; massive structure; *in situ* firm moist friable dry hard; few fine fibrous roots; sharp, irregular boundary.
Clg	70-87	Silt loam; dark grey (2.5Y4/0); dry light yellowish brown (10YR7/3); many fine prominent sharp yellowish red (5YR4/6) mottles; massive structure; very moist deformable slightly sticky very plastic dry hard; smooth, gradual boundary.
C2g	87-98	Silt loam; dark grey (2.5Y4/0); dry light grey (10YR6/1); many medium prominent sharp yellowish brown (10YR5/8) mottling; massive structure; very moist deformable; wet slightly sticky very plastic; dry hard; sharp, smooth boundary.
Oa	98-128	Peat; fresh dark brown (7.5YR3/2) on exposure rapidly to very dark greyish brown (10YR3/2); well humified vPII - vPIII; wood remains; infilling with water at this depth; sharp, smooth boundary:
Cg	128+	Sand; dark grey (2.5Y4/0) dry light grey (10YR7/1); wet massive structure; dry loose soft; calcareous.

Table 4.23: Profile Analyses - Alluvial Soil 1

Horizon	Al	Eg	Clg	C2g	Oa
Depth (cm)	0-19	19-70	70-87	87-98	98-128
Particle size distribution analysis (%)					
Coarse sand	12	1	2	1	1
Fine sand	4	1	2	1	2
Silt	59	63	54	65	50
Clay	25	35	42	33	47
pH	6.6	7.5	7.4	6.5	6.0
CEC, mEq/100 g	31.2	24.9	37.4	31.2	90.0
TEB, mEq/100 g	16.29	17.61	24.48	20.07	44.77
Base saturation, %	52	70	65	64	50
Carbon, %	3.0	1.9	3.2	3.5	13.8
Nitrogen, %	0.35	0.13	0.26	0.30	0.94
C/N ratio	8.6	14.6	12.3	11.7	14.7
Free iron, %	2.1	1.7	9.0	0.6	1.1
TNV, %	-	1.4	2.2	-	-

Representative profile description: Alluvial Soil 2

Location:	Chevychase townland, Co. Offaly, Grid Ref. 259728 216707
Relief:	Flat river flood plain
Slope of site:	0°
Elevation:	63m O.D.
Vegetation and land use:	Ley pasture cut for first crop hay
Drainage:	Poorly drained
Parent material:	Calcareous silty clay alluvium and lake marl
Great Soil Group:	Gley
Sub-group	Peaty

Horizon	Depth (cm)	Description
Oap	0-9	Peaty loam; very dark brown (10YR2/2) with inclusions of silty clay olive brown (5Y4/2) and dark grey (5Y4/1) drain spoil material and lake marl light olive grey (5Y6/2); peaty loam weak fine granular structure; moist soil strength weak brittle; tubular coarse macropores earthworms present; common fine fibrous roots; sharp, slightly wavy boundary.
Ck	9-13	Lake marl; light olive grey (5Y6/2); common fine prominent sharp reddish brown (5YR5/4) mottles in fossil root channels; massive structure; soil strength weak brittle; common fine fibrous roots; sharp, slightly wavy boundary.
Oe	13-18	Peaty loam; dark grey (2.5Y4/1); massive structure; soil strength moderately weak brittle; very fine common fibrous roots; calcareous; clear, smooth boundary.
CI	18-39	Silt loam to silty clay loam material; grey to light grey (2.5YN6/0) with common medium distinct clear greyish brown (2.5Y5/2) mottles; with intermixed lake marl white (2.5YN8/0) and common fine distinct clear yellowish red (5YR4/6) mottles intermixed; massive structure; soil strength moderately weak brittle; fine common fibrous roots; clear, smooth boundary.
C2	39-55	Silty clay loam; dark grey (2.5YN4/0) with many medium to coarse distinct clear greyish brown (2.5Y5/2) mottles; massive structure; very moist soil strength moderately firm deformable; slightly plastic; calcareous; gradual, smooth boundary.
C3	55-65	Silt loam to silty clay loam; dark grey (2.5Y4/0) massive structure; very moist soil strength moderately firm; moderately plastic; calcareous; sharp, smooth boundary.
C4	65-85	Sand bands inter-varving with silt loam materials; massive structure; very moist soil strength weak; very calcareous.
C5 .	85+	Description as 55-65.

Table 4.24: Profile Analyses - Alluvial Soil 2

Horizon	Oap	Ck	Oe	CI	C2	C3	C4	C5
Depth (cm)	0-9	9-13	13-18	18-39	39-55	55-65	65-85	85+
Particle size distribution analysis (%)								
Coarse sand	-	-	47	4	1	1	1	1
Fine sand	-	-	24	3	1	1	1	1
Silt	-	-	18	47	53	54	53	51
Clay	-	-	11	46	45	44	45	47
pH	7.7	7.8	8.1	8.1	8.2	8.2	8.1	8.2
CEC, mEq/100 g	80.0	30.4	8.0	12.4	12.4	12.8	14.8	14.8
TEB, mEq/lOOg	48.89	20.91	6.80	11.91	11.44	11.89	13.08	12.84
Base saturation, %	61	69	85	96	92	93	88	87
Carbon, %	18.0	5.4	1.3	0.5	0.8	0.6	0.7	0.6
Nitrogen, %	1.22	0.45	0.08	-	-	-	-	-
C/N ratio	14.8	12.0	16.3	-	-	-	-	-
Free iron, %	3.0	1.4	0.5	1.8	2.9	2.0	1.7	0.8
TNV, %	81.8	74.3	57.7	50.0	41.2	43.4	44.5	46.1

Soil Complexes

Fifteen mineral and peat soil complexes were mapped covering 70,578 ha (35.5%) of the county. Three of these complexes associated with the peatlands landscape occupy 37,565 ha (18.9%) of the county; the remaining twelve cover an area of 33,013 ha (16.6%). Eight complexes occur on undulating topography and can be separated into five complexes comprised of dry, well-drained soils covering 28,078 ha (14.1%) of the land area and three dominated by gley soils cover an area of 518 ha (0.26%); the remaining four are associated with river floodplains and bog margins and cover 4417 ha (2.2% of the county). These relatively extensive areas reflect both the complex nature of the landscape morphology and soil parent materials laid down during the Midlandian glaciation and differing hydrologies associated with the development of the river floodplains. Table 4.25 summarises the areas of the different complexes, their Series components, placement in Great Soil Group and an estimate of the proportions of the different Series within the complex; a brief description of the topography and parent material is also included. The individual components are discussed in the order in which they are shown in Table 4.25. Profile descriptions and analytical data are presented for the more extensive components not previously recorded and discussed.

Table 4.25: Soil Complexes, by Soil Map Unit No., extent, Series and Great Group placement, topographic setting and parent material

Soil Map Unit No.	Area%	Component Soils	Great Soil Group	Proportion %	Topography/Parent material
207	5.47	Patrickswell Baggotstown	Grey Brown Podzolic Brown Earth	55 45	Gently undulating/gravely till, calcareous
207A	1.64	Baggotstown Patrickswell	Brown Earth Grey Brown Podzolic	60 40	Gently undulating/gravely till, calcareous
208	4.59	Patrickswell Baggotstown Elton	Grey Brown Podzolic Brown Earth Grey Brown Podzolic	40 40 20	Gently undulating/gravely till, calcareous
209	1.87	Baggotstown Crush	Brown Earth	70 30	Undulating/gravely till, calcareous
243	0.50	Baggotstown Carlow	Brown Earth Brown Earth	60 40	Undulating/gravely till, calcareous
213	0.12	Howardstown Baggotstown	Gley Brown Earth	55 45	Gently undulating/gravely till, calcareous
214	0.03	Ballyshear Patrickswell	Gley Grey Brown Podzolic	65 35	Gently undulating/gravely till, calcareous
215	0.09	Howardstown Patrickswell	Gley Grey Brown Podzolic	60 40	Gently undulating/gravely till, calcareous
131	0.92	Allenwood - Mylerstown Series - Ballinteinple - Banagher	Gley Gley Histosol	20 20 60	Very gently undulating to flat/peat and calcareous glacial till
132	0.58	Finnery river - Alluvium - Drombanny	Regosol Histosol	70 30	Flat/alluvium and peat
263	0.48	Callow -Alluvium - Banagher - Drombanny	Regosol Histosol Peaty gley	55 25 20	Flat/peat and alluvium
267	0.22	Garryhinch - Podzolised gley - Humic gley - Peaty podzolised - Gley	Gley Gley Gley	50 40 10	Very gently undulating to flat/outwash gravely *sandy* glacial till

patrickswell/Baggotstown Complex (Soil Map Unit No. 207)
Complex 207 is comprised of the Patrickswell and Baggotstown Series and is widespread throughout the county. Topographically the complex is gently undulating to undulating with slopes ranging from 1-5 degrees. The complex pattern of the Series relates to the variability of the topography the smoother slopes with Patrickswell and the uplifts dominated by Baggotstown.

Baggotstown/Patrickswell Complex (Soil Map Unit No. 207A)
In this complex the more hummocky terrain gives rise to the dominant Baggotstown Series with Patrickswell being the subordinate soil.

Patrickswell/Baggotstown/Elton Complex (Soil Map Unit No. 208)
The deeper Elton Series component occurs on the flatter or more depressed areas within the complex. Due to the topographical variation and soil variability that occurs within these complexes the land use of the component soils generally pre-supposes them to grassland utilisation. Soil moisture availability in these soils would be a constraint on yields throughout the growing season.

Baggotstown/Crush Complex (Soil Map Unit No. 209)
This complex is dominated by gravelly parent materials and occurs in association with esker topography. Slope changes of 15° degrees are sharp at the esker interface.

Baggotstown/Carlow Complex (Soil Map Unit No. 243)
Complex 243 was mapped on the western foot slopes of the Slieve Bloom Mountains between 150 and 250 m. The complex previously mapped in Co. Laois by Conry (1987) occurs in Co. Offaly at higher elevations with the component soils derived from predominantly limestone gravely glacial drift. However, parent materials with a higher sandstone component can occur at higher elevation in the area mapped. The complex is suited to grassland production through the combined effects of topography and Elevation. At the higher elevation the increased proportion of sandstone in the parent material may require lime applications to maximise grassland production.

Howardstown/Baggotstown Complex (Soil Map Unit No. 213)
The Howardstown/Baggotstown Complex reflects a soils pattern derived from intermixing of heavier and lighter glacial till components and the slope factor.

Ballyshear/Patrickswell Complex (Soil Map Unit No. 214)
This complex occurs in the southwest of the county on the County Tipperary/Offaly border. As with the last-mentioned complex it occurs in association with soils developed in the low-lying topographical situation.

Howardstown/Patrickswell Complex (Soil Map Unit No. 215)
A complicated distribution pattern of esker, peaty soils and alluvium constitutes the Howardstown/

Patrickswell Complex and is associated with low-lying topography. The soil variability reflects the intermixing of the glacial drift materials deposited. Land use is suited to grassland utilisation through the combined effects of slope and drainage patterns. Management of these soils is influenced by the poorer-drained components and stocking density should reflect these considerations.

Allenwood Complex (Soil Map Unit No. 131)
The Allenwood Complex of soils occurs mainly on the margins of raised bogs landscape units. The soils that comprise it are mineral Gleys (Mylerstown Series), Peaty Gleys (Ballintemple Series) and shallow (<100 cm) organic soils (Banagher Series), although deeper phases of the organic component may also be found. The Mylerstown and Ballintemple Series have been described previously.

The organic component of this complex (shallow Banagher) (pages 83-85) varies in depth from 30 to 100 cm approximately. The shallower organic layers are black to dark greyish brown with weak to moderate structure and are well decomposed down to the underlying gleyed mineral substratum. The deeper organic layers have a black surface horizon which is well decomposed with weak to moderate structure, and with a sub-surface horizon which shows black to dark reddish brown coloration with some recognisable plant remains in a well humified matrix. Owing to the fluctuating water table within the shallower organic layers the presence of sulphides is not always detectable.

Soil suitability: Land use is usually poor permanent pasture. The most serious limitation is drainage, which could be improved by the provision of major outfalls. Where field drainage has been carried out and associated good management with fertiliser usage, good grass production is possible. Forestry potential is dependent on species and drainage state.

Finnery River Complex (Soil Map Unit No. 132)
The soil components of the Finnery complex owe their origins to river action within the post-glacial period. They consist principally of poorly to very poorly drained organic soils and regosols either as separate entities or in a random inter-layered manner.

The organic component has a variable thickness of peat (30 to over 100 cm) formed under relatively base-rich conditions, is occasionally underlain by shell marl *(Chara* marl matrix permeated with shell residues) 60 cm or more thick with a further layer of calcareous silty clay beneath the marl.

Recent alluvium of variable texture and depth has been deposited over glacial drift, or even over post-glacial peat formations. In the latter situations ferro-manganiferous concretionary material can be found at the junction of the shallow alluvial deposits and the peat layer, providing evidence of a fluctuating watertable.

In all these environments, which are subject to intermittent, regular or even prolonged waterlogging, soil development is confined to the surface horizons. The permanent watertable within organic profiles can be determined by lighter-coloured anaerobic peat and the strong smell of sulphides.

Soil suitability: The present land use is restricted mainly to rough summer grazing and production of poor quality hay. The vegetation cover is mainly sedge, rushes and poor pasture species with meadow-sweet *(Filipendula ulmaria).* The major limitation is the high watertable in winter and spring, but with provision of major outfalls in many places, such soils would be eminently suitable for grassland production. Areas of deeper (>70 cm) peat soils have a forestry potential but where marl layers occur at peat depths less than 70 cm planting is not recommended.

Callow Complex (Soil Map Unit No. 263)
The Callow Complex, a characteristic feature of the Shannon Basin, bordering the River Shannon and its tributary the Little Brosna occupies 961 ha (0.22%) of the county (Photo 1.1). The soils are derived from parent materials of peat and alluvium origin. They exhibit a shallow surface A horizon over a poorly drained C horizon. Rooting is extensive in the A horizon but decreases sharply with depth into the C horizon. Depending on parent materials and the effect of siltation from periodic flooding, surface textures vary from silty clay loams through to humic silt loams to peat. The soils are poorly drained and are subject to high winter watertables and the risk of winter and spring flooding.

Soil suitability: The land use of the Callow Complex (263) is limited by their low-lying topography and high watertables in early spring and, depending on season late summer as well. The indigenous vegetation is a semi-natural grassland with a high proportion of sedges *(Carex nigra, C. panicea* and C. *lepidocarpa)* and non-productive grasses *(Briza media, Festuca rubra* and *Agwstis tenuis* (Heery, 1983)) and is used for extensive summer grazing of dry cattle and hay meadows. The callow areas are of significant interest in that they are the breeding areas for the very rare summer migrant corncrake *(Crex crex)* and also one of the most productive feeding areas in Europe for winter migrant birds.

Garryhinch Complex (Soil Map Unit No. 267)
The Garryhinch Complex occupies 448 ha (0.22%) of the county. The soils of this complex occur on low-lying topography developed from the sandy outwash deposits associated with the Graceswood Series in the southeast of the county. Whilst the parent materials are of dominantly sandy composition, till-like materials also occur. Within the complex three soil profiles, a Gley, Humic Gley and a Peaty Podzolised Gley were described to represent contrasting topographical positions. Surface horizon textures vary from sandy loams to loam through humic to peaty. Structure is weak in the surface to massive in the sub-surface horizons. Whilst the soil profiles of the Complex exhibit extensive mottling indicative of poorly-drained soils, the actual soil water regime is

improved due to the lowering of the local watertable following drainage of the surrounding bogland by Bord na Mona for peat extraction. The analyses in Tables 4.26, 4.27 and 4.28 show that these soils are near neutral to slightly alkaline in the surface, increasing to strongly alkaline with depth. The increase in organic carbon levels in the surface horizons reflects the differences in the drainage regimes. Cation exchange and base saturation values also reflect the combined effects of surface organic carbon levels and the lower clay contents in the subsurface horizons.

Soil suitability: The components of Garryhinch Complex are generally restricted to grassland usage. The overall lowering of the ground-water from bogland drainage improved land use potential and satisfactory production from these soils is attainable where farmers have reseeded and improved the soil fertility. The possibility of high watertables in spring and early autumn could severely restrict the tillage option.

Representative profile description: Garryhinch Series 1

Location:	Rathmore townland, Co. Offaly, Grid Ref. 251067 212198
Relief:	Flat
Slope of site:	0°
Elevation:	73 m O.D.
Vegetation and land use:	Old pasture, hay
Drainage:	Imperfectly drained (improved)
Parent material:	Stony calcareous boulder till
Great Soil Group:	Gley
Sub-group	Mineral

Horizon	Depth (cm)	Description
Ap	0-18/22	Loam: very dark grey brown (10YR3/2); with yellowish red (5YR4/6), common, distinct fine to very fine root mottles: weak medium sub-angular blocky breaking to medium granular structure; moist firm to friable; abundant fine roots in surface 10cm falling off rapidly below; distinct, smooth boundary.
Bl	18-39	Loam; dark grey (10YR4/1), massive structure; moist firm; few roots; sharp, wavy boundary; discontinued.
Bwg	39-42	Loam; grey (2.5YN 5/0) with abundant coarse distinct light olive 1539 brown mottles (2.5YN 5/4); massive structure with infilled earthworm channels; moist firm; few roots; calcareous; sharp, wavy boundary.
Clg	42-55	Sand loam; dark grey (2.5YN 4/0); massive single grain structure; moist friable; very few roots; calcareous; sharp, wavy boundary.
C2g	55+	Loam; grey (2.5YN 5/0); massive structure; moist firm to friable; calcareous.

Table 4.26: Profile Analyses - Garryhinch Series 1

Horizon Depth (cm)	Ap 0-22	Bl 22-39	Bwg 39-42	C1g 42-55	C2g 55+
Particle size distribution analysis (%)					
Coarse sand	25	17	19	37	29
Fine sand	23	25	20	23	18
Silt	30	37	45	30	36
Clay	22	21	16	10	17
pH	7.2	7.9	8.3	8.3	8.3
CEC mEq/100 g	32.1	16.8	4.6	2.0	4.6
TEB. mEq/100 g	22.43	14.38	7.16	4.41	6.60
Base saturation, %	72	86	Sat	Sat	Sat
Carbon, %	3.69	1.01	0.24	0.10	0.08
Nitrogen, %	0.44	0.08	0.03	0.02	.01
C/N ratio	8.4	12.6	8.0	5.0	8.0
Free iron, %	0.9	0.4	0.9	0.9	0.4
TNV, %	-	-	36.9	44.4	49.9

Representative profile description: Garryhinch Series 2. Grid Ref. 247530 210019

Location: Barranaghs townland, Co Offaly,

Relief: Flat
Slope of site: 0°
Elevation: 73 m O.D.
Drainage: Moderate to poor
Vegetation and land use: Poor pasture
Parent material: Sandy calcareous glacial drift
Great Soil Group: Gley
Sub-group Humic

Horizon	Depth (cm)	Description
Ap	0-21	Humic sand loam; very dark brown (10YR 2/2); weak medium sub-angular blocky to very fine granular structure; moist friable; common roots; sharp boundary, irregular due to biological activity.
	21-27	Loam sand; light grey (10YR7/1) to grey (10YR6/1); with yellowish brown (2.5Y6/4) common diffuse mottles; speckled with yellowish brown (10YR5/6) very fine abundant mottles; massive compact structure; moist friable, compact *in situ;* sparse roots; clear, slightly wavy boundary.

Btg	27-45	Sand loam; light brownish grey (10YR6/2); with light yellowish brown (2.5 Y 6/4) mottles; massive structure; breaking to random angular fragments, random in size; moist firm; few roots; clear, slightly, wavy boundary.
Cgl	45-72	Loamy sand to sandy loam; light brownish grey (10YR6/2); with yellowish brown (10YR5/6) common diffuse mottles; massive structure with 0.5% micropores; moist friable; sparse roots.
Cg2	72+	Sandy loam; massive structure; calcareous.

Table 4.27: Profile Analyses - Garryhinch Series 2

Horizon	Ap	E	Btg	Cg1	Cg2
Depth (cm)	0-21	21-27	27-45	45-72	72+
Particle size distribution analysis (%)					
Coarse sand	45	39	39	43	35
Fine sand	21	30	22	31	23
Silt	24	20	22	16	27
Clay	10	11	17	10	15
pH	6.5	7.7	7.7	8.1	8.1
CEC, mEq/lOOg	32.0	9.0	8.4	4.4	9.6
TEB, mEq/lOO g	22.43	5.19	5.71	3.05	7.40
Base saturation, %	70	58	68	69	77
Carbon, %	3.88	0.52	0.15	0.36	0.66
Nitrogen, %	0.33	0.04	0.02	0.01	0.03
C/N ratio	11.8	13.0	7.5	36.0	22.0
Free iron, %	1.0	0.5	1.2	0.4	0.4
TNV, %	-	-	-	-	25.1

Representative profile description: Garryhinch Series 3

Location:	Barranaghs townland, Co. Offaly, Grid Ref. 247439 210140
Relief:	Flat
Slope of site:	0°
Elevation:	73 m O.D.
Vegetation and land use:	Poor pasture
Drainage:	Imperfect
Parent material:	Sandy calcareous glacial drift
Great Soil Group:	Gley
Sub-group	Peaty

Horizon	Depth (cm)	Description
Oap	0-21	Peat, dark reddish brown (5YR 2/2); strong fine sub-angular blocky structure; moist friable; abundant roots good biological activity, sharp, slightly wavy boundary.
E1	21-31	Sand loam; grey (2.5YN6/0) massive structure, few micro pores less than 0.5%; moist friable, sparse roots; sharp, smooth boundary:
E2	31-49	Sand loam; dark grey (2.5 Y 4/0); massive structure; (upper A22 more compact), few micropores; moist friable; sparse roots; slow permeability; sharp, smooth boundary.
Btg	49-55	Sand loam; grey (2.5YN 5/0); with common fine distinct light olive brown (2.5Y 5/6) mottles; massive structure; moist firm to friable; moderate to slow permeability; calcareous; diffuse, smooth boundary.
	55+	Loam; grey (2.5YN5/0); massive structure; moist firm; slow permeability; highly calcareous.

Table 4.28: Profile Analyses - Garryhinch Series 3

Horizon Depth (cm)	Oap 0- 21	El 21-31	E2 31- 49	Btg 49-55	Cg 55+
Particle size distribution analysis (%)					
Coarse sand	35	37	35	29	31
Fine sand	30	29	27	27	20
Silt	26	26	29	32	32
Clay	10	9	9	12	17
pH	7.0	8.1	8.3	8.4	8.2
CEC, mEq/100 g	72.8	6.8	2.2	4.4	9.6
TEB, mEq/100 g	23.08	5.22	2.98	4.25	7.16
Base saturation, %	33	77	Sat	97	75
Carbon, %	17.0	0.36	0.31	0.15	0.54
Nitrogen, %	0.59	0.02	0.01	0.01	0.02
C/N ratio	29.0	18.0	31.0	15.0	26.5
Free iron, %	1.2	0.1	0.1	0.4	0.4
TNV, %	-	-	-	26.5	38.8

Peats (Histosols)

Peat soils by definition are comprised of peat materials with over 30% organic matter and at least 30 cm deep in the drained condition and 45 cm when undrained. The peat soils mapped in Co Offaly occur within the three peatland landscape units Raised Bog (Photos 1.1, 4.14), Blanket Bog (Photo 4.18) and Fen (Hammond, 1979).

Raised Bog

The Raised Bog landscape unit is a characteristic feature of Central Ireland. The formation is a result of the combination of low-lying topography, poor drainage gradients and climatic changes throughout the post-glacial period, i.e. the past 10,000 years. In their unmodified state they are extremely wet (95% water by volume). Their development was initiated under the influence of base-rich groundwaters and the basal layer of raised bogs within the Midland plain is invariably comprised of fen peat materials. Subsequently, however, the formation of peat materials of increasing thicknesses changed the soil water regime to one of less basicity. With increased rainfall, plant species changed to ones suited to more acidic soil conditions and the growth of *Sphagnum* mosses, forming the characteristic raised dome shape typical of the landscape unit. Three Series were mapped and identified in the Raised Bog landscape

Allen Series

The Allen Series occupies 8257 ha (4.14%) of the county (Photos 4.12, 4.14). In general terms its profile is comprised of alternating layers of variable humified *Sphagnum* mosses, interspersed with peat materials of *Calluna* and *Cyperaceae* origin. Little or no soil development has taken place and the aerated layer (acrotelm) extends to only a few centimetres deep. The profile is extremely wet throughout in the natural state but near the edges where drainage has been carried out to facilitate peat fuel winning the margins are somewhat drier. The main response to drier conditions is the increased growth of *Calluna vulgaris* (heather). The Series is characteristically strongly acid with low bulk densities and high Saturated Pyrophosphate Extract Colour (SPEC) values (Table 4.29).

Soil suitability: In its undrained natural state this series is unsuited to any form of enterprise other than amenity and conservation value. However, the increasing intensity of drainage from the 1920's onwards resulted in widespread exploitation of this natural resource. The complex geogenesis of the raised bog landscape unit is reflected in the selection of different bogs for moss peat or fuel peat production. Also in recent years when the peat is drained, conifer forestry has also become a land-use option.

Representative profile description: Allen Series

Location	Clonbrin townland, Co. Offaly, Grid Ref. 262372 216714
Relief	Convex edge of raised bog
Slope of site	2°
Elevation	64 m O.D.

Vegetation and land use	*Calluna vulgaris* (heather) dried out edge of raised bog.
Drainage Parent	Poorly drained
material Great Soil	Ombrotrophic peat material of *Sphagnum* origin
Group Sub-group	Histosol (USDA Classification)
	Medihemist

Horizon	Depth (cm)	Description
Oal	0-20	Peat; dark reddish brown (5YR3/2); cyperaceous *Sphagnum* origin; poorly humified vPI; clear boundary.
Oel	20-60	Peat; dark reddish brown (5YR3/2) and dark grey (5YR4/1); *Sphagnum/Calluna* origin; poorly humified residues; slightly pasty vPI; clear boundary.
Oa2	60-85	Peat; dark reddish brown (5YR3/2) to very dark grey (5YR3/1); residues of *Sphagnum* origin with cyperaceous remains; poorly decomposed; clear, smooth boundary.
Oe2	85-100	Peat; reddish brown (5YR3/2) and very dark grey (5YR3/1); cyperaceous origin; little peat material squeezes between fingers, poorly humified; clear boundary.
Oe3	100-110	Peat; dark reddish brown (5YR3/2); *Sphagnum* origin; poorly humified vPI; clear boundary.
Oa3	110-150	Peat; dark reddish brown (5YR3/2); *Sphagnum* origin with cyperaceous residues; moderately well-humified vPII.

Table 4.29: Profile Analyses - - Allen Series

Horizon Depth (cm)		Oal 0-20	Oel 20-60	Oa2 60-85	Oe2 85-100	Oe3 100-110	Oa3 110-150
Fibre per cent volume Unrubbed Rubbed		16	30	14	22	28	14
Bulk density g/ml % Moisture (Saturated SPEC	gravimetric)	0.349 1011 7	0.128 1387 7	0.112 2641 7	1552 7	1266 7	1360 7
Ash, %		3.8	1.8	1.3	1.2	0.9	1.4
PH		3.4	3.8	3.9	4.0	3.9	4.1
Carbon, %		56.0	57.1	57.4	57.4	57.6	57.3

Garrymona Series

The Garrymona Series occupies 233 ha (0.11%) of the county (Photo 4.13) but it rarely occurs in units large enough to be mapped at the adopted publication scale. The soil was formed as a result of man's activity in draining the peats of the Allen Series with shallow surface drains and subsequently paring and burning the surface and applying marling materials. These included calcareous gravelly till excavated from the surrounding mineral uplands to increase the fertility and load-bearing capacity of the soil as well as correcting acidity. A representative profile now exhibits a black surface horizon with strong granular structure, profuse rooting and a very sharp boundary to the unchanged acidic *Sphagnum* peat of the raised dome. Analyses in Table 4.30 reflect man modification, with a slightly acid pH, relatively high bulk density and ash values, and low SPEC value in the surface horizon.

Soil suitability: This series is most suitable for grassland production and with fertilisation, capable of producing moderately high grass yields and grazing by lighter drystock. In isolated circumstances they are used to grow potatoes, for home use, thus reflecting a position in former times when they were probably used extensively for this purpose.

Representative profile description: Garrymona Series

Location:	Clongarret townland, Co. Offaly, Grid Ref. 257400 224505
Relief:	Flat organic terrain
Slope of site:	0°
Elevation:	71.9 mO.D.
Vegetation and land use:	Permanent pasture
Drainage:	Moderate to poorly drained
Parent material:	Ombrotrophic peat of *Sphagnum* origin
Great Soil Group:	Histosol (USDA Classification)
Sub-group	Sphagnofibrist

Horizon	Depth (cm)	Description
Oap	0-25	Peat; black (5YR2/1); sapric; no identifiable plant remains; greasy well-humified; fine well developed crumb structure, especially on drying out; previously heavily marled; abrupt, smooth boundary.
Oil	25-110	Peat; dark reddish brown (5YR2/2); fibric; *Sphagnum* peat; non-greasy poorly humified vPI; on squeezing slightly turbid water; plant remains easily identifiable; clear boundary.
Oa2	110-150	Peat; dark reddish brown (5YR3/2); sapric; *Calluna/Sphagnum* origin; well-humified wet on squeezing half material passes through fingers vPIII; strong smell of sulphides.

Photo 4.13: Peat section showing Garrymona soil profile. *(R.F. Hammond)*

Photo 4.12: Allen Series, Sphagnofibrist.
(R.F. Hammond)

Photo 4.14: Allen Series, Clara Bog.
(C. O'Rourke)

Table 4.30: Profile Analyses - Garrymona Series

Horizon	Oap	Oil	Oal
Depth (cm)	0-25	25-110	110-150
Fibre per cent volume			
Unrubbed			
Rubbed	12	35	10
Bulk density g/ml	0.364	nd	nd
% Moisture (Saturated gravimetric)	424	982	1056
SPEC	3	7	7
Ash, %	25.1	8.9	4.5
pH	6.2	4.7	4.5
Carbon, %	43.5	53.0	55.5

Gortnamona Series

The Gortnamona Series is an extensive series occupying 3625 ha (1.82% of the county). It jg mapped on bog peripheries where the levelled, previously cut-over surface of the Allen Series was used for drying hand-cut turf and subsequently reclaimed for agriculture. The soil profile is characterised by an upper layer of peat materials derived from the Allen Series consisting of the top strippings of the bog surface, which were considered poor fuel value; these lie on a variable thickness of fen peat materials which were left *in situ* after fuel extraction. Soil development has taken place in the acid layer. Its surface horizon, depending on the age of land reclamation, can have physical characteristics very similar to those of the Banagher Series. Land reclamation in recent times would not have included "marling" and, therefore, surface horizons of resultant soils have lower ash content. The profile described is a relatively mature one with good structural development and dark black colours in the Oap. This is confirmed by the analytical data in Table 4.31 that show slightly acid surface pH, high bulk density and ash values, and low SPEC reading.

The age and intensity of land reclamation is reflected in the thickness of the surface horizon. Soil reaction in the sub-surface horizons is strongly acid and the morphology is similar to that of the Allen Series.

Soil suitability: The Gortnamona Series has potential for grassland, forestry and fuel production by tractor mechanised turf machines. In some areas, wider land use options are possible on this Series but much depends on physiographic position, access and management potential. As with the Banagher Series, optimum cropping potential depends on drainage outfall, access and the thickness of the surface horizon to maximise rooting potential. Frost damage is a factor with annual field crops and is a serious problem for certain field vegetable crops. When ground limestone is applied it is extremely important to mix it thoroughly throughout the plough layer. If land reclamation is carried out with strict control of these factors the Series is capable of good grass production.

Representative profile description: Gortnamona Series

Location:	Lullymore townland. Co. Kildare, Grid Ref. 270071 226226
Relief:	Hand cut edge of raised bog
Slope of site:	0°
Elevation:	77 m O.D.
Vegetation and land use:	Poor permanent pasture with herbs
Drainage:	Good
Parent material:	Minerotrophic peat
Great Soil Group:	Histosol (USDA Classification)
Sub-group	Medihemist

Horizon	Depth (cm)	Description
Qap	0-30	Black (5 YR 2/1); extremely well-humified, no recognisable plant remains; fine medium granular structure; abundant roots; presence added mineral matter; abundant roots; abrupt, smooth boundary.
Oa2	30-70	Dark reddish brown (5 YR 3/2); humified *Calluna-Sphagnum* (Cs) peat; few recent roots; layered structure: smooth, clear boundary.
Oa3	70+	Dark reddish brown (5 YR 2/2); humified fen peat with woody remains.

Table 4.31: Profile Analyses - Gortnamona Series

Horizon	Oap	Oa2	Oa3
Depth (cm)	0-30	30-70	70+
Fibre per cent volume	7	9	10
Unrubbed Rubbed			
Bulk density g/ml	0.349	0.128	0.112
% Moisture (Saturated gravimetric)	402.8	741.7	883.5
SPEC	1	5	6
Ash, %	36.8	5.3	3.1
pH	6.5	4.8	5.0
Carbon, %	25.0	55.0	56.3

Fen

The fen peat materials that occur within the lowland landscape of Co. Offaly developed in basin situations where watertables were at, near or above the land surface. Being limestone-floored the fen formed under the influence of base-rich groundwaters and the plant remains which comprise these peat materials are reed, sedges, non-sphagnum mosses, other semi-aquatic plants and wood remains of trees (willow, alder etc.). The fen landscape unit is found in river flood plains, poorly-drained hollows and on the periphery of Raised Bogs. Variations can occur in the botanical composition of the peat (parent) material, less humified-Carex-enriched peat to highly-humified *Phragmites* reed-swamp peat. These differences can influence physical properties and therefore land use, if considered for purposes other than grassland; their nutrient status, and soil reaction are generally similar. At the scale of mapping employed no separations are made with respect to botanical characteristics.

Two fen Series were mapped on the basis of the drainage condition: In the drained and reclaimed state, Banagher Series and in the undrained state, Pollardstown Series.

The schematic landscape section (Fig. 4.3) illustrates the topographic relationship of the different peat soil Series mapped in the course of the Co. Offaly soil survey.

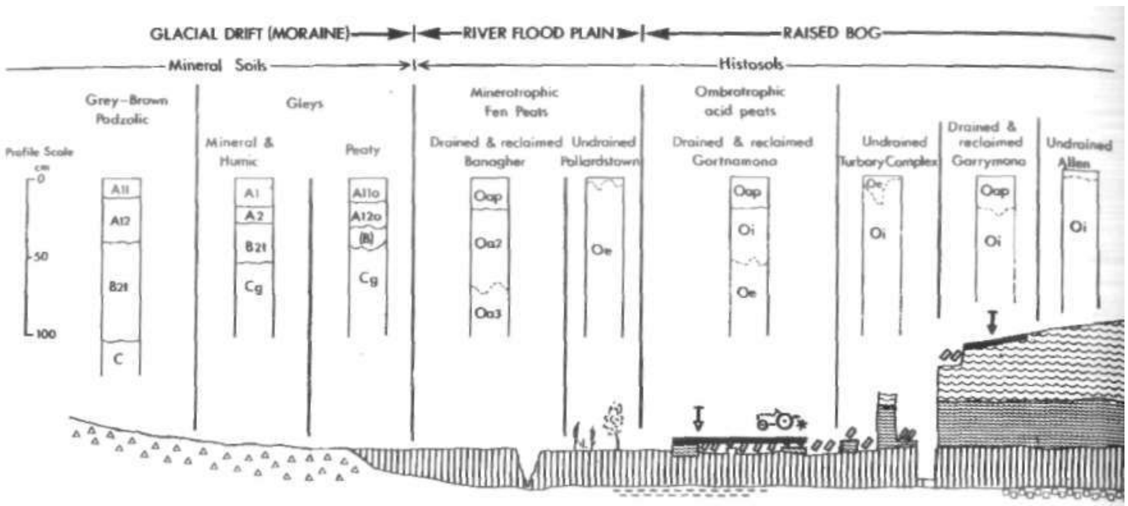

Figure 4.3: Schematic cross section of typical organic soils landscape in the Irish Midlands. *(Hammond, 1979)*

Banagher Series (Shallow and deep phases)

Occupying 16,834 ha (8.64%) of the county the Banagher Series occurs not only as large units in the landscape but also as small inclusions within many of the soil complexes, which occur in the kame-and-kettle landscape (Soil profile, Photo 4.15). The Banagher Series bounds many of the small streams that occur within these complexes. Shallow and deep phases were identified and described. The analytical data of both are presented in Tables 4.32 and 4.33. The surface horizon of a typical profile under permanent pasture exhibits a well-developed granular structure and abundant rooting. Fine to medium gravels within this horizon indicates that marling was carried out in previous generations to improve soil fertility. In river valleys a thin surface layer of alluvium may also be present. A permanent watertable can be recognised by the strong smell of sulphides that usually occur about 70 cm below the surface.

Both phases exhibit amorphous peat but the shallow version has developed the black colours of oxidised peat while the deeper, less oxidised exhibits sub-surface dark reddish brown colours. Analyses (Tables 4.32 and 4.33) show that both profiles are slightly acid with the shallow phase (pH 8.3) reflecting a calcareous substratum, and both show well-developed structure in the surface horizon. The shallow phase has consistently higher bulk density values, reflecting more intense drainage and the lower moisture contents.

Soil suitability: Depending on their position in the landscape and drainage condition, soils of the Banagher Series can have a moderately wide to wide use range. The risk of frost is a major factor and later sowing is advisable for frost-sensitive crops. In general, soil pH is favourable but this requires to be checked prior to establishing a cropping programme. Some areas are devoted to permanent grassland of variable quality. Sedges and rushes dominate the vegetation of rough urazing areas. High levels of production can be achieved with careful drain maintenance and an adequate fertiliser regime.

Representative profile description: Banagher Series - shallow phase

Location:	Cloghan townland, Co. Offaly, Grid Ref. 207400 219300
Relief:	Shallow depression
Slope of site:	0°
Elevation:	38 m O.D.
Vegetation and land use:	Rush-infested permanent pasture
Drainage:	Poorly drained
Parent material:	Amorphous minerotrophic peat
Great Soil Group:	Histosol (USDA Classification)
Sub-group	Medisaprist

Horizon	Depth (cm)	Description
Oap	0-10	Amorphous peat; black (5YR2/1); moderately developed fin granular structure; moist well-humified greasy; no recognisable fossil plant remains; common recent roots; clear, smooth boundary.
Oa2	10-20	Amorphous peat; black (5YR2/1); weakly developed fine sub-angular blocky to moderately developed coarse granular structure; greasy with no visible recognisable plant structures; fine few fibrous roots; gradual, smooth boundary.
Oa3	20-35/40	Amorphous peat; black (5YR2/1); moderately developed medium sub-angular blocky structure; very moist very weak brittle consistence; sharp, smooth boundary.
2C	35/40+	Sandy loam; grey (5Y6/1); massive structure; wet non-sticky non-plastic; calcareous.

Table 4.32: Profile Analyses - Banagher Series - shallow phase

Horizon	Oap 0-10	Oa2	Oa3	2C
Depth (cm)		10-20	20-35/40	35/40+
Fibre per cent volume Unrubbed Rubbed	49 6	46 2	46 4	-
Bulk density g/ml gravimetric	0.240	0.281	0.255	1.124
% Moisture (Saturated)	435	370	436	151
SPEC	5	4	1	
Ash, %	20.8	48.7	36.7	98.5
pH	6.79	6.50	6.96	8.28
Carbon, %	46.0	24.6	36.8	0.9

Representative profile description: Banagher Series - deep phase

Location:	Clonony More townland, Co. Offaly, Grid Ref. 205951 224505
Relief:	Level
Slope of site:	0°
Elevation:	43 m O.D.
Vegetation and land use:	Rush-infested poor permanent pasture
Drainage:	Poorly drained
Parent material:	*Phragmites/Carex* minerotrophic peat.
Great Soil Group:	Histosol (USDA Classification)
Sub-group	Medisaprist

Horizon	Depth (cm)	Description
Oap	0-10	Peat; very dusky red (2.5YR2/2); weakly developed fine granular structure; moist very weak soil strength; slightly deformable; amorphous well-humified with greasy feel; common fine fibrous roots; sharp, smooth boundary.
	10-20	Silty clay loam; dark grey (2.5YN4/0) with clear olive brown (2.5Y4/4) layer mottling; massive structure; moist moderately firm and very moist deformable; sharp, smooth boundary.
Oa2	20-25	Peat; very dusky red (2.5YR2/2); massive structure; amorphous well-humified greasy; clear, smooth boundary.
Oa3	25-35	Peat; black (5YR2/1); massive structure; very moist amorphous well-humified matrix with *Phragmites* remains; rhizome fragments and stems; gradual, smooth boundary.

Oa4 35-45 Peat; black (5YR2/1) to dark reddish brown (5YR2/2); massive structure; wet amorphous peat greasy with no recognisable plant remains; clear, smooth boundary.

Oa5 45-60 Peat; dark reddish brown (5YR2/2); massive structure; well-humified amorphous matrix with *Phragmites* and *Carex* sedge remains; very wet greasy; no further samples due to watertable; no smell of sulphides suggesting a fluctuating watertable

Table 4.33: Profile Analyses - Banagher Series - deep phase

Horizon	Oap	A	Oa2	Oa3	Oa4	Oa5
Depth (cm)	0-10	10-20	20-25	25-35	35-45	45-60
Fibre per cent volume						
Unrubbed	20	-	40	40	46-	37
Rubbed	3	-	6	4	43	
Bulk density g/ml	0.298	0.74	0.130	0.134	0.122	0.120
% Moisture (Saturated gravimetric)	393	212	1148	771	851	865
SPEC	1	2	2	2	2	2
Ash. %	20.8	71.0	19.4	16.6	16.7	17.9
pH	6.64	6.46	6.88	6.41	6.35	6.34
Carbon, %	46.0	16.9	46.9	48.5	48.4	47.7

Pollardstown Series

Previously believed to be extensive, the Pollardstown Series occupies 1639 ha (0.82% of the county). Its now very limited extent reflects drainage and reclamation of fen areas for agriculture. An abbreviated profile description is presented, accompanied by analytical data (Table 4.34). It exhibits the conventional properties of a fen soil with high pH, low bulk density and very high gravimetric moisture content.

Soil suitability: The Pollardstown Series is unsuitable for agriculture. It is best used for botanical studies and as a wildlife habitat with potential for amenity and conservation purposes.

Representative profile description: Pollardstown Series

Location:	Whigsborough townland, Co. Offaly, Grid Ref. 209006 212219
Relief:	Shallow depression
Slope of site:	0°
Elevation:	60m O.D.
Vegetation and land use:	Fen species *Potamogeton natans* (Pondweed), *Menyanthes trifoliata* (Bogbean), *Mentha aquatica* (Mint)

Drainage:	Waterlogged
Parent material:	Amorphous minerotrophic peat
Great Soil Group:	Histosol (USDA Classification)
Sub-group	Medisaprist

Horizon	Depth (cm)	Description
Oal	0-15	Very wet amorphous peat; black (5YR2/1); structureless; no recognisable fossil plant remains; common recent roots; clear, smooth boundary.
Oa2g	15-45	Amorphous peat; black (5YR2/1); structureless; greasy with no visible recognisable plant structures; with many recent roots; smooth boundary.
Cg	45 - 100	Shell marl abrupt boundary.
Oa3	100-110	Amorphous peat.
Oa4	110-140	Fine grained gytta.
Oa5	140-150	Very fine grained gytta.

Table 4.34: Profile Analyses - Pollardstown Series

Horizon	Oal	Oa2g	Cg
Depth (cm)	0-15	15-45	45-100
Fibre per cent volume			
Unrubbed	56	36	34
Rubbed	36	8	4
Bulk density g/ml	0.10	0.14	0.27
% Moisture (Saturated gravimetric)	991.1	668.5	348.0
SPEC	5	4	1
Ash, %	7.9	8.9	79.8
pH	6.28	6.50	7.27
Carbon, %	47.7	46.9	10.4
Nitrogen, %	2.0	2.19	0.95
C/N ratio	23.9	21.4	10.9

Peat Complexes

Two lowland peat complexes were mapped in Co. Offaly. Both are anthropogenically modified.

Turbary Complex

The Turbary Complex mapping unit occupies 10,762 ha (5.40%) of the county and arises from hand cutting of peat fuels in past centuries. It occurs solely within the Raised Bog landscape unit and represents over 50% of the original area of Raised Bog within the county. Such areas have generally remained derelict for decades due to several factors, namely; poor access, poor drainage and uneven topography. The Allen Series occurs on the peat hags within the Complex whilst the remaining areas are representative of a miscellaneous land unit comprising open water and raw, strongly acid, and in, general poorly to very poorly drained soils. The vegetation patterns within the complex are good indicators of drainage status, e.g. where there is a strong growth of *Calluna vulgar™* (heather) soils are relatively drier than areas where bog cotton *(Eriophorum* spp). predominate. Peat depths also vary widely depending on past management during the course of hand cutting for peat fuel.

Soil suitability: In their present state the Turbary Complex is unsuited to agriculture but has a potential for forestry and in many areas is being developed for the production of peat fuels using tractor mounted turf-cutting machines.

Industrial Peat - Milled Peat, Machine Peat Complexes

The Industrial Peat complex (previously Boora and Clonsast Complexes) occupies 26.803 ha (13.66%) of the county. Since the late 1930's Bord na Mona (The Irish Peat Development Authority) has developed large expanses of raised bog (Allen Series) (Photo 4.14) for the production of milled (Photo 4.16) and machine peat. In earlier county surveys the peat soils present in the industrial peat complex were defined on the basis of the method used, i.e. milled turf Boora Complex from Boora Bog, Co. Offaly and sod turf Clonsast Complex from Clonsast Bog, Co. Offaly. A re-definition to Industrial Peat complex is required. The reasons for this change are explained under soil character below.

Soil character: Fuel production removes the greater part of the profile sequence (Allen Series) leaving behind a variable depth of fen peat materials depending on the topography of the underlying bog floor. After milled peat production all peat materials are of a minerotrophic nature whereas on the cutover areas of sod turf production a bi-partite profile remains consisting of the strippings from the upper layer of ombrotrophic peat materials over a sub-surface layer of minerotrophic peat materials. In recent years, however, improved techniques for fuel harvesting (Hakuu Method) now allow milling of the cutover areas of sod turf bogs to extend the bog's productive span, thus obviating the formation of an upper layer of ombrotrophic materials.

Since the completion of the soil survey these changes in production methods will influence the soils pattern remaining. However, the names 'milled' and 'machine' are retained in the legend to indicate historically the areas of the different production processes so that if some areas in the future are not milled, the reason for differing soil characteristics will be understood. Subsequent to these changes, soil parent materials in bog areas, irrespective of the type of fuel production, are likely to be the same. The Clonsast Complex will, however, occur in smaller areas where further milling to extend the productive life of a sod turf bog is not economically feasible.

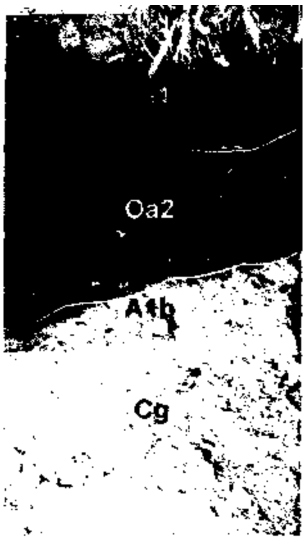

Photo. 4.15: Profile of Banagher soil - shallow phase. *(R.F. Hammond)*

Photo 4.16: Industrial milled peat on raised bog (Allen Series) and electricity generating station, Bord na Mona, Derrygreenagh, Co. Offaly, looking east from Croghan Hill. *(R.F. Hammond)*

Soil suitability: The suitability of the two complexes is basically dependent on the depth and type of peat which remains after fuel production has ceased, and on the type of sub-peat mineral "soil". However, the selection of a particular land use enterprise to be followed, i.e. vegetable field crops, grassland or forestry, will depend largely on the soil type and social and economic circumstances. In the overall evaluation of this land type the amenity aspect is an important alternative land use system as seen at Lough Boora Peatlands and Turraun (Photo 4.17).

Photo 4.17: Wetlands nature reserve created from worked-out Bord na Mona milled peat operations at Turraun, Co. Offaly. *(C. O'Rourke)*

HILL AND MOUNTAIN SOILS

Hill and Mountain Soils are defined as those which occur at elevations greater than 150m. In Co. Offaly the Slieve Bloom Mountains, the northeastern foothills of the Silvermine Mountains and the Permian/Carboniferous volcanic plug of Croghan Hill in the north-central part of the county are regarded as having a Hill and Mountain physiography. The dominant rock formations in the Slieve Bloom and Silvermine Mountains are Upper Silurian (Llandovery) Shale and Devonian (Old) Red Sandstone, and Greenstone (Diorite) and Greenstone Ash of Croghan Hill.

Within the Slieve Bloom Mountains area elevations range from 150 to over 500 m, and a topographical separation is made within the area defined by elevation, the foothills (150-320 m) and mountain land (320-530 m). The soil types and distribution patterns prevailing reflect differences in parent materials, the influence of Quaternary glaciations and climatic regimes at different elevations. Four groups of soils have been identified in the Slieve Bloom and Silvermine Mountains. They have developed in glacial drift-dominated parent materials of 1) Carboniferous Limestone composition mainly, 2) Shale composition mainly, 3) Old Red Sandstone composition mainly, and 4) organic materials.

The general elevational sequence of soils as follows: Above 280 m organic soils dominate and are derived from blanket bog ombrotrophic peat accumulations. Between 175 and 250 m the soils are derived from dominantly shale and sandstone parent materials. They were placed in the following Great Soil Groups: Podzols, Brown Podzolic/Brown Earths, Gleys and Peat (Histosol) soils. Between 150 - 175 m the soils are formed from parent materials dominated by Carboniferous Limestone and occur within the following Great Soil Groups: Grey Brown Podzolics, Brown Earths, Gleys and Organic soils.

Slieve Bloom Mountains

The Slieve Bloom Mountains covering an area of 10,425 ha (5.24%) of the county are formed from Devonian Red Sandstone and Silurian Shales, gritstone, and "shlig" in local terminology, respectively. The dominant rock formation is Devonian Red Sandstone. The colour of the sandstones is quite varied from white/yellow to various shades of brown, purple and red (Photo 2.1). The Silurian shales, grey and greenish grey colour, occur chiefly on the deeply-incised valleys which are a characteristic feature of the central portion of the mountains between Kinnitty in Co. Offaly and Camross in Co. Laois. The area has been strongly glaciated with glacial drift covering most of the underlying rock formations.

Figures 4.4 and 4.5 are schematic cross sections of 1:126,720 scale to show the topographical relationship of the mapped Soil Series to the drift mantle overlying the bedrock geology. The landscape sections shown in Figures 4.4 and 4.5 run in a northerly and westerly direction, respectively.

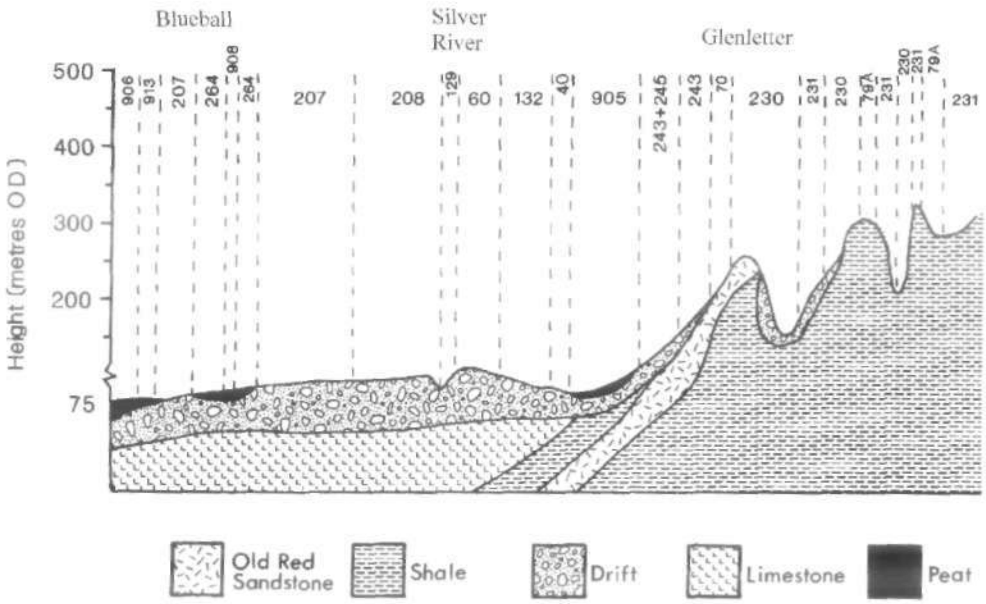

Figure 4.4: Schematic cross section of the Co. Offaly landscape running northwards from Farbreague Mountain to The Blueball west of Tullamore. Soil Series shown by Soil Map Unit numbers.

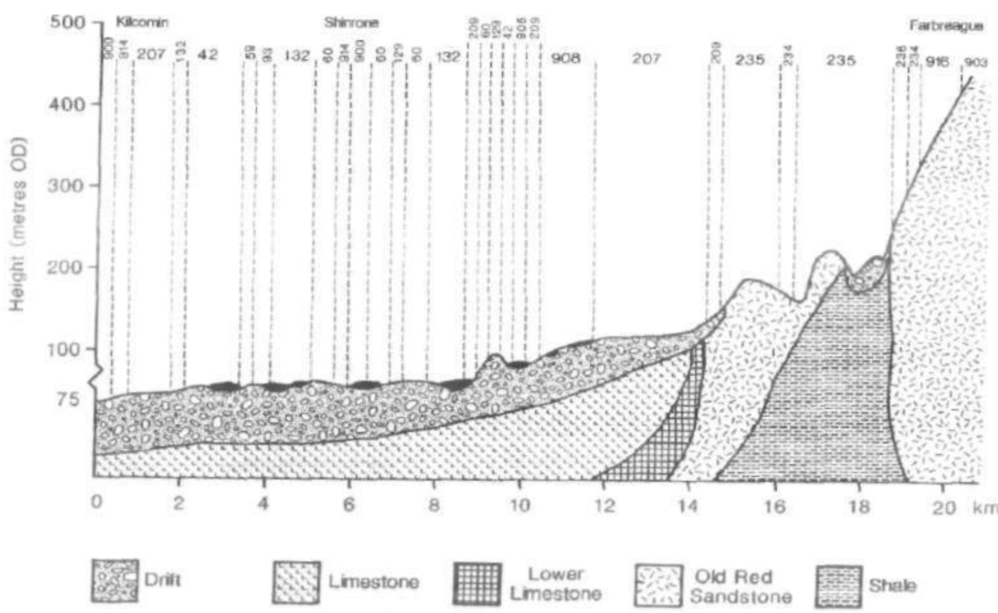

Figure 4.5: Schematic cross section from Farbreague Mountain running south-westwards to Kilcomin on the Offaly/Tipperary county boundary. Soil Series shown by Soil Map Unit numbers.

Shale-derived soils

Soils derived from shales occupy 1810 ha (0.91%) of the county and form an important group of soils in the Slieve Bloom Mountains not because of their extent (17.36% of the area) but because they are some of the best agricultural soils in the hill area. They occur chiefly in the central part of the mountains where the deeply incised valleys are a noted feature of the landscape. The softer shale rock has been weathered and eroded giving rise to steep-sided valleys. Most of the shale soils are derived from glacial drift deposits, composed mainly of Silurian shale with a small admixture of sandstone and the occasional erratic of Galway granite. In the more elevated areas and especially where the slopes are very steep, the drift mantle has been eroded and the soils are derived therefore from weathering shale bedrock. The soils belong to four Great Soil Groups, namely Brown Earths, Podzols, Reclaimed Podzols and Gleys.

Brown Earth Group

Brown Earths are found on gently undulating to rolling topography on slopes ranging from almost level to 18° and occurring at Elevations between 150 - 320 m. These soils are derived mainly from glacial till composed of shale with a variable but small admixture of sandstone. Three Series, Baunreagh, Ballylanders and Rathmoyle were mapped.

Baunreagh Series

Baunreagh soils cover an area of 611 ha (0.30%) of the county at elevations between 150 - 320 m. The profile morphology is characterised by a dark-brown friable loam to clay loam surface A horizon over a distinct yellowish red or strong brown sub-soil Bw horizon. They are moderately deep, well drained, with good structure and friable consistence. The analyses (Table 4.35) show the soil to be acid and of very low base status.

Soil suitability: As a result of their favourable physical characteristics these soils have a wide land-use range. Grassland and arable production requires a high level of management, as fertiliser and lime inputs need to be maintained to achieve production targets. Elevation is also an important factor as climatic limitations can influence land use potential.

Representative profile description: Baunreagh Series

Location:	Baunreagh Wood, Co. Laois, Grid Ref. 220500 198400
Relief:	Rolling
Slope of site:	Straight 9°
Elevation:	230 m O.D.
Vegetation and land use:	Grassland with wood-rush *(Luzula sylvatica),* bramble (Blackberry, *Dris: Rubus fruticosus),* and bracken *(Pteridium aquilinum)*
Drainage:	Well drained

Parent material:	Non-calcareous glacial till composed mainly of shale with some sandstone influence Brown Earth
Great Soil Group:	

Horizon	Depth (cm) 0	Description
A	- 28/30	Loam to clay loam; brown to dark brown (I0YR4/3); moderate medium sub-angular blocky and fine crumb structure; moist friable; abundant roots; clear boundary.
Bwl	28/30 - 70/90	Loam to clay loam; strong brown (7YR5/6); moderate fine crumb structure; moist very friable; plentiful roots; gradual, tonguing boundary.
Bw2 C	70/90 - 90/95	Transitional horizon.
	90/95+	Sandy loam; olive grey (5Y5/2); structureless; glacial till; non-calcareous.

Table 4.35: Profile Analyses - Baunreagh Series

Horizon	A	Bwl	C
Depth (cm)	0-28/30	28/30-70/90	90+
Particle size distribution analysis (%)			
Coarse sand	18	25	35
Fine sand	17	16	21
Silt	38	14	30
Clay	27	25	14
pH	4.9	5.5	5.4
CEC, mEq/IOOg	27.4	24.0	9.8
TEB, mEq/lOOg	1.3	0.9	0.2
Base saturation, %	5	3	2
Carbon, %	2.8	1.6	0.9
Nitrogen, %	0.28	0.14	-
C/N ratio	10.0	11.4	-
Free iron, %	3.1	4.0	2.0
TNV, %	-	-	-

Brown Earth Group - slope phases

Baunreagh Steep phase

The steep phase soils occur between 200 - 300 m O.D. and occupy 68 ha (0.03%) of the county. The physical and chemical properties of the phase soils do not differ significantly from the soils described above. The soils occur on slopes ranging from 18 - 32° with the majority in the range 18 - 25°. The slope factor restricts land use to grassland and forestry. Where grassland management has been neglected pastures become infested with bracken {*Pteridium* spp.) and gorse (furze, *Ulex* spp)- in many instances this land type has been used for forestry planting. On the very steep slopes (>25°) these soils were never cultivated and the natural vegetation is a mixture of poor grasses, heather, bracken and gorse. Under this vegetation type, the soil consists of a 5cm organic layer over a thin sub-surface leached layer, overlying the yellowish-red sub-soil. This land is only suited for forestry and these areas have already been extensively afforested.

Ballylanders Series

The Ballylanders Series occupies 110 ha (0.05%) of the county, at elevations of 200 m O.D. on strongly sloping-topography, derived from shale drift or colluvium. The soils are shallow, well drained of loam texture with weakly developed structure and in some instances the Bw horizon fingers into the shale bedrock (Fig. 4.6). The analyses (Table 4.36) show the soil to be acid with moderate base saturation.

Soil suitability: The soils of this series are predominantly suited to grassland production with limitations for tillage in respect of slope and elevation.

Representative profile description: Ballylanders Series

Location:	Loyer townland, Co. Offaly, Grid Ref. 203600 179800
Relief:	Hilly
Slope of site:	Straight simple
Elevation:	228 m O.D.
Vegetation and land use:	Rough grazing
Drainage:	Well drained
Parent material:	Shale bedrock
Great Soil Group:	Brown Earth

Horizon	Depth (cm)	Description
Al	0-7	Gravelly loam to silt loam; dark brown (10YR3/3); weakly developed medium to coarse granular structure; friable; 2% medium to large stones; many fine fibrous roots; clear, smooth boundary.
A2	7-14	Stony, gravelly loam; dark yellowish brown (10YR3/4); moderate sub-angular blocky breaking to fine to very fine sub-angular blocky structure; moist friable; sub-rounded slightly stony; many fine fibrous roots; gradual, smooth boundary.
Bw	14-33/36	Moderately stony loam; brown (7.5YR4/2); weakly developed fine to very fine sub-angular blocky structure; moist friable; common fibrous roots with few fleshy roots; abrupt, irregular boundary.

R	33/36+	Upper Silurian (Llandovery) Shale; jointed fractured; thinly bedded; hard.

Table 4.36: Profile Analyses - Ballylanders Series

Horizon	Al	A2	Bw	R
Depth (cm)	0-7	7-14	14-33/36	33/36+
Particle size distribution analysis (%)				
Coarse sand	20	21	18	
Fine sand	15	16	16	
Silt	40	36	41	
Clay	25	25	25	
pH	5.8	5.7	5.9	-
CEC, mEq/100 g	29.4	28.6	26.4	-
TEB, mEq/lOOg	8.7	5.1	5.1	-
Base saturation, %	30	18	20	-
Carbon, %	5.4	4.3	2.7	-
Nitrogen, %	0.40	0.36	0.26	-
C/N ratio	13.5	11.9	10.4	-
Free iron, %	2.6	2.2	2.5	-
TNV, %	-	-	-	-

Figure 4.6: Profile drawing of Ballylanders Series (Brown Earth) developed over shale bedrock (see Fig. 4.2 for explanation of symbols).

Rathmoyle Series

The Rathmoyle Series occupies 543 ha (0.27%) of the county and occurs at elevations of 150 - 200 m O.D. on strongly rolling to hilly topography. The soil is derived from glacial drift parent material of shale, sandstone and limestone. The solum is relatively deep (>100 cm), moderately drained but showing signs of gleying. The profile displays a very dark greyish-brown surface horizon overlying greyish-brown sub-surface horizons; soil consistence is friable in the surface but becomes plastic in the Bw horizon. Structure is weakly developed. Rooting is common in the surface but decreases in abundance with depth. The analyses (Table 4.37) show that soil pH is low in the surface but increases with depth; base saturation values follow the same pattern, reflecting a limestone influence.

Soil suitability: These soils have a relatively wide use range. Limitations for grassland and arable crop production relate to elevation and slope factors. The occurrence of areas with surface water gleying from seepage and steeper slopes restricts land use to grassland. The soil's acid reaction requires liming to maximise production.

Representative profile description: Rathmoyle Series

Location:	Lisdavuck townland, Co. Offaly, Grid Ref. 200200 179000
Relief:	Hilly
Slope of site:	6°
Elevation:	180 m O.D.
Vegetation and land use:	Ley cut for silage/ploughing for cereals
Drainage:	Moderate
Great Soil Group:	Brown Earth

Horizon	Depth (cm)	Description
Ap	0-27/33	Very dark greyish brown (10YR3/2); loam; 2-5% stones; weal developed weak fine sub-angular blocky structure breaking to fine medium granular; moist friable; fine to very fine common fibrous roots; distinct, smooth boundary.
Eg	27/33 - 87	Light greyish brown to greyish brown (2.5Y6/2 - 5/2); sandy clay loam; 5% stones; many common distinct sharp to clear strong brown (7.5YR5/6) mottles; weakly developed to massive structure; moist firm to friable; clear, slightly wavy boundary.
Bw	87-117	Greyish brown (10YR5/2) with greyish brown (2.5Y5/2) patches; common very fine distinct and diffuse yellowish brown (10YR5/4) mottles; sandy clay loam to clay loam; 5% stones; weakly developed structure to massive *in situ;* wet plastic; few fine fibrous roots; clear, wavy boundary.
	117+	Greyish brown (2.5Y5/2); stony sandy clay loam to clay loam; 25-30% stones; massive structure; wet sticky; calcareous.

Table 4.37: Profile Analyses - Rathmoyle Series

Horizon	Ap	Eg	Bw	C
Depth (cm)	0-27	27-87	87-117	117+
Particle size distribution analysis (%)				
Coarse sand	30	24	22	20
Fine sand	17	16	15	16
Silt	37	40	40	41
Clay	16	20	23	23
pH	5.5	5.9	6.8	8.3
CEC, mEq/100 g	23.8	6.2	6.8	5.4
TEB, mEq/lOOg	6.5	1.9	3.8	6.0
Base saturation, %	27	30	56	Sat
Carbon, %	3.0	0.4	0.4	0.4
Nitrogen, %	0.23	-	-	-
C/N ratio	13.0	-	-	-
Free iron, %	1.0	1.7	2.1	1.6
TNV, %	-	-	-	-

Shale-derived Gley Group

The shale-derived gleys are represented by the Bawnrush Series. Due to their topographical position and physical nature such soils are agriculturally restricted to grassland. Under grassland management, limitations such as poaching, rush infestation and a short growing season reduce the production potential. Where these soils have been afforested with Sitka spruce *(Picea sitchensis)*, high yield classes have been achieved.

Bawnrush Series

Occupying 478 ha (0.24%) of the county the Bawnrush Series is of limited extent. It was first mapped in County Laois (Conry, 1987; Conry and Hammond, 1984;). The soils occur in association with the Baunreagh and Knockastanna Peaty phase in footslope and depression situations. The soil is characterised by a dark greyish-brown strongly-mottled surface layer over grey and mottled sub-surface horizons. Soil structure is weak and root development largely confined to the surface horizon.

Soil suitability: These soils are limited in their land use, confined to grassland of generally poor quality, especially where no remedial drainage has been carried out. Where these soils have been planted to coniferous species, notably Sitka spruce *{Picea sitchensis)*, tree growth has been very satisfactory.

Shale-derived Iron Pan Podzol Group

Podzol soils occur at elevations >275 m where the higher precipitation and lower temperatures are conducive to leaching and the acid conditions created at the soil surface allow the accumulation of organic matter and the formation of a surface peaty layer. This surface layer varies in thickness but is generally 25 cm. overlying a greyish horizon depleted of iron, aluminium and humus. Much of these constituents accumulate down the profile, forming a yellowish red sub-soil with a continuous thin dark red iron pan at its upper boundary. The pan is a physical boundary to the penetration of roots and the downward flow of water. The use of modern machinery and recently developed techniques for land reclamation has caused soils of this type, on less steep slopes, to be developed for grassland.

In their natural state the land use range of these soils is restricted to rough grazing. In the last few decades large areas have been afforested with Sitka spruce *{Picea sitchensis)* and lodgepole pine *(Pinus contorta).* The Knockastanna Series, and its peaty phase, were first mapped in Co. Limerick, developed in weathered shale and colluvium. The peaty phase was the dominant soil in the Slieve Bloom Mountains and a description and analytical data are presented for it in Table 4.39.

Knockastanna Series - Peaty Phase

The peaty phase of the Knockastanna Series occupies 912 ha (0.45%) of the county and occurs at Elevations over 200 m on the slopes of the Slieve Bloom Mountains. It is generally above normal cultivation limits and is wetter owing to the higher rainfall. The presence of an iron pan causes gleying in the E horizon. The soil is imperfectly drained; textures below the surface layers of peat range from sandy loam to silt loam. Structure is massive in the E horizon and weakly developed in the Bs horizon. The iron pan generally occurs beneath the E horizon at about 50 cm depth. pH values are all <5. Roots are common in the surface but decrease sharply with depth. The analytical data (Table 4.38) show the soil to be strongly acid, with very low base saturation and high organic carbon values in the surface and increases in free iron values in the Bs horizons.

Soil suitability: The use-range is very limited and is confined to extensive grazing. Forestry can be successfully established in the exposed upper reaches of the mountains but the growth rate is generally slow.

Representative profile description: Knockastanna Series - Peaty Phase

Location:	Glendine Pass, Co. Offaly, Grid Ref. 221000 198803
Relief:	Mountainous
Slope of site:	-10°
Elevation:	275 m O.D.
Vegetation and land use:	Sitka spruce *(Picea sitchensis)* with undercover of purple moor grass *(Molinia caerulea)* and heather *(Calluna vulgaris)*
Drainage:	Well drained with depth impeded in the surface

Parent material:	Silurian shale with colluvial influence
Great Soil Group:	Podzol
Sub-group:	Peaty Iron Pan

Horizon	Depth (cm)	Description
Oe	30 -0	Peat; black (5YR2/1); compact massive structure; greasy well humified amorphous peat matrix with recent roots and few recognisable cyperaceous plant remains; common fine fibrous roots in the surface; abrupt, smooth boundary.
	0-10	Loam to silt loam; greyish brown (10YR5/2); massive structure; moist friable; abrupt, smooth boundary.
Bm	10-10.5	Indurated iron pan; red (7.5YR5/6); abrupt, wavy boundary.
Bsl	10.5-25	Sandy loam; strong brown (7.5YR5/6); within horizon dark reddish brown (5YR2/2) organic matter stained patches; weak structure fine sub-angular blocky tending to fine granular; many macropores; moist very friable; few fine fibrous roots; gradual boundary.
Bs2	25-45	Loam; strong brown (7.5YR5/6); within horizon dark reddish brown (5YR2/2) organic matter stained patches; weak structure; moist very friable; few fine fibrous roots; clear, smooth boundary
	45+	Loamy sand; brown (10YR5/3) to yellowish brown (10YR5/4); massive structure; compact *in situ* moist friable.

Table 4.38: Profile Analyses - Knockastanna Series - Peaty Phase

Horizon	**Oe**	E	Bsl	Bs2	C
Depth (cm)	30-0	0-10	10.5-25	25-45	45+
Particle size distribution analysis (%)					
Coarse sand	-	17	36	32	37
Fine sand	-	14	24	20	25
Silt	-	44	27	30	34
Clay	-	25	13	18	4
pH	4.5	4.2	4.8	4.7	4.2
CEC, mEq/100 g	33.6	41.2	23.2	23.2	-
TEB, mEq/lOOg	1.56	0.30	0.10	0.13	-
Base saturation, %	5	1	<1	<1	-
Carbon, *%*	36.0	8.5	0.7	1.2	-
Nitrogen, %	1.50	0.37	-	-	-
C/N ratio	24.0	22.9	-	-	-
Free iron, %	0.4	0.5	2.5	2.9	-
TNV, %	-	-	-	-	-

Sandstone-derived soils

c$_0$jls derived from sandstone glacial drift occupy 4509 ha of the defined mountain area. Siliceous chert found in the drift material indicates that it originally contained a proportion of more soluble limestone. However, almost all of this limestone has been removed by post-glacial weathering and the material underlying a vast proportion of the sandstone soils therefore consists of till composed of coarse-grained sandstone and chert with some shale conglomerate and, very occasionally, Galway granite erratics. On moderately steep and steep slopes, where post-glacial weathering has removed the drift deposits, the soils are derived from the underlying bedrock. The only extensive and mappable Great Soil Groups developed in sandstone-dominated tills were Gleys and Podzols. Small areas of other Great Groups were mapped as complexes. Two gley Soil Series were identified as Slieve Bloom and Gortaclareen.

Sandstone-derived Gley Group

Gley soils occur throughout the mountain area. Their occurrence is related to topographical position. Most are found in low-lying areas but on gentle slopes seepage gleys are common. The profile usually consists of a dark greyish brown surface horizon, generally higher in organic matter than better-drained soils, overlying sub-surface horizons, which are strongly mottled. Surface horizon textures are loamy sands to loams with weakly developed structures.

Slieve Bloom Series

The most important and extensive group of soils on the Slieve Bloom Mountains are Gley soils, derived from predominantly sandstone drift material. The most extensive sub-groups are Peaty Gleys and are interspersed by two phases, non-Peaty and undulating, and components of complexes (below). The Peaty Gleys occur on rolling topography at elevations ranging from 150 to 450 m in places. Excluding peaty gleys which have been mapped as slope phases, the Series covers 1301 ha, (0.65%) of the area of the county. Slopes vary from 5 to 16° but most are between 5 and 10°.

Although they occur on moderate slopes they are predominantly wet due to the slow permeability of the compact subsoil. The low permeability is due not to a high content of fine material in the soil but to the close packing of the finer material (silt and clay) between the coarser particles (Collins *et al.*, 1977). Such an arrangement of soil particles severely reduces the void and air space, thus minimising soil permeability. The slow permeability of the soil together with the cool wet climate at these elevations contribute to the development of these soils.

The soil profile consists of a peaty surface layer, which overlies grey and mottled subsoil horizons. The lower part E horizon is compact and grey in colour, but the upper part is friable and dark-coloured due to humus accumulation. The grey and mottled subsoil Bwg horizon grades into the compact sandstone parent material at a depth of about 1 metre. The peaty surface layer varies in thickness from 5-35 cm but it is generally 10-25 cm. This variability in thickness is due to intermittent and irregular sod removal for fuel. Where these soils have been mapped at higher elevations there is strong evidence that many of them originally carried a thicker layer of peat. The profile analyses (Table 4.39) show the soil to be slightly acid with moderate base saturation values The organic carbon level reflects the peaty nature of the surface horizon.

The peat layer is normally wet and spongy with surface-water lodging in the local depressions except in dry periods. Irrespective of peat depth it carries a typical heavily grazed wet-heath type vegetation dominated by heather *{Calluna vulgaris),* heath rush *(Juncus squarrosus),* deergrass *(Scirpus caespitosus)* and moss *{Sphagnum* spp.) with smaller amounts of bog cotton *{Eriophorum angustifolium),* purple moor-grass *{Molinia caerulea),* bog asphodel *(Narthecium ossifragum)* and cross-leaved heath *(Erica tetralix)* (Cotton, 1974.)

Rocky areas occur frequently within this mapping unit, especially where the sandstone grades into quartzitic conglomerates.

Some small areas of very wet flush soils also occur within the Slieve Bloom Series, in flattish areas and local depressions where seepage waters accumulate. The soil consists of a wet peat that may be 30-70 cm (occasionally > 1 m) deep over strongly-gleyed compact subsoil horizons derived from sandstone drift deposits. These soils carry a typical wet vegetation (Type 5a; Cotton, 1974) lacking bog cottons *{Eriophorum* spp.), rush species, both *Juncus effusus* and /. *acutiflorus,* are more prominent; *Sphagnum* mosses are common together with plants like tormentil *(Potentilla erecta),* sweet vernal grass *{Anthoxanthum odoratum)* and marsh violet *{Viola palustris),* which indicate higher levels of nutrients.

Soil suitability: These soils have a limited use range. In the past they were used only for rough grazing by cattle in the period from June to September. But in the last two decades an increasing area has been planted, principally with Sitka spruce *(Picea sitchensis)* and contorta pine *(Pinus contorta).*

Representative profile description: Slieve Bloom Series

Location:	Gorteen townland, Co. Offaly, Grid Ref. 218110 194248
Relief:	Rolling
Slope of site:	4 - 6°
Elevation:	275 m O.D.
Vegetation and land use:	Sitka spruce *(Picea sitchensis)* plantation with undercover of purple moor grass *(Molinia caerulea)* and heather *(Calluna vulgaris)*
Drainage:	Poorly drained
Parent material:	Sandstone glacial drift
Great Soil Group:	Gley
Sub-group	Peaty

Horizon	Depth (cm)	Description
01	0-10	Amorphous organic layer with washed-in sand grains; black (5YR2/1); massive structure; well decomposed wet slightly greasy; abundant fine fibrous roots; sharp, wavy boundary.
Eg	10-40	Loamy sand; dark greyish brown (10YR4/2) light grey (10YR7/2) dry; few distinct medium fine strong brown (7.5YR5/6) mottles; massive structure; few macropores; wet non-sticky dry slightly hard; many fine fibrous recent and fossil roots; smooth boundary.
Bg	40-110	Loam; weak red (10YR4/2); (10YR5/2) dry; yellowish brown (10YR5/8) weathered sandstones; in lower part Bg very fine distinct brownish yellow (10YR6/8) mottles in fossil root channels; massive structure; wet slightly sticky dry hard; recent and fossil fine fibrous roots in upper part of horizon; clear, irregular boundary.
	110+	Loam; weak red (10Y4/2); massive compact structure; incipient yellowish red (10YR6/8) Bm at 120cm underlain by black (7.5YRN/2) manganese cementation in reddish brown (5YR4/3) matrix.

Table 4.39: Profile Analyses - Slieve Bloom Series

Horizon	Ol	Eg	Bg	C
Depth (cm)	0-10	10-40	40-110	110+
Particle size distribution analysis (%)				
Coarse sand	54	48	19	43
Fine sand	23	24	33	17
Silt	13	20	29	24
Clay	10	8	19	16
pH	6.2	6.2	6.2	6.8
CEC, mEq/lOOg	45.0	14.2	8.4	9.0
TEB, mEq/lOOg	19.9	2.4	3.6	4.2
Base saturation, %	44	17	42	47
Carbon, %	13.1	-	-	-
Nitrogen, %	0.89	-	-	-
C/N ratio	14.7	-	-	-
Free iron, %	0.5	0.2	2.8	2.2
TNV, %	-	-	-	-

Slieve Bloom Series - Undulating Phase

These soils are very similar to the Slieve Bloom peaty gleys with which they are closely associated on the landscape. As they occur on flattish slopes on lower portions of the topography they show some differences. Firstly, the peaty surface layer of the gently-undulating phase is wetter for a longer part of the year due to slower run-off on these flattish slopes. Secondly, the parent material of this soil is calcareous at depth. Otherwise the soils are very similar in profile characteristics.

In the semi-natural state they have the same use range as the Slieve Bloom Series. However, they are less suitable for reclamation because surface water is more difficult to dispose of on these flatter slopes. There is strong evidence that a considerable depth of peat has been removed for domestic fuel from some of these soils

Slieve Bloom Series - Non-Peaty Phase

These poorly drained non-peaty podzolised gleys occur at a wide range of elevations from 150-300 m. They occupy 882 ha (0.44%) of the county and are generally found in low-lying situations but they can occur more extensively on average slopes where seepage water from the higher ground contributes to the poor drainage. At lower elevations, around the periphery of the mountains on flattish topography and local depressional areas, the original limestone content of the till has been largely preserved by its protected position.

The profile described consists of a dark greyish-brown sandy loamy surface horizon overlying a grey and mottled compact subsoil horizon. The mottling can be extensive in places. The outstanding feature of these soils is their low permeability. Despite the rather high content of coarse particles the soils are compact with low content of voids and air space. A close packing arrangement of the soil constituents has caused the finer material (silt and clay) to fill the spaces between the coarser sand grains. The analyses (Table 4.40) show the soil to be acid with low base saturation and low organic carbon content.

Representative profile description: Slieve Bloom Series - Non-Peaty Phase

Location	Clashroe townland, Co. Offaly, Grid Ref. 218500 197100
Relief	Mountainous
Slope on site	Straight simple 15°
Elevation	300 m O.D.
Vegetation and land use	Rough grazing, rush *(Juncus* spp.), sedge *(Carex* spp.), crested dogstail *(Cynosurus cristatus),* fescue *(Festuca* spp.), bilberry *(Vaccinium myrtillus)* in drier locations
Drainage	Poor
Parent material	Sandstone till
Great Soil Group	Gley
Sub-group	Mineral

Horizon	Depth (cm)	Description
A	0-10	Sandy loam; few platy sub-rounded sandstone stones; dark greyish brown (10YR4/2); very weakly developed to almost massive structure; moist friable, weak brittle; very fine common fibrous roots; distinct, slightly wavy boundary.
	10-23	Sandy loam; common sub-angular sandstone stones; dry grey (5YR6/1); massive structure; compact *in situ*, moist friable, dry brittle; few very fine fibrous roots; clear, slightly wavy boundary.
Bwg	23-49	Sandy loam; many platy angular sandstones; reddish brown (5YR4/4) light reddish brown (5YR6/3) dry; with yellowish brown (10YR5/6) weathered sandstones; massive structure; compact *in situ*, moist friable, dry moderately weak to firm brittle; few very fine fibrous roots; clear, slightly wavy boundary.
C	49+	Sandy loam; many platy angular sandstone stones; dry reddish grey (5YR5/2); to pinkish grey (5YR6/2); massive structure; compact *in situ* friable dry moderately weak to firm brittle; few very fine fibrous roots.

Table 4.40: Profile Analyses - Slieve Bloom Series - Non- Phase

Horizon	**A**	E	Bw	C
Depth (cm)	0-10	10-23	23-49	49+
Particle size distribution analysis **5(%)**				
Coarse sand	41	43	34	43
Fine sand	30	31	28	29
Silt	15	14	19	14
Clay	14	11	19	14
pH	5.4	5.5	5.5	5.4
CEC, mEq/lOOg	17.2	8.4	6.4	4.4
TEB, mEq/lOOg	4.6	2.17	1.01	0.47
Base saturation, %	27	26	16	11
Carbon, %	2.3	0.5	0.3	0.2
Nitrogen, %	0.25	-	-	-
C/N ratio	24.0	22.9	-	-
Free iron, %	0.7	1.3	1.4	1.4
TNV, %	-	-	-	-

Soil suitability: The use range of these soils is rather limited and depends to a large extent on artificial drainage. On the whole, they are inherently poor nutritionally and difficult to manage Even when artificially drained they are unsuitable for cropping due to the poor physical properties and unfavourable climate at these elevations. Where a high standard of management is practised on areas that have been artificially drained they can. with adequate liming and fertilising, produce a fairly satisfactory yield of grass. At the other end of the spectrum, where management is poor, these soils become rush-infested and are generally unproductive. They are suitable for forestry, especially for Sitka spruce *(Picea sitchensis).*

Gortaclareen Series

The Gortaclareen Series occupies 85 ha (0.04%) of the county. While common in other counties this Series is restricted to the south west of Co. Offaly occurring in depressions and rolling relief, at elevations of *ca.* 120 m associated with the Rathmoyle and Elton Series, on account of common sandstone influence. It was first mapped and characterised in Co. Limerick (1966).

The Gortaclareen soils have loam textures of high base status; they have been classified as podzolic Gleys (Table 4.41). The profile is characterised by greyish-brown, loam surface horizons with mottling in the lower part, overlying horizons that are mostly dark-brown, heavier textured and more extensively mottled. The upper horizons are fairly friable but the lower ones are mainly plastic. Roots are well developed in the surface only. The most common vegetative cover on these soils is poor quality rush dominant *(Juncus* spp.) old pasture. Analytical data (Table 4.41) show the surface horizon to be slightly acid, increasing with depth to alkaline, which is reflected in the base saturation values. A moderately high organic carbon value in the surface relates to the poor drainage associated with the Gortaclareen Series. The B/A clay ratio of 1.3 confirms the presence of a texture increase in the Bt horizon.

Soil suitability: Due to their physical nature and topographical position the land use potential of this Soil Series is restricted to grassland and forestry use.

Representative profile description: Gortaclareen Series

Location:	Co. Limerick
Relief:	Gently rolling morainic topography
Slope of site:	2°
Elevation:	58 m O.D.
Vegetation and land use:	Old grassland
Drainage:	Poorly drained
Parent material:	Glacial drift, predominantly Devonian Red Sandstone composition with some shale-limestone admixture of Weichsel Age
Great Soil Group:	Gley

Horizon	Depth (cm)	Description
Al	0-13	Loam; greyish brown (10YR5/2); moderate fine crumb structure; friable; abundant, diffuse roots; gradual, smooth boundary.
A2	13-23	Gravelly loam to sandy loam; light brownish grey (10YR6/2) with few, medium prominent, red (2.5YR4/6) mottles; weak fine crumb structure; friable but wet slightly sticky: plentiful roots; smooth boundary.
Btgl	23-35	Gravelly sandy clay loam to loam; dark brown (10YR4/3), brown (10YR5/3) and reddish brown (5YR5/4); with many medium, prominent, yellowish brown (10YR5/6) mottles; columnar breaking to weak, fine sub angular blocky structure, wet plastic; few roots; clear, smooth boundary.
Btg2	35-63	Gravelly sandy clay loam; brown (10YR5/4) and grey (10YR6/1) within a reddish brown (5YR5/4) matrix; common medium prominent yellowish brown (10YR5/6) mottles; grading towards columnar structure; wet slightly plastic; few roots; clear, smooth boundary.
	63-122	Gravelly sandy clay loam; otherwise similar to above

Table 4.41: Profile Analyses - Gortaclareen Series

Horizon Depth (cm)	Al 0-13	A2 13- 23	Btgl 23-35	Btg2 35-63	C 63-122
Particle size distribution analysi (%)					
Coarse sand	25	28	24	27	24
Fine sand	25	24	24	21	23
Silt	32	29	28	21	23
Clay	18	19	24	25	25
pH	6.5	7.7	7.6	7.9	8.5
CEC, mEq/lOOg	19.9	11.4	10.47	6.1	5.1
TEB, mEq/100 g	18.7	-	-	-	-
Base saturation, %	94	Sat	Sat	Sat	Sat
Carbon, %	4.8	1.3	0.9	0.3	0.2
Nitrogen, %	0.47	0.09	0.06	0.03	0.02
C/N ratio	10.0	14.4	15.0	10.0	10.0
Free iron, %	1.3	2.1	1.9	1.1	0.8
TNV, %	-	-	-	-	7.2

Sandstone-derived Peaty Iron Pan Podzol Sub-group

Rossmore Series

The Rossmore Series is very limited in extent and is mapped as an inclusion within a complex.

The Rossmore Series occurs within the Turbary/Slieve Bloom/Rossmore complex which covers 352 ha (0.17%) of the county. It occurs on rolling topography at elevations of 120 - 400 m where the increased rainfall and lower temperatures are conducive to intensive leaching and the formation of surface peat. The soil parent material is glacial till composed mainly of Old Red Sandstone with the admixture of chert and sometimes shale. It is postulated that where the shale content is significant, more poorly drained soils develop. There is considerable evidence to suggest that the peaty surface was much thicker but that it has been largely removed as domestic fuel.

The profile consists of a peaty surface horizon overlying a well-developed gleyed Eg horizon and a thin iron pan, which in turn overlies a strong brown spodic B horizon in which there is a substantial accumulation of iron oxides and humus. Structure is massive. The analyses (Table 4.42) show that the soil has relatively low clay and silt contents. The soils strongly acidic reaction and the organic carbon and free iron values confirm accumulation of organic matter and iron oxide in the Bs horizon.

Soil suitability: Until relatively recently these soils were only used for rough summer grazing for cattle. An increasing acreage has now been planted, mainly with Sitka spruce *{Picea sitchensis)* and contorta pine *(Pinus contorta).* These Podzols are suitable for reclamation provided ploughing is deep enough to break the impervious iron pan. With deep ploughing, rotovation, levelling, seeding and the use of adequate lime and fertilisers, and a good level of management, productive swards are attainable. The grazing season, however, is relatively short at these elevations. In a few places outcropping or subsurface rock can be an obstacle to reclamation. The fact that most of these soils occur as commonage is a far more serious constraint on development than any physical limitations.

Representative profile description: Rossmore Series

Location:	Gorteen townland, Co. Offaly, Grid Ref. 219123 194323
Relief:	Rolling
Slope of site:	Straight slope simple 5°
Elevation:	275 m O.D.
Vegetation and land use:	Sitka spruce *(Picea sitchensis)* plantation with undercover of heather *(Calluna vulgaris)*
Drainage:	Poor in surface, moderate beneath iron pan
Parent material:	Sandstone glacial till
Great Soil Group:	Podzol
Sub-group	Peaty, iron pan

Horizon	Depth (cm)	Description
Oa	18-0	Peat; black (5YR2/1); compact massive structure; amorphous greasy well-humified vPIII matrix with few recognisable plant remains; many fine roots in surface; abrupt, smooth boundary.
Eg	0 - 8/22	Loamy sand; dark greyish brown (10YR4/2); to greyish brown (10YR5/2); yellowish brown (10YR5/6) weathered sandstone fragments; few medium distinct yellowish brown (10YR5/8) mottles; massive structure; moist friable; common roots; abrupt, irregular boundary.
Bm/Bsm	8/22 - 22/23	Indurated iron pan; dark reddish brown (5YR3/3), beneath pan strong brown (7.5YR5/6); dense root mat on pan surface both recent and fossil roots; abrupt, irregular boundary.
C	23+	Loamy sand; reddish brown (5YR4/3); massive structure; compact *in situ* moist friable.

Table 4.42: Profile Analyses - Rossmore Series

Horizon	Oa	Eg	Bm/Bsm	C
Depth (cm)	18-0	0-8/22	8/22-22/23	23+
Particle size distribution analysis (%)				
Coarse sand	55	43	38	31
Fine sand	30	26	27	28
Silt	2	19	22	29
Clay	13	12	13	12
pH	4.7	4.4	4.2	nd
CEC, mEq/lOOg	nd	nd	nd	nd
TEB, mEq/100 g	nd	nd	nd	nd
Base saturation, %	nd	nd	nd	nd
Carbon, %	36.0	1.4	2.0	-
Nitrogen, %	0.74	0.11	0.12	-
C/N ratio	22.9	12.7	16.7	-
Free iron, %	0.9	0.6	3.5	nd
TNV, %	-	-	-	-

VOLCANIC ROCK PARENT MATERIAL

Brown Earth Group

A single Series, Croghan a representative of the Brown Earth Great Group was mapped on a small volcanic outlier in the county.

Croghan Series

The Croghan Series occupies 72 ha (0.03%) of the county. The small area of this soil relates to its situation on the summit of a volcanic plug of greenstone ash. The soil is shallow, well drained, with strongly developed structure in the A horizon but weakly expressed in the underlying B horizon. Rooting is abundant throughout the profile. Analyses in Table 4.43 show that this soil is strongly acid with very low base saturation and a moderately high organic carbon value in the surface A horizon.

Soil suitability: The location of this soil limits its potential to that of permanent grassland. The physiography of the area restricts mechanisation to allow more intensive production.

Representative profile description: Croghan Series

Location:	Croghan Hill townland, Co. Offaly, Grid Ref. 248044 233107
Relief:	Hill crest plateau
Slope of site:	Straight 2°
Elevation:	200 m O.D.
Vegetation and land use:	Permanent pasture
Drainage:	Well drained
Parent material:	Igneous volcanic rock (Permian/Carboniferous)
Great Soil Group:	Brown Earth
Sub-group	Acid

Horizon	Depth (cm)	Description
Al	0-12	Silt loam; few large sub-angular stones; moist dark brown (7.5YR3/2); strongly developed fine granular structure; fine macropores; moist very weak brittle wet slightly sticky non-plastic; abundant very fine fibrous roots; clear, smooth boundary.
Bw	12-34	Sandy loam to sandy silt loam; few large and common small stones; moist dark brown (7.5YR3/2 - 4/2); weakly developed medium sub-angular blocky with fine granular structures; fine macropores; moist weak brittle wet slightly sticky; many very fine fibrous roots; locally abundant also few coarse fleshy thistle roots; sharp, irregular boundary.
C	34+	Volcanic (Greenstone) ash bed rock.

Table 4.43: Profile Analyses - Croghan Series

Horizon	Al 0-	Bw 13-34	C
Depth (cm)	12		34+
Particle size distribution analysis (%)	14	14	16
Coarse sand Fine sand Silt Clay	10	12	16
pH	40	40	41
CEC, mEq/100 g	36	34	27
TEB. mEq/100 g	5.0	4.5	4.8
Base saturation, %	57.2	56.0	34.2
	3.22	1.01	0.31
	6	2	1
Carbon, %	7.8	5.0	2.0
Nitrogen, %	0.76	0.52	0.23
C/N ratio	10.3	9.6	8.7
Free iron, %	3.6	4.1	3.5
TNV, %	-	-	-

HILL AND MOUNTAIN COMPLEXES

Four soil complexes have been mapped on sandstone dominated parent materials. Collectively they cover an area of 2924 ha (1.47%) of the county. Their characteristics and analyses are presented in the following section.

CI on in Complex

The Clonin Complex occupies 1889 ha (0.19%) of the county, derived mainly from sandstone glacial till containing a proportion of chert and shale. In many places where the slopes are very steep, the soils are developed in the underlying sandstone bedrock. The soils derived from till are complex both in profile characteristics and distribution patterns. In fact the pattern is so complex that, representatives of one, two or even three well-defined Great Soil Groups can be recognised in one profile pit, including Brown Earths, Brown Podzolics, Reclaimed Podzols and Gleys. The dominant soils, however, in this area are free-draining with various degrees of podzolisation. Generations of cultivation, together with the addition of liming agents and fertilisers, tend to obscure their horizonation and give a uniform appearance to the topsoils.

Their common characteristics include rolling topography, sandstone parent materials and uniform textures. They have relatively low silt and clay contents - silt varies from 22 to 27% but is generally 18-21%, while clay content is seldom above 17% and is normally 10-15%. They also have a fairly uniform dark brown sandy loam surface A horizons. The analytical data in Table 4.44 show that the soil profile sampled has characteristics of a Brown Earth, which is strongly to moderately acid, reflected in low base saturation. Free iron values are uniformly distributed down the profile. The surface horizon organic carbon value reflects the grassland land use.

The dominant soils in the Complex are Brown Podzols to Podzolic intergrades. They are moderately deep, friable, well-drained soils with a sandy loam texture and good structure; the soil profile consists of a brown A horizon overlying a brown to dark-brown subsoil B horizon. In most profile pits the presence of a leached E horizon and humus Bh horizons at least in part of the profile provides evidence of even more intense podzolisation.

A sizeable proportion of soils of the complex occur in local depressions and on sloping ground, which receive seepage from above. They range from Gleyed Brown Earths in the less-impeded areas to poorly-drained Gleys. They form an intricate pattern within the well-drained leached soils but are not separated at the scale of mapping employed.

In some places where the drift cover is thin or absent, rock comes close to the surface and the soil consists of a shallow Brown Podzolic overlying shattered sandstone bedrock.

Although huge volumes of stones, both large and small, have been removed from these areas over the years, many fields still contain a proportion of smallish or flat stones.

Soil suitability: The Complex has a fairly wide use-range. These soils are easily cultivated due to their sandy loam texture, granular structure and friable consistence. The high stone content can be a hindrance to some activities. They are capable of growing a variety of tillage crops including bailey, oats, beet, swedes, mangels, kale, rape and potatoes. On account of their inherently low fertility, lime and fertilisers must be applied regularly. Even with adequate fertiliser use, climatic limitations impose restrictions on almost all tillage crops and particularly on cereal production.

Representative profile description: Clonin Complex

Location:	Ballymacmurragh townland, Co. Offaly, Grid Ref. 218479 201697
Relief:	Rolling hilly
Slope of site:	4 - 6°
Elevation:	2l3mO.D.
Vegetation and land use:	Reclaimed pasture
Parent material:	Flaggy sandstones
Drainage:	Good
Great Soil Group:	Brown Earth/Brown Podzolic

Horizon	Depth (cm)	Description
Al	0-10	Sand loam; dark brown (7.5YR3/2) dry brown (10YR5/3); weak to moderate medium fine granular; moist friable; brittle dry soft; many fine to very fine fibrous roots; gradual, smooth boundary.
A2	10-18/28	As horizon above but marked decrease in rooting and organic matter; clear wavy boundary with abrupt change at interface with boulders.
Bw	18/28-51/63	Sand loam; dark brown (7.5YR4/4) dry brown (10YR5/3); very weak fine granular almost single grain; moist friable to brittle dry soft; infilled elongated earthworm channels in upper part; few to locally many very fine fibrous roots; clear, irregular boundary.
	51/63+	Shattered weathered sandstone bedrock; dark reddish grey (5YR4/2).

Table 4.44: Profile Analyses - Clonin Complex

Horizon Depth (cm)	Al 0- 10	A2 10- 28	Bw 28-63	C 63+
Particle size distribution analysis (%)				
Coarse sand	35	38	39	29
Fine sand	24	23	26	29
Silt	24	22	22	27
Clay	7	17	13	15
pH	5.5	5.5	5.6	5.5
CEC, mEq/100 g	20.0	14.6	7.4	5.6
TEB, mEq/lOOg	1.42	14.6	7.4	5.6
Base saturation, %	7	5	2	3
Carbon, %	3.33	1.67	0.37	0.16
Nitrogen, %	0.25	0.13	0.03	0.01
C/N ratio	13.3	12.8	12.3	16.0
Free iron, %	1.6	1.6	1.5	1.5
TNV, %	-	-	-	-

Cardtown Complex

The Cardtown Complex, first recognised and mapped in County Laois (Conry, 1984), occupies 160 ha (0.08%) of the county and occurs only in the Slieve Bloom Mountain region. The soils are derived from fluvio-glacial outwash gravels comprised of sandstone, shale, quartzite and chert. These deposits occur at about 200 m and are very varied topographically with gradients of 2-24°. The profile morphology is that of a well-drained soil. At depth; however, the high organic carbon content of the surface horizon and the formation of an incipient iron pan indicates progression towards podzolisation. Their sandy texture reflects the loose sandy/gravelly composition of the parent material. They range from moderately shallow to deep depending on the topographical position. At the higher elevations, and depending on drainage status, organic matter content in the surface can attain humic status. Soil structure is weakly developed in the surface and massive in the B horizon. Analytical data in Table 4.45 show that the soil is neutral with an even distribution of free iron down the profile and high organic carbon levels in the top 20 cm.

Soil suitability: The land-use pattern on these soils in the greater Slieve Bloom Mountains area varies from tillage to permanent pasture. Where topographical position or aspect does not impose limitations, lime and fertilisers can be applied to raise fertility levels and arable cropping is possible. Due to their coarse textures and gravel, soil moisture is a limiting factor in dry periods. In certain areas these deposits have been exploited for ballast materials and building. Erosion can be a problem in areas where sheep tracks in combination with steep slopes expose potentially loose materials.

Representative profile description: Cardtown Complex

Location:	Clashroe townland, Co. Offaly, Grid Ref. 218985 196524
Relief:	Hilly
Slope of site:	2-3°
Elevation:	240 m O.D.
Vegetation and land use:	Permanent pasture, crested dog's tail *(Cynosurus cristatus)*, mixed herbs.
Drainage: Parent	Well drained
material: Great Soil	Gravels of quartzite sandstone, shale and chert origin
Group:	Brown Earth/Podzolic intergrade

Horizon	Depth (cm)	Description
Al	0-8	Humic loamy sand; dark greyish brown (10YR4/2), dry dark grey (10YR4/1); common fine distinct reddish brown (5YR4/4) root mottles; weakly developed fine granular almost single grain structure; moist friable, dry loose to brittle; clear, smooth boundary.
A2	8-20	Humic gravelly loamy sand; dark greyish brown (10YR4/4), dry hard grey (10YR4/1); weakly developed structure; moist friable dry loose; some biological activity aestivating earthworms due to drought conditions prevailing; common fine fibrous roots sharp, irregular boundary.
Bm	20 - 20.5	Incipient placic iron pan; yellowish red (5YR4/6); sharp irregular boundary.
Bw2	20.5 - 30	Gravelly sand loam; dark brown (7.5YR4/4); massive structure; moist friable wet slightly deformable; few fine fibrous roots; clear, smooth boundary.

Bw2	30 - 50	Gravelly loamy sand; dark brown (7.5YR4/2 - 4/4); massive structure; moist friable dry loose; clear, smooth boundary.
Q	50+	Gravel coarse sandy loam; dark brown (10YR4/3); massive structure; moist friable dry slightly deformable; gravels of chert quartzite, shale sandstone.

Table 4.45: Profile Analyses - Cardtown Complex

Horizon	Al	A2	Bwl	Bw2	C
Depth (cm)	0-8	8-20	20-30	30-50	50+
Particle size distribution analysis (%)					
Coarse sand	52	53	57	61	47
Fine sand	15	12	12	11	16
Silt	25	21	19	16	24
Clay	8	14	12	12	12
PH	6.7	6.8	6.8	7.0	6.9
CEC, mEq/100 g	36.4	36.4	9.0	8.4	7.2
TEB, mEq/100 g	19.85	21.48	3.61	3.54	2.46
Base saturation, %	55	59	40	42	34
Carbon, %	5.0	5.7	0.6	0.5	0.4
Nitrogen, %	0.32	0.35	-	-	-
C/N ratio	15.6	16.3	-	-	-
Free iron, %	1.2	1.7	1.6	1.6	1.6
TNV, %	-	-	-	-	-

Mountrath Complex

The Mountrath Complex was initially recognised in Co. Laois (Conry, 1984). In Co. Offaly it occupies 523 ha (0.26%) of the county and consists mainly of poorly-drained soils occurring as gleys, peaty gleys and the occasional shallow peat area in the lowermost depressions in the terrain. Whilst the distribution pattern and the overall morphology in the field are comparable to the mapping unit described in Co. Laois, the soil depth is somewhat shallower. Soil textures in the surface are sandy loams to humic loams to peats with subsurface horizons of loam to clay loam texture. Soil structures are moderately well developed in the surface horizon and weak-to-massive in subsurface horizons. Consistence is friable in the surface, tending to moist plastic with depth. Rooting is common in the surface and sub-surface horizons but decreases sharply with depth.

So/7 *suitability:* The overall poor drainage within this complex confines these soils to grassland production with the consequent management problem of poaching restricting the grazing season.

Turbary/Slieve Bloom/Rossmore Complex

Occupying 352 ha (0.17%) of the county the Turbary/Slieve/Bloom/Rossmore Complex occurs at *circa* 250 m O.D. The mapping unit arises from the anthropogenic activity where the previous covering of peat, Aughty Series, has been mostly cut-away leaving a thin surface layer of organic materia] over the mineral part, which is either gleyed or podzolised, depending on the underlying topography. The component soils with their relevant profile descriptions and accompanying analytical data are presented in pages 103 - 105.

Soil suitability: The principal land use that can be considered for the soils of this complex is the forestry option. However, this complex has very limited flexibility for the growth and management of trees. The principal limitations are adverse climate and poor soil conditions. The soils include podzols, peaty gleys and peats.

Miscellaneous land types

The United States Department of Agriculture (USDA), Soil Survey Manual Agriculture Handbook No 18 (1962) defines Miscellaneous Land Types as areas of land that have little or no natural soil or that are too inaccessible for orderly examination. In the course of the survey such areas were mapped in the county associated with the deeper incised watercourses emanating from the Slieve Bloom Mountains on shale bedrock. Whilst there are several such features in the Slieve Bloom Mountains only one such unit was considered large enough to be shown on the map. They are characterised by very steep slopes and vegetated by shrubby vegetation and a mixture of hardwood trees.

Peats (Histosols)

Blanket Peat

Blanket peat accumulates under conditions of high rainfall and humidity. In the west of Ireland under these climatic factors and certain soil conditions blanket bog, as the name suggests, covers the landscape from sea level to hill and mountain. Drier climate at the lower elevations in the Midlands restricts blanket bog formation to the mountains, e.g. Slieve Bloom and Silvermine Mountains.

Climatic peats at the higher elevations vary from 1 -2 m in depth and are usually characterised by an upper layer dominated by fibrous roots, a sub-surface layer of pseudo-fibrous peat and a basal layer of highly humified peat within which pine stumps may be found. The peat materials are comprised mainly of plants of cyperaceous origin embedded in a highly humified matrix. In the basal layer, variations may occur in botanical composition due to topographic and edaphic conditions influencing past nutrient status. Most of the peats in this environment belong to the Aughty Series and its phases.

Aughty Series and phases

The Aughty Series and associated phases occur at the highest elevations in the Slieve Bloom Mountain area (Table 4.46, Photo 4.18). They occupy 1662 ha (0.82%) of the county. The depth varies from 40 cm to >200 cm on the gentler slopes. The profile is wet, well humified, with cyperaceous remains, anaerobic and raw in nature with no evidence of soil development. The upper metre exhibits prolific fibrous rooting, embedded in a greasy matrix. The content of fibrous roots decreases at a depth of one metre but the overall matrix is of a similar nature as described. A very highly humified black, greasy, layer can occur at the junction with the mineral sub-soil. The profile characteristics of the phases are not any different but were separated on the basis of their physiography. The slumping phase is characterised by a more profuse growth of heather and reflects better drainage. The erosion phase is characterised by channelling and the physical loss of peat material through entrainment and transport by water.

Soil suitability: Wetness and elevation combine to severely limit the land use options for this soil. Peats have restricted rooting depths unless intensive drainage is carried out. In the past two or three decades areas of blanket bog have been planted with coniferous species. Extensive rough grazing with sheep is a further option, as is the option to conserve these areas as a natural environment.

Representative profile description: Aughty Series

Location	Glenregan townland, Co. Offaly, Grid Ref. 226360 204157
Relief	Mountain plateau
Slope of site	Flat
Elevation	396 m O.D.
Vegetation and land use	Natural blanket bog vegetation
Drainage	Poorly drained
Parent material	Ombrotrophic peat of cyperaceous origin
Great Soil Group	Histosol (USDA Classification)
Sub-group	Medisaprist

Horizon	Depth (cm)	Description
Oal	0-25	Peat; black (5YR2/1); cyperaceous plant remains in well-humified matrix; pasty residues, on squeezing, one third peat material passes through fingers; vPIII; clear, smooth boundary.
Oa2	25-80	Peat; dark reddish brown (5YR3/2); many prominent long fine fibres in humified matrix vPII; on squeezing, little peat material passes through fingers; gradual smooth boundary.
Oa3	80-150	Peat; dark reddish brown (5YR3/2); fine fibres embedded in highly humified matrix two thirds peat material passes through fingers on squeezing; abrupt, smooth boundary.
Al	150-158	Loam; greyish brown to light brownish grey (10YR5/2 - 6/2); massive structure; wet sticky; many fine fossil roots; clear, smooth boundary.
A2	158+	Loam; light grey (10YR7/2) massive structure; common fossil roots.

Table 4.46: Profile Analyses - Aughty Series

Horizon	Oal	Oa2	Oa3
Depth (cm)	0-25	25-80	80-100
Fibre (%) vol			
Unrubbed			
Rubbed Silt			
Clay			
pH	3.6	3.5	3.6
SPEC	7	6	6
Bulk density g/ml.	0.109	0.093	0.096
Moisture field gravimetric, %	556	554	411
Ash, %	3.5	1.	1.7

Turbary Complex (mountain)
This Complex occupies 337 ha (0.16%) of the county. Man's activity has created a complex of bare soil, peat hags and bog holes. The exposed mineral soil materials within the Complex reflect the physical characteristics of the soils developed from sandstone glacial drift described in the section Hill and Mountain Soils. The residual peat materials found reflect the different characteristics as described above for the Aughty Series.

Soil suitability: The factors of soil conditions, aspect and access makes this type of complex unsuitable for agriculture and restricts the land use to wildlife and forestry applications as described for the Aughty Series.

Photo 4.18: Landscape of Slieve Bloom Mountains showing the Aughty Series slumping phase of blanket bog. *(R.F. Hammond)*

CHAPTER 5

SOIL SUITABILITY

Introduction

Soil suitability classification is essentially a grouping of soils according to the potential use or uses to which they are most adaptable, and is based principally on the significance of the more permanent characteristics of the soil. A further step in the suitability classification consists of an assessment of the production potential of each soil, for the normal range of farm and forest crops, under defined management standards. Such information provides the essential link between the physical and economic aspects of the use of soils. However, reliable quantitative data on the productive capacity of each soil are required; these can only be provided by detailed field experimentation and yield observations over a number of years on sample areas representative of particular soils. Information of this nature within Co. Offaly is confined to pasture production on certain Soil Series. These quantitative assessments are presented for grazing capacity but apart from these the system of soil suitability evaluation used is a qualitative, rather than a quantitative, appraisal of the potentialities of the different soils in the county.

Although physical, chemical and biological properties of the soil merit foremost consideration in assessing soil suitability, environmental factors such as elevation, aspect and local climate, must also be taken into account. For instance, local features such as exposure to strong winds and late spring frosts can limit forest tree growth regardless of soil quality. Environmental, legislative and other factors can influence considerably the economics of production and hence can modify the use-range of soils, to which they are otherwise ideally suited.

Furthermore, the concept of land quality has changed radically in recent years. With modern fertiliser technology, natural nutrient fertility problems in soils have become subordinate to physical ones such as defective natural drainage, "heavy" texture and poor structure, which are difficult and costly to rectify. Mechanisation has also drastically altered the feasible cultural and management practices of many soils.

Suitability for Grassland and Cultivation

Suitability Classification

A widely used system for the interpretation of soil survey data from the point of view of land classification consists of assessing the capacity of each soil unit for permanent sustained production, and arranging the units according to the USDA system of Land Capability Classification (Klingebiel and Montgomery, 1961). This is a standard eight-class system in which classes I to IV are suited to cultivated crops, classes V to VII are suited to grazing and forestry, and class VIII is suited only to wildlife/amenity.

The USDA system emphasises the adaptability of a soil for a range of uses and implies a hierarchy of use capacity, *viz.* cropping, grazing, forestry. In relation to land use practice in Ireland this hierarchy is not relevant as the priority use of land is dairy livestock production, which has a large grazing component. Since economic priorities change with time, value judgements based on economic criteria should be excluded as far as possible from a technical land classification.

The system adopted in Ireland (Finch, 1971) is to evaluate the degree of suitability of each soil unit for a set of uses, viz. cultivation and grassland, where all types of use have equal rank. This system could be extended to include suitability for forestry or urban development where appropriate. Choice of optimum use of a soil unit could be derived at any time from the suitability classification by assigning a weighting to each type of use based on the prevailing economic circumstances.

Soil suitability depends largely on the physical properties of the soil and the environment. These are rarely ideal and the limitations affect productivity and cultural practices. The degree of limitation is assessed from such factors as wetness (w), drought (d), liability to flooding (f), slope (s), rockiness (r), boulders (b), textural and structural properties affecting tilth and susceptibility to poaching (t). On the basis of these factors the soils are grouped into five classes designated A, B, C, D and E (Table 5.1). In the case of cultivation the ease of cultivation as well as productivity are taken into account.

In the legend (Table 5.1) the suitability classes are divided into sub-classes by principal limiting factor. Sub-classes are indicated by a subscript which indicates the type of limitation, for example w = wetness, s = slope, etc. The degree of limitation increases from the higher to the lower categories.

Every map separation can be represented by a class letter for grassland (usually capital), class number (usually Roman capital) for cultivation and the subscript letter for kind of dominant limitation, e.g. 1) Aid indicates class A for grassland, Class I for cultivation and liability to drought as the dominant limitation, and 2) CIIw indicates class C for grassland, class II for cultivation and wetness as the dominant limitation.

Suitability Classes

Soils capable of high production levels of grass and arable crops (AI) cover 21.8% of the county. These soils are widely distributed across the county, with larger expanses associated with mid-eastern and southwestern parts of the county. Limitations to production arise from the longer dry periods where there are shallow phases of soil series, e.g. Patrickswell on sharper uplifts in the undulating terrain. Soils in Class A suitability for grassland were placed in two cultivation suitability sub-classes, i.e. I and II. The separation was made on the basis of likelihood of drought eg. Patrickswell) and a heavier texture limitation, where physical problems can delay in cultivation, e.g. Knock and Mortarstown Series, respectively. The major limitation within Class B grassland soils at lower elevations is drought. The drought factor is compounded by the shallower nature and/or lighter textures of these soils, derived from gravelly and/or sandy parent materials, e.g. Ballincurra, Baggotstown and Graceswood Series.

The Baggotstown soil is widespread both as a Series in its own right and a component of complexes with other well-drained Grey-Brown Podzolic and Brown Earth soils throughout south-west and central Offaly.

Table 5.1: Soil suitability ratings for grassland and cultivation, Co. Offaly

"Suitability Class					
Grassland	**Cultivation**				
Class (% land area)	**Class**	**Sub-Class**	**Area (ha)**	**% Total land area**	**Mapping Unit**
A (21.8%)	**I**	d	29,520	14.92	Patrickswell
	II	t	13,605	6.88	Elton, Mortarstown, Knock
B(17.5%)	**I**	d	29,434	14.88	Baggotstown, Baggotstown/ Patrickswell, Patrickswell/ Baggotstown, Baggotstown/ Patrickswell/Elton, B aggotsto wn/C arlo w Complexes, Graceswood Ballincurra
	II	dbw	5164	2.61	Patrickswell Lithic and Bouldery phases, Baggotstown/Cmsh, Kilpatrick
C (26.6%)	**I**	e	3043	1.54	Baunreagh, Clonin Complex, Rathmoyle
	III	se	342	0.17	Cardtown Complex Ballylanders, Croghan
	III	w	49,177	24.85	Mylerstown, Howardstown, Ballyshear, Mountrath Complex, Lowland Peat Industrial Complex (part of), Gortnamona, Banagher, Howardstown/Baggotstown Ballyshear/Patrickswell, Howardstown/Patrickswell

Table 5.1: (cont.)

Class (% land area)	**Class**	**Sub-Class**	**Area (ha)**	% **Total land area**	**Mapping Unit**
D(17.5%)	**IV**	w	21,568	10.90	Allenwood Complex, Clonlisk, Ballintemple, Garryhinch Complex, Garrymona, Industrial Peat Complex (part of), Banagher
		f	11,653	5.89	Alluvium, Callow
		ew	1445	0.73	Bawnrush, Slieve Bloom Non-peaty Phase, Gortaclareen
E(16.6%)	V	**wf**	1301	0.66	Slieve Bloom Peaty Phase
		ew	68	0.03	Baunreagh Steep Phase
		we	3263	1.65	Upland Peat (Aughty Series and all Phases) Gortaclareen, Knockastanna Peaty Phase, Rossmore
		w	20,658	10.44	Lowland Peat (Allen Turbary Complex) Pollardstown
		dr	274	0.14	Burren
		w,f	7359	3.72	Industrial Peat Complex (part of), Finnery River Complex

d= drought   w = wetness   s = slope   b = boulders   f = liability of flooding
r = rockiness   t = textural and structural properties affecting tilth and susceptibility to poaching.

For tillage rating purposes the soils of the Patrickswell Series are placed in Class I, due to their lighter textures; the Baggotstown Series rate as some of the best malting barley soils in the country. The soil series in Class II cultivation are those with shallow lithic and/or bouldery phases liable to drought and wetness in early spring and autumn.

Class C grassland soils occupy 26.6% of the county. They have limitations with respect to elevation, slope and wetness. The first two limitations apply to soils occurring in the Slieve Bloom Mountain uplands, less than 2% of soils in this category. For cultivation they are categorised as Class I and Class III soils. In the former category, whilst they are moderately deep soils with medium textures, elevation is the major limitation and in the case of the Baunreagh and Clonin Complexes, lime status. Class III soils are also limited by elevation but slope is also a major limiting factor.

The remaining Class C soils occur at the lower elevations where their major limitation is one of wetness due to high watertables. The Mylerstown, Ballyshear and Banagher series, fringing raised bog complexes, are now relatively dry, a direct consequence of the drainage of raised bogs for industrial peat production. The organic soils placed in this category support a six month summer grazing period. This soil type has a distinct advantage in extremely dry years over lighter mineral soils as their high waterholding capacity can sustain grass production. Cultivation is possible and soils such as Mylerstown and Ballyshear are cultivated for spring cereals and the Banagher Series is used for the production of vegetable crops, e.g. celery, especially in the south west of the county.

Class D grassland soils occur predominantly in lowland areas and occupy 17.5% of the county. A high proportion of them are organic soils occurring within the confines of the worked-out industrial peat areas. Their potential has been assessed by research carried out in 1955-1988 by An Foras Taluntais (The Agricultural Institute) (Cole, 1989; Hammond, 1989). All are placed in Class IV cultivation suitability class (Table 5.1). Here production can be limited by proximity to high seasonal watertables and early and late frosts. The Banagher Series juxtaposed to raised bogs, the extensive areas of callow land bordering the River Shannon, and the alluvial soils of the tributaries that feed the Shannon also can be prone to frost, high seasonal watertables and flooding in prolonged wet periods. The remainder of the soils in this category are located on the Slieve Bloom Mountains, having limitations of elevation, slope and drainage.

Class E and Class V soils occupy 16.6% of the county. In the lowlands Class E soils are organic soils and small areas of exposed rock. Eighty five per cent of the Class E soils are lowland peat areas, comprising undrained raised bogs, hand cut turf production areas, industrial peat extraction and river complexes. The limitations here are ones of wetness, flooding and shallow soil depth. Within the industrial peat areas soils limited by wetness usually occur between the lowest sub-surface and intermediate contours of the bog floor. The organic soils at the lowest contours are generally underlain by lake marls and in the 1990's were being actively allowed to flood to provide open water habitats and recreational areas for wildlife and coarse sport fishing e.g. Lough Boora Parklands (Photo 4.17).

The remaining soils are to be found in the Slieve Bloom Mountains with slope, elevation and wetness being the limiting factors to utilisation. Seventy per cent of Class E soils, at highest elevations in the Slieve Bloom Mountains are blanket bog soils and here are conserved in part as a nature reserve but have been planted in some areas with coniferous forestry. Limitations are wetness and elevation.

Correlation with CORINE classification

A European Union funded Correlation of Information on the Environment (CORINE) programme was carried out using SPOT satellite imagery to interpret the land use patterns in Ireland with maps published at 1:250,000 scale. The CORINE coverage can be accessed at different interpretation levels depending on classification detail. Co. Offaly data used Level Three Interpretation which enables the analysis to be based on three classification levels of grassland productivity (high, low, mix hi-lo). The data were used to calculate the areas of the different categories of land use (Table 5.2).

Grassland constituted 64% of all land use in the county, with 4% of the county under arable. Coniferous forest at 3% reflects the predominance of the peatland soils within the county. The 7% classed as transitional woodland scrub also had a high proportion of coniferous woodland.

Table 5.2: Land use categories as defined for the CORINE project, areas and percentage areas within Co. Offaly

Code	Description	Area (ha)	%Area
111	Continuous Urban Fabric	93	0.05
112	Discontinuous Urban Fabric	879	0.44
131	Mineral Extraction Sites	214	0.11
133	Construction Sites	0.3	0.0001
142	Sport & Leisure Facilities	0.2	0.0001
211	Non-irrigated Arable Land	7664	4.00
2311	High Productivity Grassland	14,768	58.35
2312	Low Productivity Grassland	3717	1.89
2313	Mix Hi-Lo Productivity Grassland	6553	3.33
242	Complex Cultivation Patterns	1385	0.07
243	Land occupied principally by agriculture, with significant areas of natural vegetation	3631	1.84
311	Broad Leaved Forest	670	0.34
312	Coniferous Forest	6003	3.05
313	Mixed Forest	34	0.02
321	Natural Grasslands	427	0.22
322	Moors and Heathlands	1911	1.00
324	Transitional Woodland Scrub	13,734	7.00
411	Inland Marshes	829	0.04
512	Water Bodies	681	0.32
4121	Peat Bogs	7925	4.03
4122	Industrial Peat Bogs	25,557	13.0
	Grand Total	196,679	99.10

Figures 5.1 and 5.2 record the geographic distribution of the four major land-use categories in the county. They show the predominance of grassland in the agricultural economy and the widely spread and discrete units of arable use. Forestry is dominated by coniferous plantings. However, with grant-aided schemes an increasingly larger area is being planted with hardwood species. The predominance of large areas of peat bogs illustrates the contribution of peat fuel and horticultural peat as a resource.

Figure 5.1: Distribution of arable and grassland land-use categories (CORINE), Co. Offaly.

Figure 5.2: Distribution of forestry and peatland land-use categories (CORINE), Co. Offaly.

Suitability classification for man-modified peat soils (Histosols)

Thirty four per cent of County Offaly is covered by peat formations and the derived soils are an important element in the agriculture of the county. Table 5.3 summarises the characteristics of the categories defined for the land-use determination of man-modified peat soils, reclaimed fens, raised bog, cut-over industrial peat areas and areas cut-over for domestic fuel.

Table 5.3: Land use classification of peats (Histosols)

Organic soils derived from base-rich parent materials of woody fen and *Carex* sedge fen peat materials.

Class 1	Organic soils with well-developed topsoil (mineral materials added in historical times). Permanent watertable *circa* 70 cm; derived from deep peat. Present land-use dominantly grassland but capable of producing a range of frost-tolerant horticultural field crops.
Class 2	Organic soils with well-developed topsoils derived from shallow peat with very similar characteristics to Class 1 but with a greater variation in watertable depths. In the winter/spring the watertable occurs nearer the surface and therefore crop production may be delayed due to the possibility of wetter soil conditions in the spring.
Class 3	Organic soils with developed topsoils derived from shallow peat materials underlain by lake deposits (silty clays and marls) and compact sub-soils. High watertables in the late winter and spring restrict the early turnout of grazing livestock.
Class 3.1	Raw, residual peat materials of variable depths, no developed topsoil, occurring on the higher contour levels of cut-away industrial peat production areas. Potential development areas for agriculture, horticulture and forestry.

Organic soils derived from base-poor parent materials predominantly of *Sphagnum* origin.

Class 4	Organic soils with well-developed topsoils (mineral materials added in historical times) on deep acid peat without artificial drainage. These soils, which have been used for agricultural production for several decades with a good level of management, are capable of producing high yields of quality grass.
Class 4.1	Organic soils with shallow topsoils on deep acid peat with or without artificial drainage. Although used for agriculture over a number of decades, grass production can be affected by prolonged drought.
Class 5	Organic soils with shallow topsoils on deep acid peat requiring artificial drainage. Poor quality swards require a relatively high level of land reclamation inputs for satisfactory grassland production.
Class 6.1	Raw organic soils, situated at the margins of hand-cutover areas of raised bog landscape units, on deep peat materials with low watertables requiring land reclamation inputs to develop a topsoil for agricultural production.

Class 6.2	Raw organic soils of hand-cutover areas of raised bog landscape units on deep peat materials with year-round high watertables requiring a high level of land reclamation inputs to develop a topsoil for agricultural production.
Class 7	Strongly acid raw organic soils of *in situ* raised bog landscape units on extremely deep peat materials with year-round high watertables, not to be considered for agricultural production.
Class 8	Strongly acid raw organic soils of *in situ* blanket bog landscape units on extremely deep peat materials with year-round high watertables, at high elevation and not to be considered for agricultural production.
Class 9	Strongly acid raw organic soils on deep blanket bog peat materials with variable watertable depths on hand-cutover areas. The level of land reclamation inputs to develop topsoil for agricultural production will depend on elevation and topographical position.

POTENTIAL FOREST PRODUCTIVITY[1]

Introduction

The area of land under forestry in Ireland at the beginning of the 20th Century was close to 1 %. Since then successive government policies have raised this figure to over 9% - still one of the lowest figures for the area of land under forestry within the European Union. The impetus for the increasing area under forestry arose from the reform of the Common Agricultural Policy (CAP) of the European Union from the mid 1980s. This placed a greater emphasis on moving production away from the major enterprises of beef, milk and cereals and to encourage diversification into Rural Environmental Protection Schemes (REPS)and Forestry under the aegis of the Operational Programme for Agriculture, Rural Development and Forestry 1994 - 1999.

Site selection for coniferous and broadleaved crops is an important element in the success of any planting programme, both nationally and at farm level, to enable successful establishment and to attain long-term production with an economic yield. Land management decisions dealing with the choice of tree species and growth are normally in effect for decades. Thus, the correlation of the species of trees and their expected productivity to soil components is of significant importance to forestry and agroforestry practitioners. Productivity interpretations are developed from analysis of field data collected for individual Soil Great Groups or in some cases Soil Series.

Suitability for Forestry

The suitability of each Soil Series and Soil Complex along with their main limitations is given in Tables 5.4 and 5.5. Suitability for both broadleaves and conifers are given separately to allow a more precise ranking for each type. Broadleaves are in general more site-demanding so soils that

[1]Compiled by M. Bulfin and R.F. Hammond

are highly productive for conifers may not be as productive or may be totally unsuitable for broadleaves. It is also possible that two soils, which have equal ranking for grass production, may not be equally productive for tree growth. Elevation is a factor, which also influences tree productivity at a slightly more rapid rate than it influences grass growth. Broadleaves, with the exception of sycamore *(Acer pseudoplatanus),* are particularly sensitive to exposed elevated sites. When considering the productivity of conifers and broadleaves it is better to assess each separately for each soil. This is the approach taken in Tables 5.4 and 5.5. The day-to-day decisions on crop management are based on the actual growth rate of the stand.

Forest productivity and output is measured in cubic volume, i.e. Yield Class (YC) in m^3/ha/annum. Small thinnings for pulp or fibre are measured by weight. This is the system used in the UK and Ireland and there are comprehensive sets of tables (The British Forestry Commission Management Tables, (Hamilton and Christie, 1971)) detailing the yield patterns of all the common forest trees. Most trees growing in plantations will follow a certain growth pattern. The quality and inherent fertility of the soil and the elevation and exposure of the site mostly determine the rate of growth.

In the first few years of a plantation, trees put on little volume but as they grow taller and develop thicker stems they begin to accumulate volume. The rate of volume increment increases over the years, until a peak is reached and crop growth begins to slow down. The element of tree growth, which combines all these factors, giving the best indication of growth rate, is the top height of the stand. Top height is the height of the 100 trees of largest diameter in the stand. As these are most likely to form the final crop it makes sense to use them as the basis of crop performance. The height of a stand at any age will determine its Yield Class. Yield Class is basically an expression of the ability of the site to produce wood volume and is, therefore, a measure of a species' ability to grow on a particular site. Different tree species will react to a given site according to their own growth potential. The same site will have many different Yield Class ratings depending on the species planted.

Yield Class is expressed in cubic metres of wood produced per hectare per annum (m^3/ha/annum) and is quoted in increasing units of 2 cubic metres. A Yield Class of 20 m^3/ha/annum means that when the total volume production is divided by the length of the optimum rotation (50 years), the average production is 20 cubic metres per hectare per annum. It is a measure which takes in not only soil productivity but other site factors such as elevation, aspect, and, indirectly, climatic factors such as rainfall, temperature and windspeed. Yield Class for conifers, as detailed in Tables 5.4 and 5.5, is based on the expected yield for Sitka spruce *(Picea sitchensis).* Sitka spruce is chosen as the criterion species because it is currently the major timber tree in Irish forestry. Sitka spruce is probably the chosen tree on approximately 60% of the area now being planted. It can be established easily and grows well on a very wide range of sites and is therefore a valuable measure of comparative site productivity. Its primary requirement is for adequate moisture and it rarely does well in areas that have annual precipitation less than 800 mm. The productivity of other conifer species can be estimated - to varying degrees of accuracy - based on the estimated Sitka spruce productivity and the soil type.

Yield Classes are given in broad categories ranging from YC 6-12, which is regarded as very poor and not worth planting, to YC 18-24, which would be regarded as very good to excellent. Some areas are listed as unplantable (UP) because they are almost incapable of supporting tree growth. While Sitka spruce grows well on a wide variety of soil types this does not exclude the use of other species. There is an environmental requirement now for a greater diversity of species to be used. This translates into prescriptions for the inclusion of species, other than Sitka spruce or lodgepole pine, on all sites which are capable of supporting them. The choice of species really depends on the expected end-use of the plantation, whether it is for timber, firewood, shelter, amenity or game development, or a combination of some of these objectives. Final choice of species should be taken on the advice of the local forestry advisor. Most foresters will be able to relate the growth and Yield Class of other conifers on any particular site to the Yield Class for Sitka spruce. Much less is known about the growth rates of broadleaves on different soil types.

In general, broadleaves require considerably better soils and climatic conditions than conifers for good growth. Also the variation in growth rate between broadleaves is considerably greater than with most of the commonly used conifers. A soil that is rated A or very good for broadleaves means that it is capable of producing good crops of a wide range of species. This may mean that it can produce oak at YC 8, ash or sycamore at YC 12 and poplar at YC 18. Also the rotations will vary considerably depending on species. Oak requires rotations of 150-200 years, ash or sycamore 40-60 years and poplar 18-25 year rotations. While certain soils will have very similar rankings for both conifers and broadleaves, with both ranked either very good or very poor, there are soils which are very different in their potential for both types of trees. The most outstanding example of this is in relation to wet mineral soils. These poorly-drained rush-infested grasslands are mostly unsuitable, or only poorly productive, for most broadleaves, but are capable of very high production under Sitka spruce. Irish wet mineral lowland soils are some of the most productive in Europe for conifer - especially Sitka spruce - forestry. This high productivity is related to both the mildness of the climate, the relatively high rainfall and the fertility of these mineral soils for conifers.

Table 5.4 indicates that soils in Category A have a wide use range with no major limitation for broadleaf production. The soils are well drained and occur chiefly below 150 m. Soils in Category B have a moderately wide use range with limitations ranging from elevation (above 150 m), shallowness, drought, high pH and liability to flooding. In Category C the soils have a somewhat limited use range mainly due to poor drainage. In Category D the main limitations are wetness, elevation and slope. The limitations of soils in Category E are very severe and are caused by high elevation, slope and wetness. The soils, designated as unplantable, are rocky or high elevation soils. With the conifers, because of their less demanding site requirements, a considerably larger proportion of soils is ranked as being of excellent productivity. This is clearly seen in Tables 5.6 and 5.7. Table 5.6 groups the soils.

Table 5.4: Soil suitability for forestry on lowland Soil Series, Co. Offaly

Great Soil Group	Mapping Unit	Area (ha)	Broadleaf		Conifer	
			Category	Limitation	Yield Class (m^3/ha/annum)	Limitation
Rendzina	Burren	274	UP	r,d	UP	r,d
Crush			UP	d	UP	d,p
Brown Earth	Baggotstown	4061	B	d	14-20	d,p
Ballincurra		461	C	r,d	14-20	r,d,p
Elton		10,082	A		18-24	
Patrickswell		29,520	A		18-24	
	Patrickwell Bouldery Phase	707 447	A	b	18-24	b
Patrickwell (Lithic) Mortarstown Grey Brown		3162	B	r,d	14-20	r,d
Podzolic Knock		397 566	B	t	18-24	
Graceswood			A	e	18-24	
			B	d	18-24	d
	Howardstown	3720	C	w	18-24	w,t
Kilpatrick Mylerstown Gley		278	C	w	18-24	fr,w,p
Ballyshear		8405	D	w	14-20	fr,p
Ballintemple Clonlisk Drombanny		4350	D	w	14-20	fr.p
		4304	C	w	14-20	fr,w
		3172	D	w	14-20	fr,w
		2161	D	w,f	14-20	fr,p,f
Regosol	Alluvium	10,692	C	f,w	14-20	f,w,fr
Allen		8257	UP		UP	UP
	Gortnamona Garrymona	3625	UP		14-20	fr,w
Histosol	Banagher shallow phase	233	UP	14-20	6-12	fr,w,
Banagher deep phase Pollardstown		1670	UP		fr,w,	
		15,164	UP		6-12	fr,w,
		1639	UP		UP	w
	Total	117,347				

Suitability Classfication

b = bouldery; d = drought (due to shallowness, coarse texture or excessive drainage); e =elevation/exposure; f = liability to flooding; fr = liable to frost damage; p = high pH; r = rockiness; s = slope; t = heavy texture; UP = unplantable; w = wetness or poor drainage.

Table 5.5: Soil suitability for forestry on lowland Soil Complexes (Series %), Co. Offaly

Great Soil Group	Mapping Unit	Area (ha)	Suitability Classfication: Broadleaf Category	Broadleaf Limitation	Conifer Yield Class (m³/ha/annum)	Conifer Limitation
Brown Earth, Grey Brown Podzolic	Patrickswell/Baggotstown (55/45) Baggotstown/Patrickswell (60/40) Patriekswell/Baggotstown/ Elton (40/40/20) Baggotstown/Crush (70/30) Baggotstown/Carlow (60/40)	10,903 3282 9147 3732 1014	A/B B/A A/B/A B/UP B/B	*-/d* d/- *-/d/-* d/UP d	18-24/14-20 d,p 14-20/18-24 r,d,p 18-24/14-20/18-24 14-20 14-20/18-24 b	
Gley, Grey Brown Podzolic	Howardstown/Baggotstown (55/45) Ballyshear/Patrickswell (65/35) Howardstown/Patrickswell (60/40)	258 67 193	*C/B* D/A C/A	w,d w/- -/w	18-24/14-20 18-24 18-24	r,d e
Histosol/Gley Gley	Allenwood Garryhinch	1847 448	D C	w,fr w,fr	14-20 14-20	d,p w
Regosol/Gley/Histosol Peat/Regosol	Finnery River Callow Industrial[1] (part of) Industrial (part of)	1161 961 20,605 6198	D D w,fr UP	w,fr w,fr D	Very variable (6-18) Very variable (6-18) Very variable (6-18)	w,t w,p w
Histosol	Turbary[2]	10,762	D	w,fr	Very variable (0-20)	w
	Total	70,758				

[1] The Industrial mapping unit comprises cutover peat soils that may vary in depth and composition. They are variable in productivity. It may be possible to grow certain broadleaved species such as birch and alder and possibly willow but not for commercial purposes. Shallow thicknesses of peat over mineral drift material may be subject to irreversible drying out.
[2] Turbary areas are complex and very variable depending on the methods of turf-cutting used. They are, therefore, ranked as of variable productivity ranging from Yield Class 0-20.

into four broad use-range or production categories for broadleaves, showing 40.9% of soils having wide to moderately-wide use range for broadleaf production. Another 10.8% are placed in the somewhat limited to limited use range and approximately 31.8% are considered to be very limited. almost 17.0% of the soils are classed as unplantable for commercial broadleaf forestry. Table 5.7 indicates the very-productive nature of most soils for conifers. The major difference between the extent of the wide to moderately-wide category for broadleaf and conifer is that the wet mineral soils are less suitable for broadleaved species.

Table 5.6: Percentage of land area below 150 m of Co. Offaly in each forestry production category

	Broadleaf	%	Conifer	%
Category	Use range		Yield Class	
A/B	Wide to Moderately wide	40.9	14-24	65.3
C	Somewhat limited	10.8	6-18	15.4
D	Limited	31.8	6-12	8.2
	Variable		0-20	5.7
UP	Unplantable	16.4	Unplantable	5.4

Table 5.7: Soil productivity for conifer species on lowland soils (based on the productivity of Sitka spruce) in Co. Offaly

Use range	Percentage of county
WideModeratelywide	65.3
SomewhatlimitedLimited	15.4
Limited	8.2
Variable	5.7
Unplantable	54

Co. Offaly is a very productive area for forestry. Both broadleaves and conifers will thrive there and give yields that are comparable to any other part of the country. The wet mineral soils, which present considerable problems for agriculture, should form the basis of any conifer forestry development programme. In a well-planned land-use programme the poorer marginal lands would be planted to conifers while blocks of broadleaves would be planted on the better soils to ensure, at least, the continuity of our lowland scenery. With the improved quality of broadleaved trees that are now being researched it is possible that broadleaves grown on 25-45 year rotations, i.e. the same length as Sitka spruce, could be planted economically on some of the current Class III tillage soils.

Forest productivity on soils of the Slieve Bloom Mountains

R.F. Hammond[2], M.J. Conry and Paul Clinch

The history of forest and woodland use in the Slieve Bloom Mountains is that the natural woodlands survived relatively untouched until fairly recent times. Forest clearance was first effected on the fertile soils of the lowlands. Much of the Slieve Bloom Mountains, particularly on the south-western foothills, remained wooded until late in the seventeenth century (Feehan, 1979). The great oak forests were denuded after Sir Charles Coote founded his ironworks in Mountrath in 1641 with others being sited in Mountmellick and Portarlington. Reafforestation of the Slieve Bloom Mountains began about 100 years ago when the Forestry Department commenced commercial planting programmes.

The forest productivity of the soils of the Slieve Bloom Mountains was addressed by Conry and Hammond (1984) in a study of the Resources of the Slieve Blooms by Conry and Hammond (1984). In the late 1970's the then Forest and Wildlife Service had carried out detailed inventory studies in the Slieve Bloom Mountains. These data, in association with soil survey information, allowed correlations to be made on the potential productivity by tree species on the different soils in the area. In the course of the preparation of this Bulletin it was opportune to include the most recent yield class data provided by Coillte (previously Forest and Wildlife Service) in the Bulletin. The recalculation of the yield class data used geographical information systems (GIS) technology to relate the vectorised forest inventory productivity data of the area to the Soil Series distribution data. The weighted average yield classes for the dominant species grown on the various soil types were calculated using Microsoft Excel® software.

Forest productivity is influenced by many factors such as seed provenance, elevation, frost aspect exposure, and as shown in studies (O'Flanagan and Bulfin, 1970; Bulfin *et ah,* 1973) that the soils factor also influences the productivity of different tree species.

Sitka spruce (73.2%), Norway spruce (6.4%) and lodgepole pine (9.4%) are the main species grown with smaller amounts of Japanese larch (0.6%), Scots pine (0.1%), Douglas fir (1.9%) and broadleaved (1.5%) species. Sitka spruce and Norway spruce are grown on a wide range of the Slieve Bloom Mountain soils, lodgepole pine is grown on the mainly poorer soils with varying depths of peat, while Douglas fir is only grown on the best soils (Brown Earths).

The Slieve Bloom Mountains have a potential for forestry production but there are very large differences in the productive capacity of the various soils for different species. This is particularly true of Sitka spruce (Table 5.8), which is by far the dominant and most productive species on the Slieve Bloom Mountains. There is also a large distribution about the weighted average mean yield

[2]Data recalculated based on Forest Potential, M.J. Conry and Paul Clinch (1984) in Soil Resources and Potential of the Slieve Bloom Mountains and Foothills, Conry and Hammond (1984).

which can be attributed to factors other than soil type, i.e. wind exposure, provenance, planting material, fertiliser use. The mean weighted average yield class for Sitka spruce ranges from 11.6 on Turbary Blanket Bog to 19.2 m^3 per annum on shale-derived gley. Sitka spruce growing on gley soils is considered highly productive. However, its yield class is considerably lower than that obtained on good drumlin soils of Co. Leitrim (Bulfin *et ai,* 1973). The Peaty Gleys, derived from sandstone parent materials, which form the single largest soil group in the Slieve Bloom Mountains (22.8%), have a yield class of 16.5 m^3/ha/annum, while the Peaty Podzols (4.7%) have a yield class of 16.2.

The High-level Blanket Peats with yield classes ranging from 11.6 to 19.9 m^3/ha/annum have the lowest capacity for Sitka spruce production in the whole of the Slieve Bloom Mountains. Cut-over portions of the Blanket Peat have the lowest yield class at 11.6.

Norway spruce, on various soil types, has a range of yield classes (11.3 - 20.7 m^3/ha/annum). Excluding the very small areas of shale-derived gley and Blanket Bog soils planted, yield classes show a narrower range of 15.0 - 20.7.

Lodgepole pine is mainly grown on the poorer soils but even on these soils its productive potential is very substantially lower than Sitka or Norway spruce. Marked differences between the varieties of Lodgepole pine are observed with the Coastal provenance always superior to the Lulu Island provenance.

Japanese larch was only planted to a limited extent and it shows a wide range in yield classes (4 - 13.2 m^3/ha/annum) the higher high potential production on the better-drained soils (Brown Earths) with lower potential on the poorer soils (Podzols and Gleys). Douglas fir, which is only planted on the good soils, also has a high production capacity.

Not only does the production potential of the various species vary between the major soil groups mapped in the Slieve Bloom Mountains, but there is also a substantial yield differences within most of the soil groups. Thus, the deeper Brown Earths on moderate slopes (<13°) derived from shale material have a substantially higher yield capacity than their shallower counterparts on steep slopes (15-25°), not only for Sitka spruce but also for Norway spruce, Japanese larch and Douglas fir. Similarly the different phases of the Peaty Gleys (Slieve Bloom Series) show substantial variation in productive capacity - the lowest yields on the rocky phases are easy to explain, the slightly lower yields on the gently sloping phase is probably due to more extreme wetness but it is difficult to explain why the Peaty Gleys on the steepest slopes have the highest average yield class. Perhaps it is due to drier soil conditions or more shelter from wind exposure. There is also a substantial difference in yield class between the species grown on the deep blanket peats compared with their shallow counterparts. The shallow peats, however, only account for a small fraction (<1%) of the total peat cover.

The use of improved silvicultural techniques and improved genetic material is likely to lead to increases in forest production rates in the future, especially on more difficult sites. Future forestry potential in the Slieve Bloom Mountains area is thus as good or better than that indicated by existing yield classes. The Brown Earths and Gleys have an average yield class potential of 19 for Sitka spruce production while the Peaty Gleys of the mountain area have a yield class over 15.0 Peaty Podzols have a yield class of 16.0, with Blanket Bog having an average yield class of around 14. The limestone-derived Grey Brown Podzolic and Gley soils of the foothills have yield classes ranging from 16.8 - 20.7. The weighted average for all the tree species (Table 5.8) planted on the Slieve Bloom Mountains is 14.7, slightly below the National Average of 15.7.

Table 5.8: Weighted average yield classes (m^3/ha/annum) of the dominant forestry species on the major Slieve Bloom Mountain soils

						Lodgepole Pine		
		Sitka Spruce	Norway Spruce	Japanese Larch	Douglas Fir	Coastal	Lulu Island	Inland
Great Soil Group	Soil Name	Yield*	Yield	Yield	Yield	Yield	Yield	Yield
Podzol	Knockastanna Peaty Phase	16.3	16.0	13.2			4.8	6.0
Brown earth	Baunreagh	19.0	16.8	11.0				
Brown earth	Baunreagh Steep Phase	19.0		4.0	15.0			
Gley	Bawnrush	19.2	11.3	12.0	18.0			
Gley	Slieve Bloom	16.0	15.0	12.6	12.6	13.8		
Gley	Slieve Bloom non-Peaty Phase	17.0	16.0	7.0	13.0			
Gley	Clonin	18.5	18.0	8.0	14.9			
Podzolised Grey Brown Podzolic	Cardtown	19.0	16.0	12.0				
Gley	Mountrath							
Peat/Gley/Podzol	Turbary Slieve Bloom Rossmore	np*				13.2	6	
Blanket Peat	Aughty		14.2			7.9	5.7	
Blanket Peat	Aughty slumping phase	13.5				6.8	-	
Blanket Peat	Aughty eroded phase	19.0				9.0	-	
Blanket Peat	Turbary Complex	11.6			16.0	8.1	5.5	
Gley	Howardstown	17.1	17.0					
Brown Earth	B'town/Carlow	14.7	20.7					
	Mountrath	-	20.1					
	Elton	-	16.8					
	Turbary	-	15.0					

* Weighted average yield class (m /ha/annum) ** np species not planted on soil type

CHAPTER 6

QUANTITATIVE GRAZING CAPACITY OF SOILS

The objective of this part of the study is to determine the potential of the soils for livestock based on grass production and utilisation. Such quantitative measurements are possible only when the nature of the soil and climate is known and when pasture and animal experimental data are available. The completion of the Soil Survey of Co. Offaly has now made this possible. By comparing the potential targets thus obtained with present livestock numbers, the possible improvements in livestock density can be ascertained.

There has been a steady increase in livestock cattle numbers in Co. Offaly from 1955 to 1996 (Figure 6.1) with a doubling in the period 1955-1975. The data are derived from two sources: Central Statistics Office for the years 1955-1980 and from the Department of Agriculture Veterinary Section returns for herd data for the period 1981-1996 (with the exception of 1991, the year of the official national census).

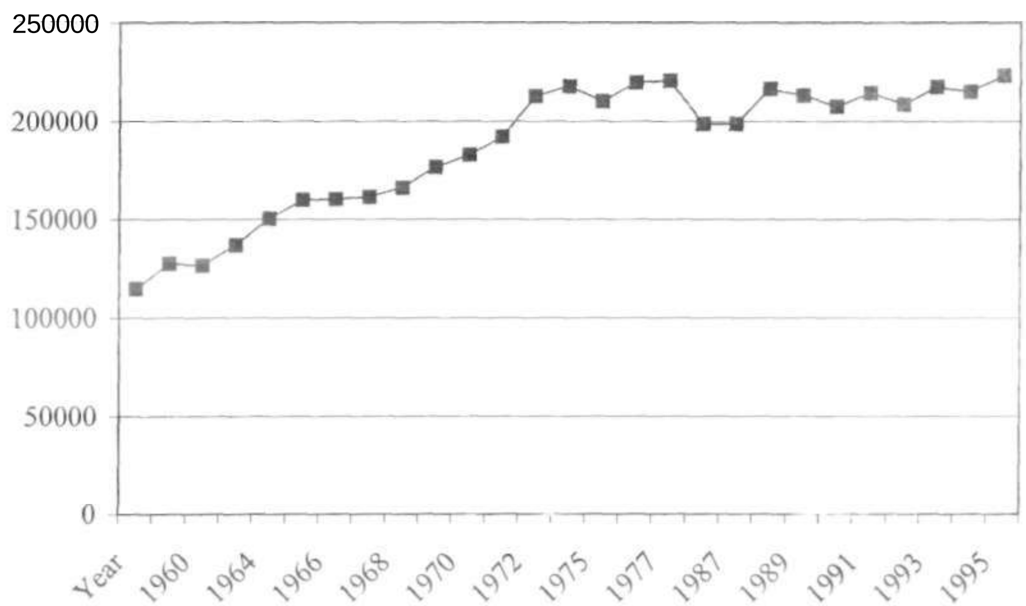

Figure 6.1: Trend in livestock numbers in Co. Offaly, 1955-1996

Grazing livestock numbers

The data in Table 6.1 show the trend in livestock units for County Offaly calculated according to Attwood and Heavey (1964). The data in this table do not include a correction value for sheep. The data show that cattle livestock units over the four decades have almost doubled. The overall number of animals nationally in 1998 was approximately $7.6x10^6$. Stock numbers in the county averaged 212,000 throughout the years 1989-1996, about 2% of the national total. The Census of Agriculture data for 1991 (CSO, 1994) allow sheep, at 5 ewes equivalent to a grazing livestock unit (LU), to be factored in to calculate the total grazing livestock units in Co. Offaly for 199j raising the figure to 189.069. The value of 125,038 hectares of grassland gives a nett value of 15] LU/100 ha of grassland. However, on a total land area basis the value decreases to 105 LU/100 ha which reflects the diluting effect of the combined areas of mountain and peat land in the county.

The determination of grazing capacity for the different soils is extrapolated from experimental sites to related areas defined by soils and climate (Lee and Diamond, 1972). The estimated grazing capacities are based on two input levels of nitrogenous fertiliser, i.e. 48 kg and 230 kg/ha. This calculation also assumes that there are adequate reserves of available phosphorus and potassium together with artificial drainage where needed. It is important to note that the lower level of nitrogen input assumes that there is a significant contribution from clover in the grazed pasture. The capacity class limits and associated symbols (A2-E) are given in Table 6.2. The Class A1 rating is not applicable since it is limited to the more climatically favoured areas along the south coast of Ireland with values >= to 276 LU/100 ha. The grazing capacities of the soil series and complexes mapped in the course of the Co. Offaly survey for lowland soils and the hill and mountains are shown in Tables 6.3 and 6.4 respectively.

Table 6.1: Trend in numbers of livestock units (LU) for selected years 1955 - 1991, Co. Offaly

Year	LU	Year	LU
1955	88,720	1972	140,600
1960	97,560	1973	154,600
1962	95,480	1975	163,850
1964	101,390	1976	160,570
1965	110,150	1977	167,100
1966	117,230	1980	165,701
1967	119,310	1987	151,086
1968	118,780	1988	151,150
1969	121,600	1989	164,574
1970	129,290	1990	162,056
1971	133,770	1991	151,837
		1991*	189069*

* *Includes a calculation correction for sheep*

When compared to the stock-carrying capacity, as calculated for the two levels of nitrogen (Tables 6.3 and 6.4), the values reflect an under-stocking of the soils of the county.

Table 6.2: Extent and definition of grazing capacity classes, Co. Offaly

Grazing Capacity Class	Grazing capacity LU/100 ha: 48 kg N /ha	Grazing capacity LU/100 ha: 230 kg N/ha	Area (ha)	%Total Area
A2	210-222	264-276	47,186	23.8
Bl	197-210	252-264	25,765	13.0
B2			566	0.2
CI	173-185	220-227	51,569	26.1
C2	160-173	188-202	278	0.1
Dl	148-160		17,058	8.6
D2	135-148		7476	3.8
E	<135		19,121	9.7
U			28,855	14.6

Table 6.3: Grazing capacity of soils of the Central Lowlands, Co. Offaly

			48 kg N/ha		230 kg N/ha	
Soil Series Phases and complexes	Area (ha)	Suitability Class	Grazing capacity LU/100 ha	Gross grazing capacity (LU)	Grazing capacity LU/100 ha	Gross grazing capacity (LU)
Patrickswell	29,520	A2	215	63,468	264	77,933
Elton	10,082	A2	220	22,180	274	27,625
Mortarstown	3126	A2	210	6565	252	7968
Knock	397	A2	210	834	252	1,000
Baggotstown	4061	A2	205	8325	255	10,355
Patrickswell lithic	447	Bl	198	2285	247	2850
Patrickswell bouldery	707	Bl	198	1399	247	1746
Baggotstown/Carlow	1014	Bl	205	2079	253	2565
Patrickswell/Baggotstown	10,903	Bl	207	22,569	257	29,020
Baggotstown/Patrickswell	3282	Bl	207	6794	253	8303
Patrickswell/Baggotstown Elton	9147	Bl	207	18,934	257	23,508
Howardstown/Patrickswell	193	Bl	207	399	203	392
Graceswood	566	B2	195	1104	245	1372
Mylerstown	8405	CI	180	15,129	222	18,659
Howardstown	3720	CI	173	6436	212	7886
Industrial peat	11,202	CI	173	19,379	212	23,748
Gortnamona	3625	CI	173	6271	212	7685

Table 6.3: (cont.)

			48 kg N/ha		230 kg N/ha	
Soil Series Phases and complexes	Area (ha)	Suitability Class	Grazing capacity LU/100 ha	Gross grazing capacity (LU)	Grazing capacity LU/100 ha	Gross grazing capacity (LU)
Banagher	16,834	CI	173	29,122	212	32,148
Baggotstown Crush	3732	CI	173	6456	209	7800
Howardstown/Baggotstown	258	CI	207	459	220	568
Ballyshear/Patrickswell	67	CI	207	119	220	147
Kilpatrick	278	C2	165	459	203	564
Alluvium	10,692	Dl	148	15,824	148	15,824
Ballincurra	461	Dl	136	626	136	626
Bally shear	4350	Dl	158	6873	158	6873
Ballintemple	4304	D2	136	5835	136	5835
Clonlisk	3172	D2	136	4314	136	4314
Burren	274	E	62	170	62	170
Allenwood	1847	E	124	2290	124	2290
Finnery River	1161	E	124	1440	124	1440
Garry hinch	448	E	124	555	124	555
Garrymona	233	E	124	289	124	289
Drombanny	2161	E	124	2679	124	2679
Industrial peat (part of)	9403	E	124	11,659	124	11,659
Callow	961	E	111	1066	111	1066
Pollardstown	1639	U				
Allen	8257	U				
Turbary	10,762	U				
Industrial peat (part of)	6198	U				
Total	187,889			294,385		347,463

Table 6.4: Grazing capacity of soils of the Slieve Bloom Mountains, Co. Offaly

			48 kg N/ha		230 kg N/ha	
Soil Series	Area (ha)	Suitability Class	Grazing capacity LU/100 ha	Gross grazing capacity (LU)	Grazing capacity LU/100 ha	Gross grazing capacity (LU)
Croghan	72	Bl	198	142	247	178
Ralhmoyle	543	CI	173	939	212	1151
Baunreagh	611	CI	173	1057	212	1295
Mountrath	523	CI	173	905	212	1108
Clonin	1889	CI	173	3268	212	4004
Cardtown	160	CI	185	296	227	363
Ballylanders	110	Dl	156	172	193	212
Bawnrush	478	Dl	148	707	148	707
Gortaclareen	85	Dl	148	126	148	126
Slieve Bloom - Non Peaty	882	Dl	156	1376	193	1702
Bunreagh - Steep Phase	68	E	124	84	124	84
Knockastanna	912	E	49	447	49	447
Slieve Bloom	1301	E	49	637	49	637
Turbary/Slieve Bloom/ Rossmore	353	E	49	172	49	172
Aughty	1050	U	-	_	-	_
Slumping Phase	423	U	-	-	-	-
Cutover Phase	337	U	-	-	-	-
Eroded Phase	189	U	-	-	-	-
Total	9796			10,186		12,014

CHAPTER 7

TRACE ELEMENTS

PJ. Parle and R.F. Hammond

Introduction

Trace elements are found in various concentrations in soils. Ranges of total contents for non-polluted Irish agricultural soils are given in Table 7.1. The total contents of trace elements in a soil depend largely on the nature and in particular on the mineral composition, of the parent material, whereas the distribution within a profile is conditioned by the soil forming processes such as weathering, leaching, biological mixing and the organic matter status. These processes, together with factors such as pH, drainage and hydrous oxide content affect the availability of trace elements to varying degrees.

Table 7.1: Typical ranges of the total contents (mg/kg) of some trace elements in non-contaminated Irish agricultural soils

Element	[1]Range (1)	[2]Range (2)	Element	Range (1)	Range (2)
Antimony	0.2-3.0	-	Manganese	20-3000	20-1567
Arsenic	1-50	3-104	Mercury	0.03-0.8	0.03-1.0
Boron	20-1000	-	Molybdenum	0.2-3.0	-
Cadmium	0.1-1.0	0.01-3.2	Nickel	0.5-100	1-150
Chromium	5-250	3-323	Selenium	0.2-2.0	0.2-9.7
Cobalt	1-25	1-53	Thallium	0.1-0.5	-
Copper	2-100	2-73	Tin	1-40	-
Fluorine	20-700	-	Uranium	1-10	-
Iodine	2-20	2.5-16	Vanadium	20-250	-
Lead	2-80	10-100	Zinc	10-200	4-239

[1] P. Parle personal communication
[2]McGrath^a/„ 2001

Total concentrations of trace elements in soils are of limited use in predicting the availability of the elements to growing plants and thus, indirectly, to the grazing animal. Where total concentrations are unduly high or extremely low it can be assumed that risks of toxicities or deficiencies are present but within these extremes total values are of little use in predicting problems in either plant or animal nutrition. Better information is obtained by extracting soils with various solutions, the premise being that these extractants simulate the growing plant in terms of nutrient uptake. Because the soil chemistry of the trace elements can differ, various solutions are required in the assessment of availability. Even then, extractants must be calibrated against crop responses in the field and these may often vary for a given crop on a given soil. Ranges of some extractable trace elements in non-polluted Irish agricultural soils are given in Table 7.2.

In the absence of response data from field calibration trials, trace-element analyses cannot provide definitive information relating to the occurrence of a crop or animal disorder. They can, however be extremely useful in indicating likely problem areas. More intensive follow-up work is then necessary to establish the extent and severity of different disorders. It is in this context that the data in Tables 7.3-7.6 and the accompanying comments should be viewed.

Table 7.2: Typical ranges of extractable trace elements (mg/kg) in non-contaminated Irish agricultural soils (A) and Interpretation (B)

Element	Extractant	Range (mg/kg)
Boron (B)	Boiling water	0.1-4.0
Copper (Cu)	0.05 molar EDTA	1-20
Manganese (Mn)	(easily reducible) 0.5 molar calcium nitrate and 0.2% quinol	1 0-600
Molybdenum (Mo)	Tamm's reagent (pH 3.3)	0.1-1.0
Zinc (Zn)	0.05 molar EDTA	2.0-15

Cobalt (Co) and manganese (Mn) are extracted with Aqua Regia, which gives values, which are practically identical with total.

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[1] Extractants are described by Byrne 1979}

B. Interpretation of trace element data

Trace Element	(mg/kg)	Interpretation
Copper - (EDTA soluble)	<3.0	Level in herbage may not be adequate to meet animal needs. Risk of Cu deficiency in cereals and sugarbeet.
Zinc - (EDTA soluble)	<2.0	Risk of Zn deficiency in cereals and some horticultural crops.
Manganese (easily reducible)	<40	Possible Mn deficiency in cereals and sugarbeet.
Boron (Water soluble)	<1.0	Possible B deficiency in swedes and some horticultural crops, sugar beet and oilseed rape.
Molybdenum (Ammonium oxalate soluble)	<0.1	Risk of Mo deficiency in brassicas.
	>0.25	Risk of Mo-induced Cu deficiency especially in young cattle but with factors such as liming (pH), soil moisture, sulphur content of feed, soil intake are involved.
Cobalt (Total)	<5.0	Risk of deficiency in lambs. Content in herbage dependent on level of Mn in the soil.

Trace element data are available for a small number of Co. Offaly soils (Tables 7.4-7.6) and are discussed according to soil group.

grown Earths

The high pH values of the Baggotstown Series will significantly decrease the uptake by plants of boron, cobalt, copper and zinc and could cause a deficiency of manganese in cereals and sugarbeet. particularly in a dry period. The uptake of molybdenum will be increased as a result of the elevated pH levels and an induced copper deficiency in animals is a possibility. The boron extractable values in this soil are satisfactory (Table 7.3) with the exception of one high value, which could cause toxicity in cereals. There are a few low copper and zinc values where deficiencies may arise. In general the cobalt concentrations are adequate but the total manganese content of the soil will influence uptake.

Table 7.3: Soil pH and trace element data for 15 topsoil samples sampled from Brown Earths in lowland and hill and mountain locations

Soil Series	Soil pH	Available (mg/kg)					Total (mg/kg)
		Cu	Zn	Mn	B	Mo	Co
Lowland							
Baggotstown	7.7	8.3	7.0	360	6.5	0.34	7.6
Baggotstown	6.7	3.0	0.8	370	3.6	0.24	6.0
Baggotstown	7.8	5.6	3.6	350	3.3	0.20	7.2
Baggotstown	7.4	5.0	4.8	400	4.2	0.24	6.0
Baggotstown	6.7	4.2	1.2	95	1.8	0.10	7.6
Complex (Soil Map Unit No. 209)	7.8	3.9	6.1	150	1.5	0.39	5.6
Hill and Mountain							
Baggotstown/Carlow Complex	6.6	2.4	5.6	195	2.8	0.10	3.6
Croghan	5.3	2.8	7.5	400	5.2	0.39	7.2
Ballylanders	7.7	1.2	0.9	165	1.6	0.20	8.0
Ballylanders	5.8	0.8	0.8	55	1.0	0.17	2.4
Ballylanders	6.1	0.7	0.8	80	0.5	0.14	3.2
Rathmoyle	6.3	1.3	1.9	245	0.3	0.20	6.8
Baunreagh	4.5	4.9	3.8	400	42.0	0.03	9.2
Clonin	5.6	2.7	0.9	820	0.8	0.31	4.4

The pH values of the Ballylanders soil are in the medium range with one exception, which may be a reflection of recent liming. The extractable boron, copper, manganese and zinc values are low (Table 7.3) and deficiencies of these elements in crops are a distinct possibility. The cobalt values are marginal and those of molybdenum are satisfactory.

Only one soil sample from the Baunreagh Series was analysed. Cobalt, copper and zinc values are satisfactory. Because of the low pH, manganese toxicity may occur in crops. A water-soluble boron value of 42 mg/kg is very high and with the soil pH of 4.5, boron toxicity in sensitive crops is a possibility. The Croghan Series, developed on shallow drift over volcanic bedrock, is marginal for extractable copper but adequate in all other extractable elements. The Rathmoyle Series, developed in a sandstone-influenced parent material, is low in extractable levels of copper and zinc.

Brown Earth/Grey Brown Podzolic Complex (Soil Map Unit No. 208)

Samples from the A horizon of Complex 208 soil have very high pH values which will have a major influence in reducing uptake of trace elements, with manganese the most likely to be affected (Table 7.4). The extractable boron values are satisfactory. Some low copper and zinc are recorded and these could give rise to deficiencies. There are also some low cobalt values and these, together with high pH and elevated manganese concentrations could give rise to cobalt deficiency in animals. Although there are only two elevated molybdenum values, consequent to the very high pH, this soil has the potential to cause scouring in cattle through excess molybdenum in herbage.

Table 7.4: Soil pH and trace element content for eight topsoil samples from Brown Earth/ Grey Brown Podzolic soils and their Complexes

Soil Series	Soil pH	Available (mg/kg)					Total (mg/kg)
		Cu	Zn	Mn	B	Mo	Co
Complex208	7.4	5.9	3.6	350	4.4	0.27	5.
Complex208	7.6	5.3	2.8	360	3.2	0.24	6.
Complex 208	7.5	0.5	3.0	340	1.2	0.20	2.
Complex 208	7.7	0.7	0.5	145	1.1	0.20	6.
Complex 208	8.1	1.8	2.7	340	1.1	0.10	9.
Mortarstown	7.7	5.5	15.7	370	4.9	0.14	7.
Complex 207	7.5	5.1	4.4	220	4.5	0.20	4.
Complex 207	7.1	2.5	3.1	250	4.6	0.24	4.

Grey Brown Podzolics

Of the Elton soil tested (Table 7.5), one of high pH value has low boron, copper, manganese and zinc extractable values, and deficiencies of these elements may occur. Cobalt uptake will be influenced by the total amount present and the molybdenum levels are satisfactory; pH values are such that molybdenum-induced copper problems in animals are unlikely.

The pH values of all the Patrickswell samples are all elevated, with one exception, and will influence plant uptake, particularly manganese (Table 7.5). Extractable boron, copper, manganese and zinc values are satisfactory. Cobalt levels are adequate, with one exception, but the uptake will be strongly influenced by pH and the total manganese. Where molybdenum levels are elevated, niolybdenosis is likely in cattle because of its solubility at high pH. Cobalt values are adequate. However, soil manganese is likely to control availability. One very high cobalt value (29 mg/kg) was found and this may be a reflection of a recent application of this element. Where pH values are inflated, molybdenosis in cattle is a possibility.
The one soil sample representing the Mortarstown Series (Table 7.5) recorded a pH of 7.2 and comments similar to the Patrickswell Series apply.

Table 7.5: Soil pH and trace element content for 28 topsoil samples from Grey Brown Podzolic soils

Soil Series	Soil pH	Available (mg/kg)					Total (mg/kg)
		Cu	Zn	Mn	B	Mo	Co
Elton	6.0	1.1	10.6	26	0.5	**0.10**	1.1
Elton	7.6	7.3	7.1	340	5.3	0.28	6.0
Elton	6.6	5.1	2.1	450	**1.9**	0.17	6.4
Elton	6.2	2.7	**0.9**	450	0.4	0.24	2.4
Elton	**6.9**	5.3	5.6	490	1.3	0.17	10.4
Elton	5.5	2.6	1.8	400	0.6	0.24	6.4
Elton	6.2	2.6	1.6	400	0.5	0.27	4.0
Elton	6.1	3.1	**1.9**	450	0.5	0.17	5.6
Elton	6.0	6.2	1.8	130	3.5	0.39	10.4
Elton	7.2	1.6	3.1	350	1.8	0.27	28.8
Elton	**5.9**	15.8	**11.2**	470	5.8	0.24	8.8
P/well Lithic Profile	7.2	7.4	12.6	460	2.3	0.24	**9.2**
Patrickswell	7.3	3.3	32.1	135	11.1	0.72	4.0
Patrickswell	7.5	2.6	3.0	470	5.4	0.17	5.6
Patrickswell	7.7	4.8	7.8	200	4.1	0.14	6.4
Patrickswell	7.5	**7.9**	2.8	350	2.8	0.17	6.0
Patrickswell	7.7	5.1	3.3	410	3.4	0.27	6.8
Patrickswell	8.0	3.5	25.1	130	20.6	0.65	4.8
Patrickswell	6.8	4.6	**6.9**	430	2.2	0.34	**9.6**
Patrickswell	7.0	3.6	3.0	370	3.0	0.46	8.8
Patrickswell		3.1	3.4	210	1.6	0.52	5.2
Patrickswell	7.1	1.8	1.5	100	1.4	0.24	2.8
Patrickswell	6.3	13.2	**4.9**	185	0.5	0.20	6.8
Patrickswell	6.3	5.1	1.2	340	8.2	**0.34**	6.4
Complex 207 (P/well)	6.0	4.4	**2.9**	340	6.6	0.88	7.6
Complex 209		6.3	4.2	**410**	1.7	0.42	8.4
Mortarstown	7.2	6.7	**4.9**	380	**5.1**	0.31	**6.8**

into four broad use-range or production categories for broadleaves, showing 40.9% of soils having wide to moderately-wide use range for broadleaf production. Another 10.8% are placed in the somewhat limited to limited use range and approximately 31.8% are considered to be very limited. almost 17.0% of the soils are classed as unplantable for commercial broadleaf forestry. Table 5.7 indicates the very-productive nature of most soils for conifers. The major difference between the extent of the wide to moderately-wide category for broadleaf and conifer is that the wet mineral soils are less suitable for broadleaved species.

Table 5.6: Percentage of land area below 150 m of Co. Offaly in each forestry production category

	Broadleaf	%	Conifer	%
Category	Use range		Yield Class	
A/B	Wide to Moderately wide	40.9	14-24	65.3
C	Somewhat limited	10.8	6-18	15.4
D	Limited	31.8	6-12	8.2
	Variable		0-20	5.7
UP	Unplantable	16.4	Unplantable	5.4

Table 5.7: Soil productivity for conifer species on lowland soils (based on the productivity of Sitka spruce) in Co. Offaly

Use range	Percentage of county
WideModeratelywide	65.3
SomewhatlimitedLimited	15.4
Limited	8.2
Variable	5.7
Unplantable	54

Co. Offaly is a very productive area for forestry. Both broadleaves and conifers will thrive there and give yields that are comparable to any other part of the country. The wet mineral soils, which present considerable problems for agriculture, should form the basis of any conifer forestry development programme. In a well-planned land-use programme the poorer marginal lands would be planted to conifers while blocks of broadleaves would be planted on the better soils to ensure, at least, the continuity of our lowland scenery. With the improved quality of broadleaved trees that are now being researched it is possible that broadleaves grown on 25-45 year rotations, i.e. the same length as Sitka spruce, could be planted economically on some of the current Class III tillage soils.

Gleys

The extractable trace element data for gleys derived from limestone parent materials are presented in Table 7.6. The surface pH values for all series are greater than 6.0. The extractable trace element levels for the series listed are generally satisfactory. However, there are instances of marginal copper, zinc and cobalt levels in the profiles sampled in the Ballintemple, Ballyshear, Clonlisk and Mylerstown Series and in the gleyed component of the soil Complex 207. Where low values are encountered deficiencies of these elements are likely. Molybdenum levels are satisfactory However, a high extractable value for molybdenum and an associated elevated pH in a profile from the Ballintemple Series could indicates that molybdenosis may occur.

The soil series mapped in the Hill and Mountain area show low extractable values for nearly all the elements of cobalt, copper, manganese, zinc and molybdenum, a reflection of the sandstone-dominated parent materials. Deficiencies of cobalt, copper, manganese and zinc can occur on these soils. Boron values are satisfactory.

Table 7.6: Soil pH and trace element content for 24 topsoil samples from Gley soils

Soil Series	**Soil pH**	**Available (mg/kg)**					**Total Img/kg)**
		Cu	**Zn**	**Mn**	**B**	**Mo**	**Co**
Sandstone							
SI. Bloom	6.2	0.8	1.4	2	8.3	0.03	1.1
SI. Bloom Peaty	5.6	0.7	1.4	9	12.4	0.03	0.8
Clonin	6.1	1.2	1.0	70	0.5	0.1	0.8
Limestone							
Howardstown	6.5	3.5	3.7	250	2.5	0.20	6.8
Howardstown	6.4	7.6	4.2	500	2.8	0.10	5.2
Mylerstown	5.9	6.0	6.1	190	3.1	0.17	4.0
Mylerstown	7.0	3.5	4.9	410	5.16	0.07	3.2
Mylerstown	6.7	3.1	2.7	420	0.8	0.24	7.6
Mylerstown		6.7	7.2	440	1.8	0.20	4.8
Mylerstown	7.2	8.1	1.0	130	0.8	0.17	5.2
Ballyshear	6.5	2.1	4.5	100	1.3	0.10	2.4
Ballyshear	7.2	10.2	7.1	370	2.7	0.17	5.2
Garryhinch	6.6	2.8	6.1	110	2.2	0.14	2.8
Clonlisk	6.4	4.3	2.0	110	0.5	0.17	5.2
Clonlisk	7.3	9.6	3.0	140	1.0	0.17	6.8
Clonlisk	6.5	2.3	1.5	220	0.4	0.10	4.4
Complex 207	7.6	2.1	2.0	145	5.7	0.14	4.8
Complex 207	6.7	3.3	10.7	65	8.7	0.14	2.4
Ballintemple	6.7	3.1	2.7	420	0.8	0.24	7.6
Ballintemple	6.8	3.3	1.3	235	6.1	0.10	6.0
Alluvium		4.6	2.9	125	2.64	0.49	5.6
Alluvium		13.3	3.2	6	1.44	0.24	6.4
Drombanny		2.0	1.8	430	5.20	0.17	0.7

CHAPTER 8

SOME PHYSICAL CHARACTERISTICS OF SELECTED SOIL SERIES

R.F. Hammond, T.N. Gleeson and L.E. Brennan

Introduction

In the course of the soil survey of County Offaly, several studies were carried out on soils-related topics. One such study was a soil type/quality of malting barley interaction study in the early 1970s (Hammond, 1972). Soil variation from farm to farm and within-field variation are commonplace. The objective of this study was to determine the effect of the within field micro-topographic factor on the yield and quality of malting barley. The profiles sampled were considered to be a representative cross-section of the soils derived from mainly limestone till in a) the Bracknagh/Rathangan area, b) an area on gravelly till south of Tullamore, and c) outwash gravels in the Blueball area west of Tullamore. The soil profiles sampled were from the Mylerstown (Soil Map Unit No. 129), Patrickswell (60) and Baggotstown (42) Series and from the Soil Complexes (207, 207A, 208, 209) which have combinations of these soils. Data from the profiles are used here to illustrate the characteristics of the soils within the malting barley growing areas and its application to the Series distribution in other parts of the county. Such data are also used in the formulation of risk criteria in the section dealing with water pollution risk.

Soil physical data

Within the study, a range of soil physical measurements were carried out (Appendix I) to determine what differences existed between the soils selected. The soils sampled were longer-term tillage soils (4-6 years) with a rotation of cereals, root crops (potatoes, turnips, sugar beet, etc.). The data in Tables 8.1 and 8.2 are for two Patrickswell soil profiles sampled at separate locations.

Table 8.1: Chemical and physical analyses for a soil profile representing the Patricks well Series (60a) in east Offaly

Depth (cm)	pH	TNV (%)	OM (%)	C.S.	F. S.	Silt	Clay	Db (stone-free)	NCP* % vol	AWP* % vol	Gravels % vol
0-5	7.7	2.3	4.8	19	24	38	19	1.27	6.3	36.6	6.7
10	7.8	2.2	4.7	20	24	37	19	1.33	5.1	31.2	5.6
15	7.9	2.5	4.9	14	31	36	19	1.33	4.5	32.3	9.4
20	7.8	2.2	4.8	18	22	42	18	1.25	7.5	37.4	8.0
25	7.8	1.2	2.2	19	22	42	17	1.14	10.8	17.3	7.6
30	7.7	1.1	2.0	21	25	36	18	1.38	13.8	22.0	6.8
35	7.8	1.2	1.6	19	30	35	16	1.44	15.2	21.9	3.5
40	7.9	1.3	-	13	37	32	18	1.43	17.2	22.8	2.6
45	7.8	1.3	1.4	17	36	30	17	1.45	11.6	17.0	2.0
50	7.9	1.1	1.6	13	33	33	21	1.48	10.9	9.1	2.3
55	8.0	1.6	1.7	10	32	35	23	1.42	10.4	13.2	2.7
60	8.1	1.5	1.4	15	27	34	24	1.38	14.7	13.8	3.0
60+	8.1	1.8	1.9	-	-	-	-	1.37	16.9	18.2	6.0

Table 8.2: Chemical and soil physical analyses for Patrickswell Series within Complex 207, < mid-south Offal} r

Depth (cm)	pH	TNV (%)	OM (%)	C.S.	F. S.	Silt	Clay	Db (stone-free)	NCP* % vol	AWP* % vol	Gravels % vol
5	6.7	2.8	10.9	40	21	27	12	1.15	7.0	31.1	11.3
10	7.3	2.7	10.8	38	21	26	15	1.20	4.2	28.9	9.1
15	7.1	3.5	10.9	39	21	30	10	1.15	8.2	28.9	9.2
20	7.5	3.4	10.1	41	19	28	12	1.16	6.8	26.8	10.3
25	7.8	5.1	6.1	38	21	31	10	1.39	9.1	17.9	9.4
30	7.9	3.5	5.9	40	21	29	10	1.43	11.4	21.0	9.8
35	7.3	1.5	4.8	41	20	28	11	1.36	15.5	22.6	9.9
40	7.5	0.9	3.7	35	25	29	11	1.45	13.9	21.9	10.3
45	7.5	0.5	2.9	41	25	25	9	1.37	17.2	20.3	11.0
50	7.8	0.7	3.5	27	23	32	18	1.33	19.6	21.9	10.3
55	7.5	1.2	3.2	31	20	33	16	1.32	16.6	22.7	11.3
60	7.7	1.2	3.2	27	23	33	17	1.23	24.2	19.5	11.4

** Appendix I for definitions*

The pH data show that Profile 60a is slightly alkaline to alkaline with Profile 207 near neutral in the surface to slightly alkaline. The higher Total Neutralising Values (TNV) in the surface 20-30 cm possibly reflect ground limestone additions when sugar beet was grown. The Patrickswell component of Complex 207 (Patrickswell/Baggotstown) (Table 8.2) has higher percentage gravel and lower clay values throughout the solum. The difference in surface layer organic matter contents between the two profiles is a possible consequence of longer-term tillage rotation on the Patricks well (60a) soil (Table 8.1).

Tables 8.3, 8.4 and 8.5 show data for bulk density, non-capillary and available water pore space (AWP) respectively, for nine profiles sampled from stubble areas. In general the stone-free bulk density data in Table 8.3 show a gradual increase with depth.

Table 8.3: Stone-free bulk densities (Mg/m^3) in representative Soil Series, from cereal growing areas, Co. Offaiy

Soil Map Unit No.	Patricks-well 60(a)	Patricks-well 60(b)	Patricks-well 60(c)	Patricks-well 60(d)	Patricks-well 207	Baggots-town 42	Crush 209	Patricks-well 208	Mylers-town 129
Depth (cm)									
5	1.27	1.28	1.11	1.24	1.15	1.27	1.01	1.08	1.34
10	1.33	1.29	1.11	1.36	1.20	1.39	1.04	1.30	1.40
15	1.33	1.28	1.19	1.35	1.15	1.36	1.13	1.21	1.20
20	1.25	1.31	1.21	1.26	1.17	1.30		1.17	1.24
25	1.14	1.47	1.46	1.49	1.39	1.14		1.42	1.35
30	1.38	1.44	1.67	1.52	1.43	1.34		1.33	1.47
35	1.44			1.55	1.36	1.40		1.36	1.43
40	1.43			1.76	1.45			1.38	1.49
45	1.45				1.37			1.41	1.70
50	1.48				1.33			1.49	
55	1.42				1.32				

The differences in stone-free bulk density data values between profiles are a reflection of the physical characteristics of the parent materials. The glacial till-derived soils, Mylerstown, Patrickswell (60 a,b,d), with the exception of Patrickswell Series, 60(c), show values = 1.2 Mg/m^3. The Patrickswell (207), Patrickswell (208) Crush and Baggotstown soils influenced by lighter-textured parent materials are generally less than 1.2 Mg/m^3, except for Baggotstown Series (42). Low (<5) non-capillary pore (NCP) space data values (Table 8.4) for soils under longer-term cultivation developed from glacial till parent materials indicate degradation of structure with some compaction in the top 20 cm. All profiles, except the Mylerstown Series, show increasing NCP values below 20 cm. Values above 7 indicate no compaction and above 11 soils are classed as porous (Jelly, in Finch, 1971). The Mylerstown Series with low NCP values down the profile reflects its gley classification.

Table 8.4: Non-capillary pore space (NCP) (% V/V) in representative Soil Series from cereal growing areas, Co. Offaly

Soil	Patricks -well	Patricks -well	Patricks -well	Patricks -well	Patricks -well	Baggots -town	Crush	Patricks -well	M.vlers -town
Map Unit No.	60(a)	60(b)	60(c)	60(d)	207	42	209	208	129
Depth (cm)									
5	6.3	5.6	4.3	6.3	7.0	9.8	7.9	12.5	4.1
10	5.1	4.0	2.5	3.7	4.2	4.5	4.8	14.0	6.2
15	4.5	4.5	2.0	4.7	8.2	9.5	6.8	16.2	10.2
20	7.5	3.7	6.1	8.5	6.8	7.3	11.5		10.3
25	10.8	7.7	13.1	9.1	9.1	11.1	26.4		7.4
30	13.8	11.5	11.6	9.9	11.4	12.8	17.1		6.1
35	15.2			10.8	15.5	16.5	16.4		8.2
40	17.2			9.7	13.9	13.5			7.9
45	11.6				17.2	12.8			6.3
50	10.9				19.6	9.7			
55	10.4				16.6				
60	14.7				24.2				
65	16.9								

Available water pore space (AWP) for the nine profiles are shown in Table 8.5. The data show that the deeper profiles of the Patrickswell Series have an adequate AWP and therefore drought is a minimal problem. The shallower components, however, of the Patrickswell Series, along with Baggotstown and the Crush Series, AWP values indicate that drought could be a problem in a dry season.

Soil water release and non- capillary and available water pore space data are shown in Figures 8.1 to 8.8 for Patrickswell (60a and 207), Baggotstown and Crush Series respectively. These figures complement the data shown in Tables 8.3, 8.4, and 8.5.

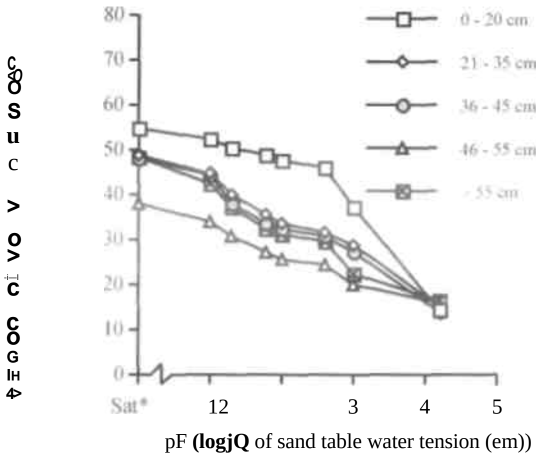
Patrickswell (60a) was sampled in the east of the county near Rathangan (Figures 8.1 - 8.2) and the Patrickswell component of Complex 207 sampled in central Offaly south of Tullamore (Figures 8.3 - 8.4).

Table 8.5: Available water pore space (AWP) (% V/V) in representative Soil Series from cereal growing areas, Co. Offaly

Soil	Patricks-well	Patricks-well	Patricks-well	Patricks-well	Patricks-well	Baggots-town	Crush	Patricks-well	Mjlers-town
Map Unit No.	60(a)	60(b)	60(c)	60(d)	207	42	209	208	129
Depth (cm)									
5	36.6	45.9	33.8	45.9	31.1	26.5	29.4	54.7	28.3
10	31.2	31.0	27.3	32.3	29.0	29.0	29.2	29.0	28.0
15	32.3	30.0	24.7	42.4	28.9	29.7	27.5	23.5	27.4
20	37.4	29.8	24.1	23.4	26.8	32.2	26.8		22.1
25	17.3	23.6	14.0	9.8	17.9	19.8	25.8		31.5
30	22.0	19.1	3.1	7.8	21.0	19.9	18.5		21.3
35	21.9		14.0		22.6	20.6	26.1		21.8
40	22.8		5.8		21.9	20.5			20.7
45	17.0				20.3	19.4			21.1
50	9.11				21.9	15.6			
55	13.2				22.7				
60	13.8				19.5				
65	18.2								

Figures 8.1 and 8.3 show the water release curves for Patrickswell soil (60a) and the Patrickswell soil within Complex 207 respectively. Figures 8.2 and 8.4 show the non-capillary and available water pore space for the same two profiles. The Patrickswell component of Complex 207 (Figure 8.3) derived from the more gravelly parent material shows a steeper gradient for water release and higher non-capillary porosity at depth.

Data for the Baggotstown Series are shown in Figures 8.5 and 8.6. The slope characteristic (Fig. 8.5) for the surface 0-20 cm is almost identical to that shown in Fig 8.3, however, the Baggotstown soil exhibits a sleeper gradient for the sub-surface 21-30 cm in comparison to the Patrickswell component of Complex 207 (Patrickswell/Baggotstown). The gradual release of soil water over all tensions is a characteristic associated with heterogeneously sized materials. The available water pore space in the Baggotstown Series shows a gradual decrease down through the solum but the non-capillary pore space shows a relative sharp increase due to the gravely nature of the parent material.



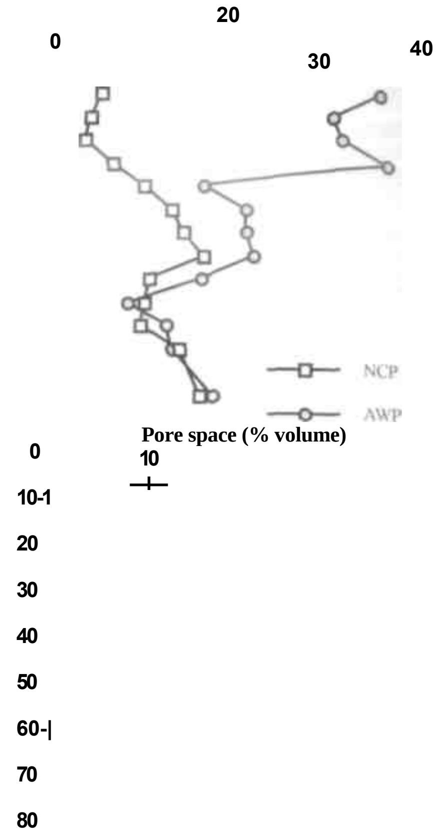
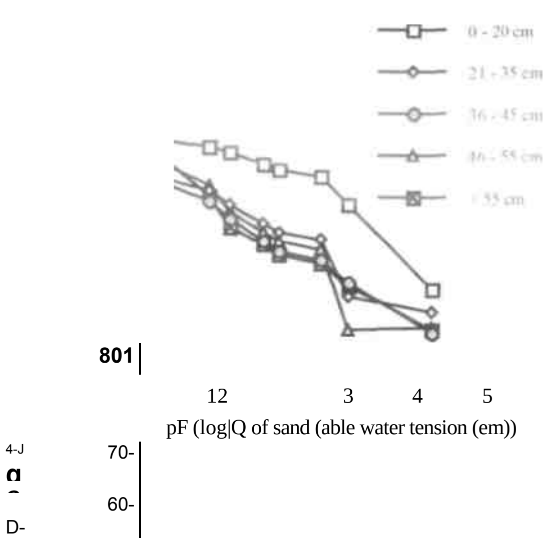
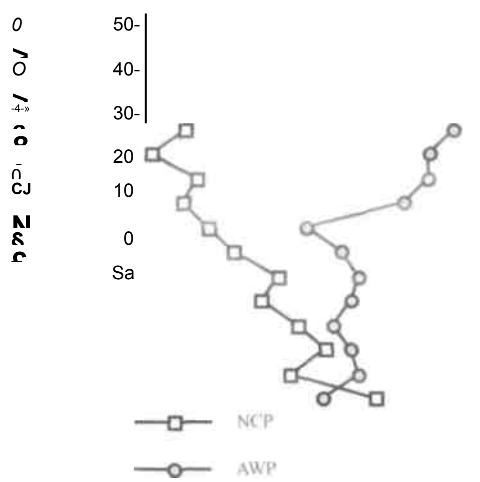


Figure 8.1: Water release curves for Patrickswell (60a) soil.

Figure 8.2: Available water porosity (AWP) and non-capillary pore space (NCP) curves for Patrickswell (60a) soil.

* Definition Appendix I





u

u Q

Pore space (% volume)

0

10

20-

30-

40

50-|

60

70-|

80

10 15 20 25 30 35

Figure 8.3: Water release curves for Patrickswell soil within Complex 207.

Figure 8.4: Available water porosity (AWP) and non-capillary pore space (NCP) curves for Patrickswell soil within Complex 207.

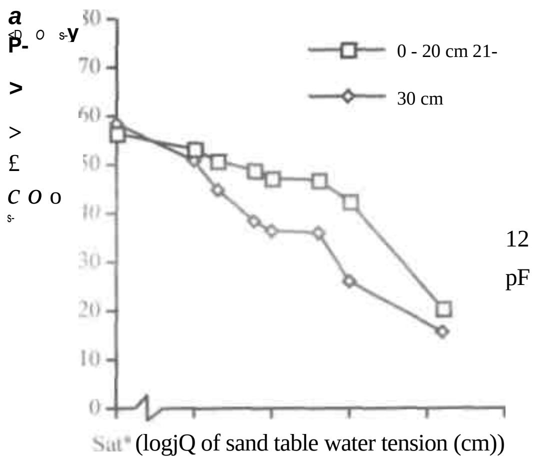


Figure 8.5: Water release curves for Baggotstown soil.

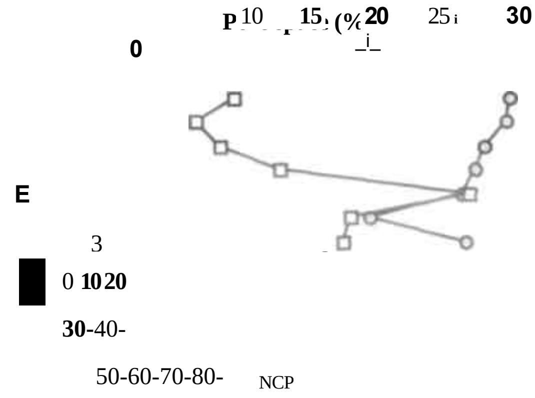


Figure 8.6: Available water porosity (AWP) and non-capillary pore space (NCP) curves for Baggotstown soil.

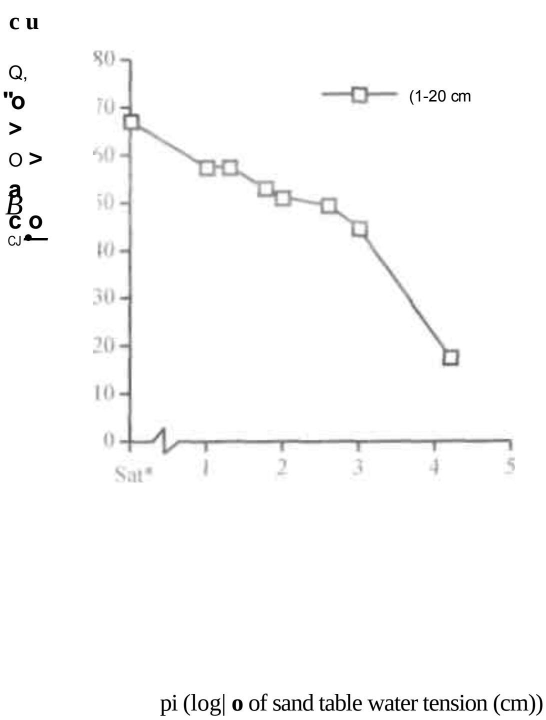


Figure 8.7: Water release curve for Crush soil.

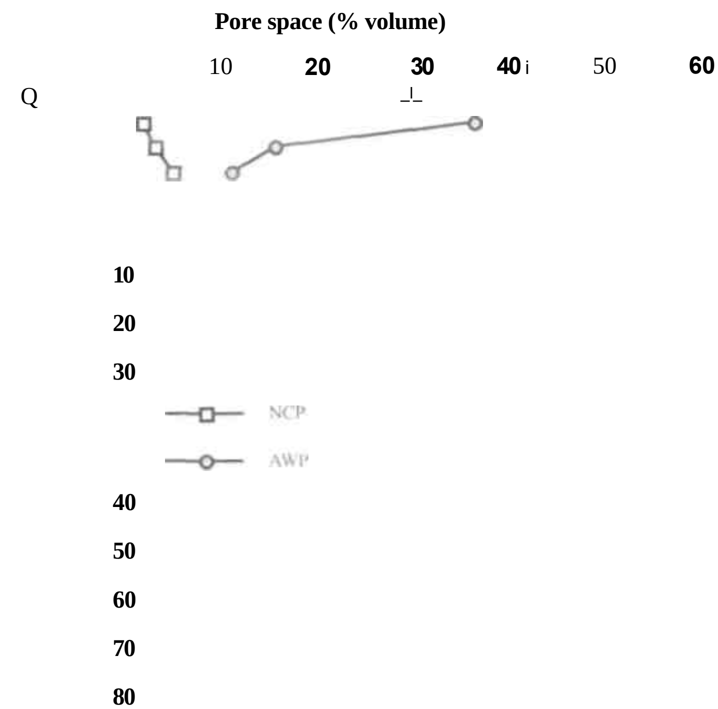


Figure 8.8: Available water porosity (AWP) and non-capillary pore space (NCP) curves for Crush soil.

The Crush Series, a component of the Complex 209, is more normally associated with crests of eskers. However, in respect of soils developed on gravelly parent materials A/C profiles are encountered on hummocks under agricultural production and the Figures 8.7 and 8.8 show the water release curves for the Ap horizon of such a soil. For the surface 5 cm depth water content at saturation is over 60%, the highest value for the three soils sampled as is field capacity and available water pore space at 55%. This reflects the higher organic matter content (13%) in the profile sampled. There is a sharp decrease in available water pore space from the surface (5cm) depth to the 10 and 15 cm depth where values are similar to the other profiles. Non-capillary pore space at equivalent depths shows a similar pattern to the other profiles.

The available soil water for the soils to a depth of 20 cm ranges from 53-72 mm, sufficient to meet up to a months evapo-transpiration needs. For total solum depth the available soil water range is 53-121 mm. The least value represents a Rendzina, the Crush Series, and the greatest a Grey Brown Podzolic, the Patrickswell Series. Since mineral fertilisers became freely available, soil nutrients (including minor and trace elements) are no longer an economic limiting factor to potential production from any Soil Series provided the Soil Series has adequate ion-exchange capacity to retain nutrients. Therefore, the drainage characteristics and available water holding capacity of the root zone are more indicative of crop production potential and agronomic value.

Particle size distribution characteristics of C horizons

Traditionally in pedology and agronomy when presenting particle size distribution analyses the percentages of coarse sand (CS), fine sand (FS), silt (S) and clay (C) are given only on the less than 2 mm fraction for standard USDA Soil Survey size fractions (USDA, 1962). This is appropriate for the solum (A and B horizons) of soils that generally have a small fraction of particles in the size range greater than 2 mm. Important physical characteristics are indicated by more complete size distribution analyses. The characteristics of the C horizon are one factor in understanding deep drainage behaviour. The ratio ol" the diameter corresponding to various percentiles on the particle size distribution curve is used to estimate various physical characteristics, for example hydraulic conductivity.

Particle size distribution analysis data (Table 8.6) were determined for nineteen selected profiles using a bank of sieves up to 38.1 mm mesh. Only 6 of the 19 samples retained material on the 38.1 mm mesh size sieve. Also included in Table 8.6 are data for the depth to the beginning of the C horizon but not the overall thickness of the parent material over the bedrock. The particle size distribution characteristic of the glacial drift parent materials is an important element in assessing their hydraulic conductivity when determining the susceptibility of groundwater contamination for soils (Fig. 9.3).

The Geological Survey of Ireland (Swartz *et ai*, in press) have evaluated the particle size analyses for a range of tills in Ireland, and have established relationships for the selected tills as follows:

i. Samples described as having moderate permeability, based on observation of recharge indicators (vegetation, drainage density), typically have less than 35% silt and also tend to have less than 12% clay.

ii. Samples, similarly described as having low permeability, have more than 50% silt plus clay, and also tend to have more than 14% clay.

iii. High permeability sand/gravel deposits tend to be sorted and have less than 7.5% silt and clay.

The data presented in Table 8.6 have been interpreted according to the parameters defined by (Swartz *et al.*, in press) and a permeability rating given as Tow', 'medium' and 'high' according to DoELG/EPA/GSI (1999) (Table 8.6).

This type of particle size analysis data (Table 8.6), and the maps showing the distribution patterns of the Soil Series and Complexes and surficial deposits, can help to determine the risk of groundwater pollution and facilitate future vulnerability mapping. Such data can also help to estimate other soil physical and mechanical parameters.

Table 8.6: Particle size analysis for the C horizons from 19 selected profiles of the mapped soils in Co. Offaly

Size fraction		Coarse gravel	Medium gravel	Fine gravel	v. Fine gravel		C.Sand	F. Sand	Silt	Clay	Recalc. Silt+Clay	Permeability rating
		>38.1mm	>19.05	>9.52	>2 mm	Total	2-1 mm	1-0.05 mm	0.05-0.02mm	<0.02mm		
Soil Map Unit No.	Depth to C (cm)		<38.1 mm	<19.05mm	<9.52 mm	<2 mm						
42	43	0	6	7	14	72	14(20)	18(25)	25(35)	14(20)	40	medium
42	45	0	12	9	14	65	13(20)	13(20)	25(38)	14(22)	39	low
42	45	10	23	17	33	17	11(61)	2(12)	3(17)	2(10)	5	high
42	42	9	9	8	18	56	25(44)	15(26)	12(22)	4(8)	17	medium
42	40	9	22	23	33	12	4(38)	1(9)	3(30)	3(23)	6	high
59	84	0	8	4	13	75	39(52)	9(12)	16(22)	10(14)	27	medium
60	72	0	9	6	13	69	8(12)	12(17)	36(52)	13(19)	49	medium
60	43	0	2	4	9	85	13(15)	19(22)	35(41)	19(22)	54	low
60	68	0	13	7	12	68	8(12)	17(25)	28(41)	15(22)	43.	low
60	28/36	0	0	7	18	74	9(12)	9(13)	45(62)	9(13)	55	medium
60	56	6	34	14	21	24	14(60)	4(16)	3(13)	3(11)	6	high
60	75	0	0	8	29	63	44(69)	2(3)	9(14)	9(14)	18	medium
60	72	14	13	5	16	51	23(46)	13(26)	10(19)	5(9)	14	medium
90	76/96	0	6	8	15	72	16(22)	14(20)	24(34)	17(24)	41	low
129	43	0	0	4	20	76	19(25)	23(30)	19(33)	9(12)	28	medium
208	32	0	5	41	12	79	12(15)	24(30)	31(40)	12(15)	43	medium
208	25	0	3	8	15	74	13(18)	17(23)	30(41)	13(18)	44	medium
208	21	0	28	27	22	24	17(72)	0.5(2)	4(16)	2(10)	6	high
207A	70	20	29	21	27	9	1(14)	1(19)	3(43)	2(24)	5	high

( ) - Percentage calculated on less than 2 mm fraction.

CHAPTER 9

SOIL SERIES AND POLLUTION RISK TO WATER

R.F. Hammond and T.N. Gleeson

Introduction

Soils are the basic resource for the production of commercial food crops and rearing of livestock. For decades it was taken for granted that soil was capable of absorbing unlimited amounts of human and animal wastes (Batjes and Bridges, 1993). However, it is now apparent that soils, surface water and groundwater could be at risk from the continued use of high applications of fertilisers, pesticides and animal slurries particularly in regions of countries with very intensive agriculture, imported feed and nutrient surpluses from animal manures. Similar risks exist from the overuse of sewage sludge and industrial wastewaters.

The protection of surface-water and groundwater quality is an important national issue and catchment surveys (Anon., 1999; Lucey *et al.*, 1999) have signalled a decrease in water quality in certain areas of the country. A more recent report has shown some improvement (McGarrigle *et al.*, 2002). The assessment of the potential of soil to mitigate the degradation of surface and groundwater quality is important. The reasons for quality changes are complex but several factors probably contribute. While fertiliser use has declined significantly since the mid 1970s the use of water (mostly non-processing) has increased, resulting in more wastewaters being emitted in both rural and urban environments. In a wide-ranging survey of European rivers the European Environment Agency has identified phosphorus from point sources, especially municipal sewage and industrial effluents, to be the main agent in the enrichment of surface waters (Kristensen and Hansen, 1994; Crouzet *et al*, 1999). The Environmental Protection Agency (EPA) in Ireland has pointed to agricultural practices for eutrophication (Anon, 1999). Present research is attempting to unravel the relevant contributions to enrichment: from overland run-off from waterlogged soils, from farmyards and from domestic, municipal and industrial sources as well as from natural background sources.

Pollution from overland flow

The ability of soils to absorb, retain and conduct water laterally and vertically is paramount when considering the potential for pollution. These characteristics vary at all scales even within fields. Gleeson (in Collins, 1992) outlined a simple conceptual model to describe the conditions under which overland flow run-off would occur. In this model overland flow would generally only occur when rainfall had first satisfied any soil-water deficit that may be present and raise the soil water content to 'field capacity' level. As infiltration into the 'single air-filled-porosity reservoir' that exists above the water-table continues, it raises that water-table towards ground level. When the water-table reaches the surface then overland flow occurs. Field studies of overland flow by Ariff (1992) have verified this model concept. Generally, overland flow will not occur on normal undamaged topsoil when the water table is below the surface regardless of slope, except for the most extreme rainfall intensities and durations, i.e. Hortonian flow (Horton, 1933). Only on soils with seriously compacted surfaces or on soils with structural degradation such as poached pasture, soils around cattle gateways and tillage soils damaged by harvesting machinery in wet weather, will low infiltration capacity impede rainfall percolation into the soil and be the cause of overland flow. Slope is of importance in that the greater the slope the less likely static shallow ponding will occur. It is also of significance in causing lateral sub-surface flow, which frequently results in seepage phreatic surfaces reaching the soil surface and thus causing overland flow. Soils with layers of very low hydraulic conductivity or pans will frequently have high water tables at or near the surface and thus overland flow will occur.

Gleeson (in Sherwood, 1992) using the parameters of bedrock geology, physiographic division, slope, rainfall, horizonation, seepage, hydraulic conductivity, texture, soil water, and drainage characteristics of the principal Soil Series gathered during field investigations for land drainage and pipeline surveys, interpreted the 1980 General Soil Map of Ireland (Gardiner and Radford, 1980) to give a Risk Ranking of 1 - 8 for overland run-off for the principal soil in the Soil Associations mapped. Risk Category 1 had the potential for the highest overland run-off and Risk Category 8 the least risk. The risk factor interpretation applied above has been modified to reflect the more detailed Soil Series mapping unit employed in the survey of County Offaly. The distinguishing criteria for the 8 categories and the Soil Series meeting these criteria are presented in Table 9.1.

A relative overland run-off risk assessment for Co. Offaly soils is given in Table 9.2 for Hill and Mountain soils and in Table 9.3 for Lowland soils. Application of this knowledge to farm management practices can assist in the reduction of surface and groundwater contamination. Using the soil map in conjunction with the current Codes of Good Farming Practice (GFP), Department of Agriculture, and Food, farmers can judge the degree of risk. Allowance for climatic conditions can be made by referring to Figs. 1.4 - 1.8 in Chapter 1 of this Bulletin. Agricultural production in County Offaly is found on the mainly gently undulating and to a lesser extent on rolling topography of the lowland soils landscape.

Table 9.1: Overland run-off risk categories for the soils of Co. Offaly, based on methodology used for the Soil Associations* of Ireland (Gleeson - in Sherwood, 1992) (1 = highest risk; 8 = lowest risk)

Hill and Mountain Soils

Risk Category	Description
la	**Soils with persistently wet surfaces:** These soils are in very high rainfall areas with high water-tables due to underlying impervious pans, impervious layers or bedrock. There can be strong seepage down slope. High Level Blanket Bog.
3b	**Soils of low hydraulic conductivity:** Peaty podzol, Peaty gley and Gley soils: on slopes with shale dominant and deep dense sandstone tills.
3c	**Soils with moderately low hydraulic conductivity and some down-slope seepage:** on slopes with sandstone and limestone tills.
5	**Soils on drier lower hill slopes with occasional seepage and wet hollows in wet weather** derived from Silurian shale and sandstone parent materials.
6	**Mainly dry soils in low rainfall areas:** Overland run-off risk and occasional seepage down-slope in prolonged wet weather only.

Lowland Soils

Risk Category	Description
lb	**Soils with persistent high water-tables:** Lowland waterlogged peats (Marshes and Fens). **Raised bog peats,** undrained, with frequent high water-tables.
3c	**Soils with moderately low hydraulic conductivity and some down-slope seepage:** derived from calcareous limestone tills.
4a	**Cutover peats and adjoining alluvial flat areas:** These soils, when not drained, have frequent high water-tables. Because they are generally flat, considerable ponding will occur before any overland run-off occurs.
4b	**Raised bog peats:** uncut, drained, bordering industrial peat areas with lowered water-tables.
5	**Soils on drier lower slopes with occasional seepage and wet hollows in wet weather:** derived from limestone-dominated gravelly glacial drift.
6a	**Dry soils (sandy loam to clay loam) and their complexes on undulating topography:** derived from limestone glacial drift.
6b	**Soil Complexes with occasional wet hollows in flat to gently undulating topography:** derived from limestone glacial drift.
	Dry light to medium textured permeable soils: on shallow limestone till and morainic limestone sands and gravel over permeable bedrock.
8	**No run-off risk, dry soils on thin till cover over very permeable bedrock:** these soils may have poor aquifer protection.

* Soils in Risk Category 2 occur exclusively on very heavy Upper Carboniferous shales and are absent from Co. Offaly.

However, a proportion of agricultural output derives from agriculture in the hill and mountain areas to the south and southwest County Offaly. In this landscape of mountain and hill many soils fall into Risk Categories between 1-3 for overland run-off. The Slieve Bloom Series and its non-peaty phase, developed on sandstone glacial drift are particularly prone to overland run-off. The soils in Category 5, developed on Silurian shale dominated parent materials are freer draining but the slope factor still needs to be taken into consideration.

Table 9.2: The overland run-off risk assessment applied to the Hill and Mountain soils of Co. Offaly (1 = highest risk; 8 = lowest risk)

Hill and Mountain soils

Great Soil Group	**Soil Names (Soil Map Unit No.)**	**Area** (ha)	**Area** (%)	**Risk Factor**	**Slope**
Peat/Gley/Podzol	Turbary Slieve Bloom Rossmore (916)	352	0.18	la	1 -3°
Blanket Peat	Aughty (903)	1050	0.53	la	0-3°
Blanket Peat	Aughty slumping phase (903Sm)	423	0.21	la	0-3°
Blanket Peat	Aughty eroded phase (903Er)	189	0.10	la	0 - 3°
Blanket Peat	Turbary Complex (914M)	337	0.17	la	0-3°
Podzol	Knockastanna Peaty Phase (79A)	912	0.46	3b	3-7°
Gley	Slieve Bloom (234)	1301	0.66	3b	1 -3°
Gley	Slieve Bloom Peaty Phase (234nP)	882	0.45	3b	3-7°
Gley	Gortaclareen (68)	85	0.04	3b	1 -3°
Gley	Bawnrush (231)	478	0.24	3c	**1** -3°
Gley	Mountrath (245)	523	0.26	3c	0- 1°
Brown Earth/Gley	Clonin (235)	1889	0.95	5	3-7°
Brown Earth	Rathmoyle (268)	543	0.27	5	3-7°
Brown Earth	Baunreagh (230)	611	0.31	5	7- 13°
Brown Earth	Baunreagh Steep Phase (230S5)	68	0.03	5	13-20°
Brown Earth	Ballylanders (45)	110	0.06	5	7- 13°
Brown Earth	Croghan (262)	72	0.04	6	7- 13°
Podzolised Grey Brown Podzolic	Cardtown (236)	160	0.08	6	1 -3°

The lowland soils are in general less at risk from overland run-off. Figure 9.1 shows the distribution of overland run-off risk, grouped into four categories (R1-R4), for the Soil Series mapped. Note that risk category applies only if prolonged rainfall results in waterlogged surface soil conditions.

Table 9.3: The overland run-off risk assessment applied to the Lowland soils of Co. Offaly (1 = highest risk; 8 = lowest risk)

Great Soil Group	Soil Names (Soil Map Unit No.)	Area (ha)	Area (%)	Risk Factor	Slope
Peat/Regosol	Callow (263)	961	0.49	lb	Flat
Peal	Pollardstown (908)	1639	0.83	lb	Flat
Peal	Allen (900) - undramed	1412	0.70	lb	Flat
Gie>	Howardstown (70)	3720	1.88	3c	0-1°
Gley	Kilpatrick (128)	278	0.14	3c	0-1°
Gley	Mylerstown(129)	8405	4.25	3c	0-1°
Gley	Ballyshear(201)	4350	2.20	3c	0- 1°
Gley	Ballintemple (264)	4304	2.18	3c	0-1°
Gley	Clonlisk (265)	3172	1.60	3c	0-1"
Gley	Garryhinch (267)	448	0.23	3c	0- 1°
Gley	Drombanny (67)	2161	1.09	4a	Flat
Regosol	Alluvium (40)	10,692	5.40	4a	Flat
Peat/Gley	Allenwood(131)	1847	0.93	4a	Flat
Peat/Regosol	Finnery river (132)	1161	0.59	4a	Flat
Peat	Gortnamona (913)	3625	1.83	4a	Flat
Peat	Banagher deep phase (905d)	15,164	7.66	4a	Flat
Peat	Banagher shallow phase (905s)	1670	0.84	4a	Flat
Peat	Milled peat (906)	21,217	10.72	4a	Flat
Peat	Machine peat (907)	5586	2.82	4a	Flat
Peat	Turbary (914)	10.762	5.44	4a	Flat
Peat	Allen (900) - drained	6844	3.47	4b	Flat
Peat	Garrymona (915)	233	0.12	4b	Flat
Brown Earth	Bagottstown/Carlow (243)	1014	0.51	5	0-3°
Grey Brown Podzolic	Patrickswell (60)	29,520	14.92	6a	0- 1°
Grey Brown Podzolic	Mortarstown (90)	3126	1.58	6b	0 - 3°
Grey Brown Podzolic	Knock (266)	397	0.20	6b	0-1°
Podzolised Grey Brown Podzolic	Graceswood (240)	566	0.29	6a	0-1°
Grey Brown Podzolic/Brown Earth	Patrickswell/Bagottstown (207)	10,903	5.51	6a	0 - 3°
Brown Earth/Greybrown Podzolic	Bagottstown/Patrickswell (207A)	3282	1.66	6a	0-1"
Grey Brown Podzolic	P'well/B'stown /Elton (208)	9147	4.62	6a	0-3°
Brown Earth/Rendzina	Bagottstown/Crush (209)	3732	1.89	6a	0 - 3°
Grey Brown Podzolic-	Elton (59)	10,082	5.10	6b	0- 1°
Gley/Brown Earth	Howardstown/Baggotstown (213)	258	0.13	6c	0- 1°
Gley/ Grey Brown Podzolic	Ballyshear/Patrickswell(214)	67	0.03	6c	0- 1°
Gley/ Grey Brown Podzolic	Howardstown/Patrickswell (215)	193	0.10	6c	0-1°
Brown Earth	Baggotstown (42)	4061	2.05	7	0-3°
Brown Earth	Ballinacurra (43)	461	0.23	7	0- 1"
Grey Brown Podzolic	Patrickswell lithic (60L)	447	0.23	7	0-1°
Grey Brown Podzolic	Patrickswell bouldery (60B)	707	0.36	7	0-3°
Rendzina	Biirren (140)	274	0.14	8	0-1°

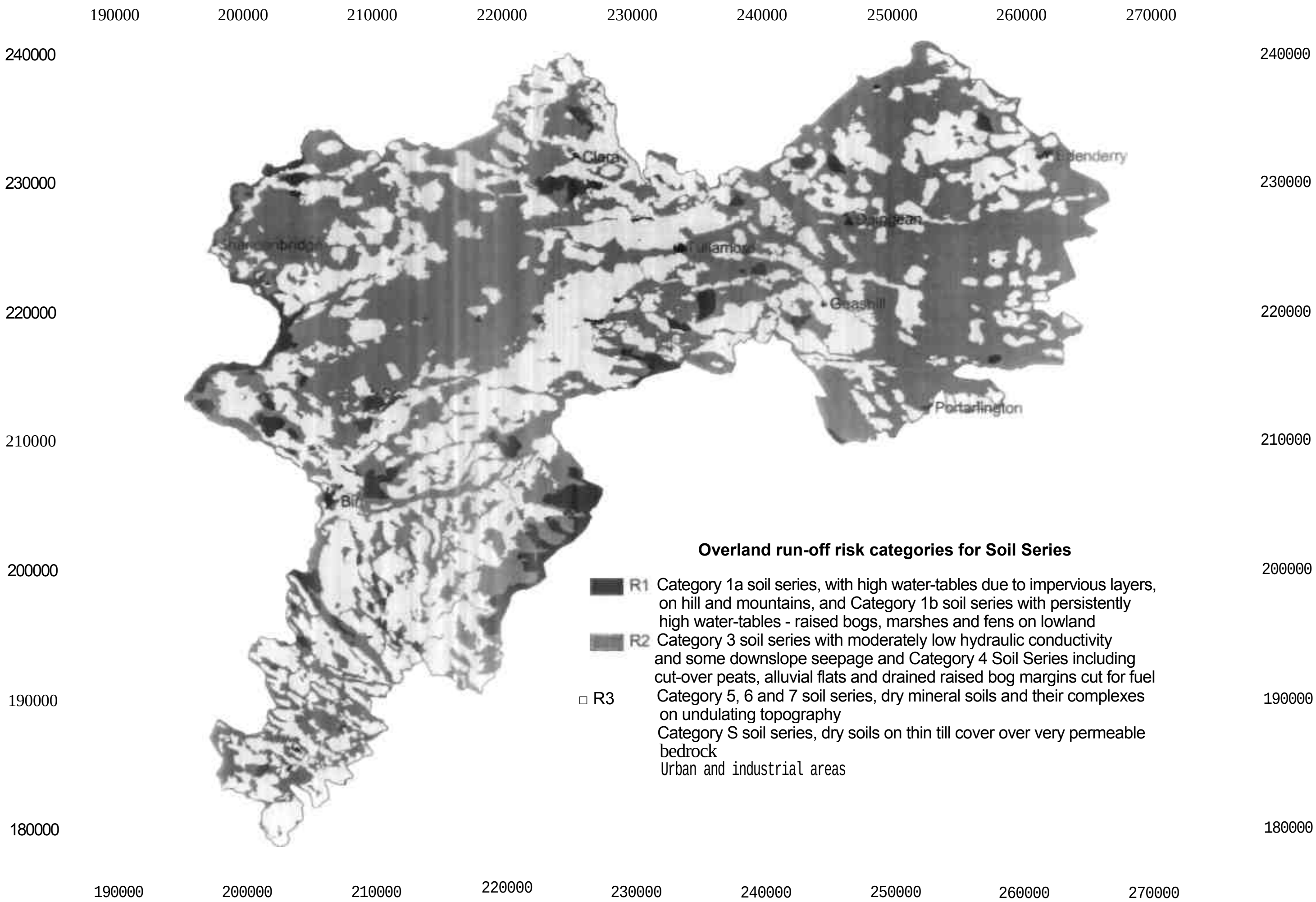


Figure 9.1: Overland run-off risk categories, Co. Offaly based on waterlogged soil conditions prevailing after heavy rainfall, interpreted from Table 9.1.

Groundwater Protection

At present groundwater supplies 20-25 per cent of Ireland's drinking water (DoELG/EPA/GSI, 1999) and European Union and national legislation has been passed to protect and prevent groundwater pollution, e.g. the Local Government (Water Pollution) Act, 1977, (No. 1 of 1977 as amended by the 1990 Act) and the European Commission Water Quality Directive (98/83/EC). The European Commission intends by 2010 that a Framework Water Quality Directive (Com (97) 49 final) will supersede previous legislation to ensure quality standards and limits for substances which must not be exceeded.

Groundwater Protection Schemes have been devised to maintain the quality and quantity of groundwater by applying a risk-assessment-based approach to groundwater protection and sustainable development. Groundwater "vulnerability" indicates the likelihood of groundwater being polluted by industrial and municipal wastes. Guidelines to protect this resource have been published (DoELG/EPA/GSI, 1999). The Geological Survey of Ireland (GSI) estimates groundwater vulnerability (Daly, 2001) by combining the main hydrogeological factors that influence contaminant attenuation, in particular information on permeability and depth to rock. GSI groundwater protection zone maps show the presence of these groundwater resources and their vulnerability to pollution by combining the vulnerability map with the aquifer map.

Soil Series ranking for groundwater susceptibility

Protection zone maps may help county planners and regulators to locate future potentially polluting activities so as to minimise the risk to groundwater contamination. Combining the mapping information for soils and surficial deposits in association with soil morphological, physical and chemical data for each Soil Series recorded in the County Offaly survey, an assessment is made of susceptibility to groundwater contamination for agricultural wastes. The capacity of surface soils and underlying geological materials to attenuate the contaminants is an important factor. A combination of climate, topography, soil distribution patterns and their associated physical characteristics within the landscape determines the management and disposal of land spreading of effluents and farmyard manures. The physical characteristics of the solum, e.g. texture, thickness and permeability, and time-of-year weather-related factors are important permutation factors when assessing the risk potential.

Farmyard liquid manures and wash waters are normally spread on the surface of forage and arable lands. In some cases they may be injected into a shallow topsoil layer not more than 200 mm in depth. Spreading rates seldom exceed 6 mm per annum for liquid manures and slurries, and seldom exceed 20 mm per annum for wash waters when properly applied to the appropriate land area. A septic tank percolation area on the other hand is designed to take 1500mm per annum of effluent recharge more than 600 mm below ground surface.

The Soil Series and Complexes mapped in the soil survey of Co. Offaly were ranked into four classes of susceptibility (Table 9.4, Fig. 9.2) to give a relative range from SI (highest) to S4 (lowest). The selection of four categories (S1-S4) of soils potential to influence groundwater susceptibility is analogous to the system used in the publication "Groundwater Protection Schemes" (DoELG/EPA/GSI, 1999). The susceptibility ratings are relative and given as a guide only for good farming practice in line with current codes defined by the Department of Agriculture and Food "Good Farming Practice".

SI category soils are thin to moderately shallow soils over fissured limestone rock. More vigilance is required with all disposals on these soils. S2 soils are shallow to moderately shallow soils in association with rock outcrop. Certain operations, e.g. disposal of large volumes of wash water from farm and food processing industries should be carried out with care on these soils. S3 soils are shallow to moderately shallow, developed from parent materials with a moderate content of sands and gravels; farmers should be aware of slight extra risk on these soils. S4 soils are deep to moderately-deep mineral soils developed from glacial drift materials and peat soils. Where normal precautions are taken there should be a very low risk to groundwaters from normal farm operations.

Category S1 soils have developed from underlying parent materials that are thin and/or permeable, presenting a lesser filter barrier to a usable aquifer. On the other hand, Category S4 soils have a thickness of solum and underlying parent material such that surface waters are filtered over a longer period, posing no threat to the groundwater. In other situations, e.g. peats, downward flux can be zero or near zero due to high watertables, pan or impervious subsoil.

These categories in association with the surficial deposits map and the groundwater vulnerability map, can give an added dimension to planning the protection of the water resources of County Offaly. However, it is important to recognise when locating any extraordinary waste spreading or disposal operation, e.g. food industry wash waters or septic tank percolation areas using a map at the published mapping scale, that a detailed on-site investigation be conducted to fully evaluate any risks, and accurately rank the susceptibility category to which the soil belongs.

Table 9.4: Soil Series and Complexes listed according to their groundwater pollution susceptibility ranking, for Co. Offaly (1 = highest risk; 4 = lowest risk)

Series and Complexes (Soil Map Unit No.)	Area (ha)	Ranking	Area (%)
Burren (140)	274	SI	0.14
Patrickswell lithic (60L)	447	S2	0.23
Ballincurra (43)	461	S2	0.23
Patrickswell bouldery (60B)	707	S2	0.36
Croghan (262)	72	S3	0.04
Ballylanders (45)	110	S3	0.06
Cardtown (236)	160	S3	0.08
Baggotstown (42)	4061	S3	2.05
Btown/Pwell (207A)	3282	S3	1.66
P/well/Btown (207)	10,903	S3	5.51
Pwell/Btown/Elton (208)	9147	S3	4.62
Btown/Crush (209)	3732	S3	1.89
Btown/Carlow (243)	1014	S3	0.51
Knockastanna Peaty Phase (79A)	912	S4	0.46
Baunreagh (230)	611	S4	0.31
Baunreagh Steep Phase (230S5)	68	S4	0.03
Rathmoyle (268)	543	S4	0.27
Bawnrush(231)	478	S4	0.24
Slieve Bloom (234)	1301	S4	0.66
Slieve Bloom Peaty Phase (234nP)	882	S4	0.45
Gortaclareen (68)	85	S4	0.04
Clonin (235)	1889	S4	0.95
Mountrath (245)	523	S4	0.26
Turbary Slieve Bloom Rossmore (916)	352	S4	0.18
Aughty (903)	1050	S4	0.53
Aughty eroded phase (903Er)	189	S4	0.10
Aughty slumping phase (903 Sm)	423	S4	0.21
Turbary Complex (914M)	337	S4	0.17
Elton (59)	10,082	S4	5.10
Patrickswell (60)	29,520	S4	14.92
Mortarstown (90)	3126	S4	1.58
Knock(266)	397	S4	0.20
Graceswood (240)	566	S4	0.29

Table 9.4: (cont.)

Series and Complexes (Soil Map Unit No.)	Area (ha)	Ranking	Area (%)
Howardstown (70)	3720	S4	1.88
Kilpatrick(128)	278	S4	0.14
Mylerstown (129)	8405	S4	4.25
Ballyshear(201)	4350	S4	2.20
Ballintemple (264)	4304	S4	2.18
Clonlisk (265)	3172	S4	1.60
Drombanny (67)	2161	S4	1.09
Alluvium (40)	10,692	S4	5.40
Ballyshear Patrickswell (214)	67	S4	0.03
Howardstown Baggotstown (213)	258	S4	0.13
Howardstown Patrickswell (215)	193	S4	0.10
Allenwood(131)	1847	S4	0.93
Finnery River (132)	1161	S4	0.59
Callow (263)	961	S4	0.49
Garryhinch (267)	448	S4	0.23
Allen (900)	8257	S4	4.17
Garrymona (915)	233	S4	0.12
Gortnamona (913)	3625	S4	1.83
Banagher deep phase (905d)	15,164	S4	7.66
Banagher shallow phase (905s)	1670	S4	0.84
Pollardstown (908)	1639	S4	0.83
Milled peat (906)	21,217	S4	10.72
Machine peat (907)	5586	S4	2.82
Turbary (914)	10,762	S4	5.44

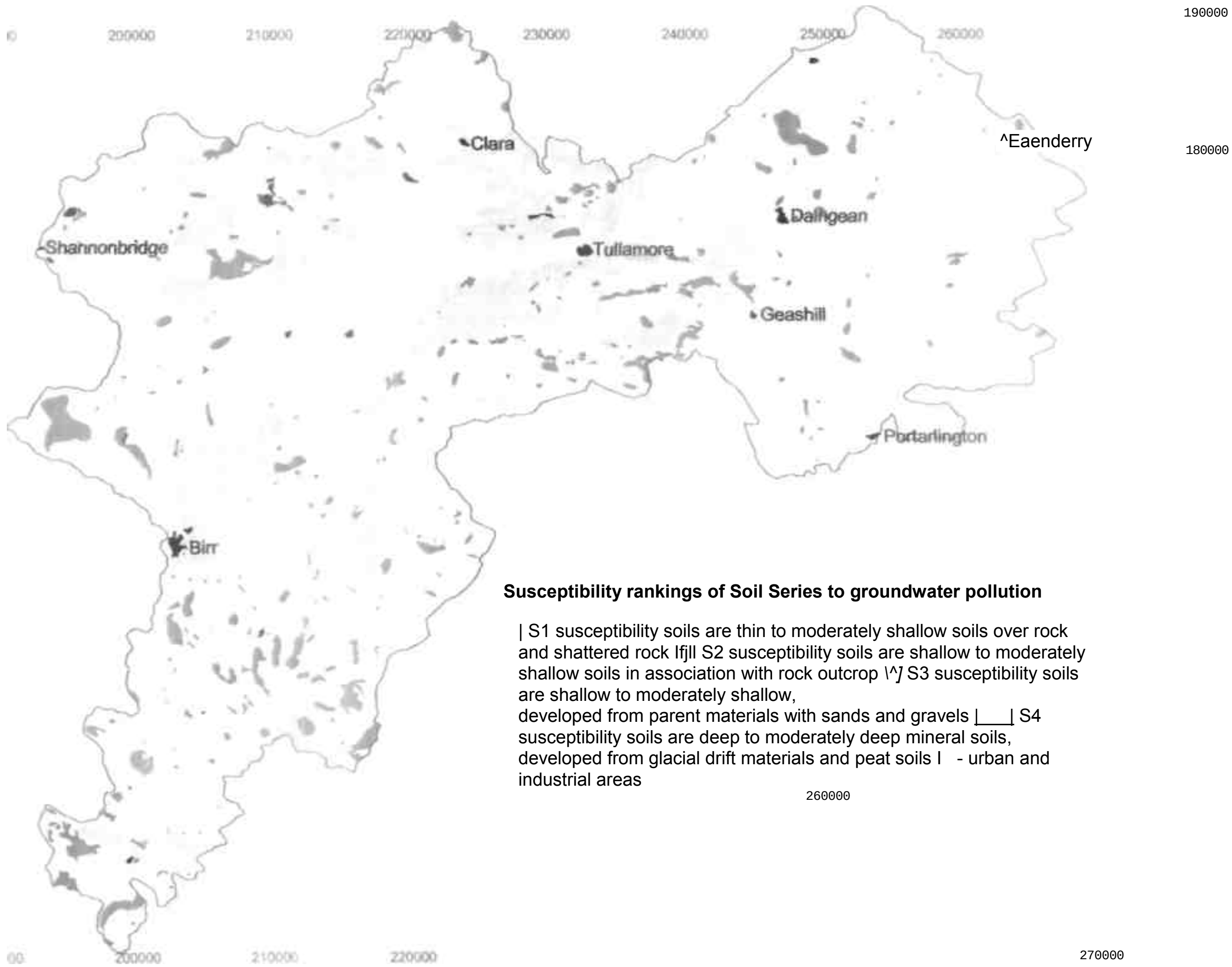


Figure 9.2: Susceptibility rankings of Soil Series in Co. Offaly to groundwater pollution.

CHAPTER 10

FARMING IN COUNTY OFFALY

T. Collins, Chief Agricultural Officer, Teagasc, Co. Offaly

Mixed farming is the principal feature of Offaly farming. Cattle, sheep and tillage crops are produced on a total of 3000 farms with milk production confined to 700 farms.

Cattle are produced from beef cow herds on 1500 farms. Eleven hundred farms have a ewe flock, while approximately 800 farms grow cereals. On 900 farms, cattle production is based on bought-in calves or store cattle.

There are approximately 3700 farm households in the county, with an average farm size of approximately 30 ha. Sixty percent of farms are less than 30 ha, while 17% are more than 50 ha.

Soil quality varies widely. Approximately 25% of soils have a wide use range, 45% have some use limitations and the remaining 30% have some serious limitations due to drainage and/or the peaty nature of the soils.

In terms of viability, 35% of Offaly farms are considered to be economically viable from farming alone. A further 30% of farm households are economically viable arising from off-farm income earned by the farmer and/or spouse. Of the remaining 30% of farm households half are both economically and demographically un-viable and are likely to 'exit' farming. The remainder (15%) arc categorised as economically un-viable but demographically viable. Supplementing farm income is a priority on these farms to achieve adequate household incomes.

Farm Incomes

Average farm income in Offaly consistently approximates the national average. Wide variations in income occur between systems - with dairying returning the highest incomes and 'drystock-only' farms returning the lowest.

Direct payments account for 57% of average farm income. Direct payments for Cattle, Arable Aid, Area Aid based payments, Ewe Premium and Extensification in 2001 amounted to €32.8m. In addition, direct payments resulting from participation in REPS, Forestry and Early Retirement schemes amounted to €10.25m in 2001.

Technology transfer

The up-take of new technology by Offaly farmers is very satisfactory, especially on the larger drystock/tillage farms and on dairy farms. The level of contact with the Teagasc Advisory Service by Offaly farmers is very high (>80%), especially by farms of more than 30 ha and in the dairying, drystock/tillage and sheep systems. Contact is lowest by farmers in mainly drystock enterprises and with those on smaller farms (<40%).

On-farm investment

On-farm investment throughout the 1990s averaged more than €33,000 per farm, mainly on buildings and machinery. One thousand farmers participated in on-farm investment schemes related to pollution control. The total investment was €15m and grant aid received was €7m. This grant-aided investment occurred in the 1994-2000 period.

Young entrants to farming

Offaly has more participants in the Scheme of Installation Aid than most other Leinster counties. Almost 150 young farmers participated in this scheme, and with the new revamped Teagasc Education Programme this number is expected to increase.

Cattle production

The most dramatic change that has occurred in County Offaly in recent years is the growth in the beef cow herd. There are now almost 50,000 cows (including dairy cows) to produce the raw material for the county's beef industry. This is the highest number of cows ever recorded in the county. Traditionally the county was a major importer of the raw material (i.e. calves, weanlings, and stores) from the dairying counties of the South. Farms with more than 10 beef cows accounted for close to half of all suckling herds. The scale of the cattle business on these farms averaged 25 suckler cows and 60 other cattle. On smaller suckler farms the average number of cows was 5, with 18 dry cattle.

Drystock-only farms are strongly associated with small farm size (average 18 ha). There is a high element of part-time farming associated with this system and it is more concentrated in West Offaly.

There is a substantial cattle enterprise on almost half of all dairy farms.

Dairy farming

There are just over 700 milk suppliers in the county, or 19% of all farms. On most of these farms dairying is the main enterprise, while the remainder have a mix of other enterprises, principally cattle.

Most commercially-viable farms in the county are in milk production. While most of the milk is for manufacturing there is also a substantial amount of liquid milk produced. Average herd size is 35 cows while average milk supplied is 130,380 litres per producer.

The greatest concentration of dairy farms in the county is South of Birr where one in three farms is in milk production, compared to 19% for the county as a whole.

Sheep
There are over 1000 ewe flocks in County Offaly, accounting for 116,000 ewes. The number of producers fell in recent years (1992-1998) by about 19%. However, the reduction in ewe numbers has been much less, at 3%.

Sheep production in the county is associated with other farming systems such as tillage and drystock. Seventy per cent of flocks have less than 100 ewes. On specialist sheep farms the average flock size is 212. There is a greater concentration of sheep in the southern part of the county.

While there is some 'early lamb' produced, the majority of sheep farmers are involved in mid-season lamb production.

The Offaly Quality Lamb Producers Group, with over 100 members, plays an active role in lamb marketing in the county.

Tillage
Cereals at 10,000 ha account for most of the area devoted to tillage, with field beans, sugar beet, potatoes, field vegetables, oil seeds, maize and linseeds, and a small amount of forage crops, accounting for the remainder.

Approximately 800 tillage farmers received EU Arable Aid payments of €4.5m in 2001. Less than 20% of tillage farmers are 'specialist' growers. Tillage is associated with larger sheep and suckler farms.

Spring barley is still the predominant crop. Some soil types are particularly suitable for growing top quality malting barley.

Pigs
In line with national trends, pig production is now concentrated in bigger units. There are approximately 5000 sows in 10 units in the county with only one unit having less than 100 sows. This trend is likely to continue. However, environmental regulations may limit the size of the larger units.

En vironmentally-friendly farming
Over 1400 farmers participated in the Rural Environmental Protection Scheme (REPS). This is expected to rise to over 2000 on completion of the REPS 2 Programme. Participation in the 30-50 ha farm size category is high, but disappointing in the less than 30 ha category on drystock farms.

Eighty eight per cent of participants expressed satisfaction with the Scheme. It is likely that changes in the REPS 2 scheme will encourage more smaller farmers to participate.

National studies have shown that REPS participants apply less phosphates and have invested in farm waste control facilities.

Nutrient Management Planning will be a feature of the Environmental Service provided by Teagasc in the future.

Farm diversification
Forestry - most recent data show that 8.6% of the land area in Offaly is under afforestation.

Private plantings at 9267 ha is slightly less than State planting. Of the 512 private plantations, 450 were classified as having been planted by farmers.

Rural tourism
About 40 farm households are engaged in providing a range of tourism products, e.g. Bed & Breakfast, Self-Catering, Town & Country Houses, Open Farms, etc.

Mushroom production, deer farming, free-range poultry and egg production, and cottage food production are minor enterprises, based on the numbers engaged in each. However, the contribution to household income is significant on the farms involved.

CHAPTER 11

SOILS AND PARENT MATERIALS

R.F. Hammond and (the late) T.F. Finch

In Table 11.1 the Soil Series described and mapped in Co. Offaly are grouped according to parent material. The majority of the Soil Series are derived from parent materials dominated geologically by the underlying carboniferous limestone (approximately 95% of the county) with the remainder characterised by the sandstone and shale of the Slieve Bloom Mountains.

Table 11.2 shows the stone count data obtained from bulk samples of 25 - 50 kg sampled from the C horizon of selected profiles considered to be representative of the major series mapped in the county. The physical composition and subsequent stone counts were determined to assess the provenance of the glacial drift. These samples were air dried, weighed and then washed to remove the <2 mm material. The size fractions of the >2 mm material were then determined by sieving through a nest of sieves. Stone counts of sub-samples from the separated materials were carried out to determine the geological composition of the glacial drift. These data were entered into a Microsoft Excel® spreadsheet and the proportion of the different counts calculated.

Table 11.1: Geological parent materials of Soil Series in Co. Offaly

Series	Parent Materials
Knockastanna Peaty Phase, Baunreagh, Ballylanders, Rathmoyle, Bawnrush	Shale bedrock and drift composed mainly of shale with a little sandstone
Croghan	Volcanic greenstone ash
Slieve Bloom, Gortaclareen, Clonin	Sandstone bedrock and drift composed mainly of sandstone with a little shale and chert
Cardtown	Fluvio-glacial gravels composed mainly of sandstone, shale and limestone
Mountrath	Calcareous drift composed mainly of limestone and sandstone
Turbary, Slieve Bloom, Rossmore	Blanket bog peat and drift composed mainly of Sandstone
Aughty	Highly humified blanket bog peat of cyperaceous origin
Patrickswell, Baggotstown, Elton, Mortarstown, Knock	Calcareous drift composed of limestone with some sandstone and shale
Graceswood	Calcareous fluvio-glacial sand
Howardstown, Kilpatrick, Mylerstown, Bally shear, Ballintemple, Clonlisk	Calcareous drift composed of limestone with some sandstone and shale
Drombanny	Lake Marl over alluvium

Table 11.1: (cont)

Series	Parent Materials
Alluvium	River Alluvium
Allenwood, Finnery river, Callow, Garryhinch	Fen peats calcareous drift and alluvium
Allen, Garrymona, Gortnamona	Raised bog peats of variable humification composed predominantly of *Sphagnum* mosses
Banagher, Pollardstown	Humified fen peats composed of variable amounts of sedges, mosses, reed and wood remains
Industrial Peat, Turbary	Raised bog and fen peats

Table 11.2: Lithological components of the parent materials of some representative soil profiles based on stone count expressed as a percentage, Co. Offaly

Great Soil Group	Series	L/stone	Shale	Chert	S/stone	Calcite	Quartz
Lowland							
Grey-brown Podzolic	Elton	69.4	11.8	15.6	2.8		1.02
	Elton	61.7	5.7	26.9	5.3	0.2	0.2
	Elton	87.1	0.8	10.5	1.6	-	
	Elton	56.4	24	13.2	6.4	-	
	Elton	73.4	3.9	13.5	9.2	-	
	Elton	65.2	10.9	17.6	5.9	0.5	
	Elton	72.2	1	5.6	20.7	0.5	
	Knock	88.9	7.8	3.3		-	
	Patrickswell	91.8	0.8	4.5	2.9	0.8	
	Patrickswell	91.4	6	2.6	-	-	
	Patrickswell	61.2	12	22.4	4.4	-	
	Patrickswell	95.6	1.1	2.7	0.6	-	
Brown Earth	Baggotstown	92.6	1.1	4.5	1.7	-	
	Baggotstown	58.8	7.8	19.6	13.7	-	
	Btown/Carlow	2.8	4.9	74.2	18	-	
	Btown/Carlow	81.5	1.8	15.5	1.2	-	
Gley	Clonlisk	89.2	3.5	4.7	-	0.2	
	Ballyshear	87	1.4	7.5	4.1	-	
	Howardstown	66.7	9.6	19.6	3.8	-	
	Ballyshear	83.3	4.8	9.2	2.7	-	
	Ballintemple	93.2	0.2	4.4	2.1	-	
		47	26.5	14.7	11.8		
Hill & Mountain							
Gley	Bawnrush	7.6	77.2	12.4	2.8		
	Bawnrush	-	68	-	32	-	
Brown Earth	Clonin	1.3	9.7	-	89	-	
	Clonin	-	0.5	-	99.5	-	
	Clonin	4.5	6.8	5.3	83.4	-	

APPENDIX I

DEFINITION OF TERMS USED IN PROFILE DESCRIPTIONS[1] AND ANALYSES

Introduction

The first major publication describing European soils was published on Russian soils in the 19th Century; since that time considerable resources have been applied to methodologies for classifying and describing soil profiles. The unique morphology of the soil profile derives from the complex interaction of the five soil forming factors, living matter, relief, time, parent material and climate (Jenny, 1941). A worldwide standard methodology to describe the soil profile has been a major goal. The basic techniques and methodologies described in the Soil Survey Manual, first published by the United States Department of Agriculture (USDA) in 1951, has been a model that many countries have adopted, with some modification to meet local requirements. The National Soil Survey of Ireland uses the USDA Soil Survey Manual to describe the soils mapped in its survey programme. The parameters used to describe the different elements of the soil profile are defined in the following sections.

Soil colour

An immediate reaction on viewing a soil is to comment on the colour. Soil colour in itself has no function on soil use but the inferences we make from its colour to its use can be highly significant. Dark colours are generally associated with increased organic matter content, reddish brown colours with iron oxides and drab grey colours with poor drainage conditions.

The Munsell Colour Company (New York) and the USDA Soil Conservation Service developed charts for classifying the colour of soils. They help the soil surveyor to record the colour of soils. 322 colour chips are mounted on nine charts: The arrangement is by- Hue, Value and Chroma. Seven hues (10R, 2.5YR, 5YR, 7.5YR, 10YR, 2.5Y and 5Y) are used to cover the range of world soils. Hue is the name of the colour family, such as red or blue. Value is the lightness or darkness of a colour. Chroma is the intensity or strength of a colour.

To reproduce and standardise soil colour, the determination is carried out at two moisture contents; (1) air dry and (2) field capacity. The colour description is given as two elements, a descriptor an J a Munsell Notation, e.g. yellowish brown (10YR5/4). Generally surface soils would have values

'The terms and conditions used here are essentially those of the Soil Survey Manual, USDA Handbook No. 18, Washington, D.C., 1951 (updated 1962 and 1993).

of four or less and chromas of >=1, whereas subsurface horizons would exhibit values of five and greater and chromas >=2.

Texture

Soil texture refers to the relative proportions of the various size particles in the mineral fraction of a soil. More especially, it refers to the relative proportions of clay, silt and sand in the fine earth mineral fraction, i.e. <2 mm in diameter. Texture, which is one of the more important of the soil's physical properties, influences such characteristics as moisture retention, drainage and tilling properties of soils, their resistance to damage by stock and heavy machinery and earliness of crop growth.

Classes of texture are based on different combinations of sand (0.05 to 2.0mm diameter size), silt (0.002 to 0.05mm) and clay (less than 0.002mm). The basic textural classes, in order of increasing proportions of the finer separates, are sand, loamy sand, sandy loam, silt-loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay. Definitions of the basic classes in terms of clay, silt and sand are presented in Figure 1.

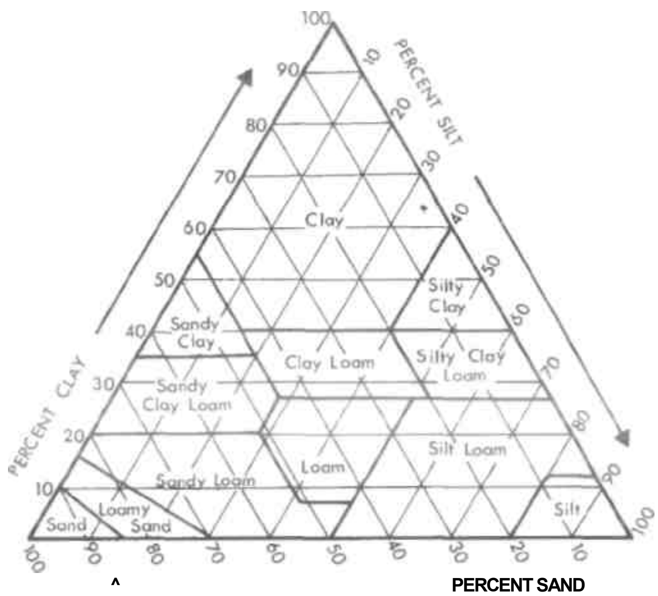


Figure 1: Percentage of clay (less than 0.002mm), silt (0.002 to 0.05mm) and sand (0.05 to 2.0mm diameter size) in the basic soil texture classes (after Soil Survey Manual, No. 18, USDA Washington D.C., 1951).

Field Estimation of Soil Textural Class

Estimation of soil textural class is made in the field by feeling the moist soil between the fingers. The field estimation is checked in the laboratory. In arriving at an estimation in the field the following considerations are taken into account.

Sand: Sand is loose and single grained. The individual grains can readily be seen and felt. Pressed when moist, a weak cast may be formed which easily crumbles when touched.

Sandy loam: A sandy loam contains much sand but has adequate silt and clay to make it somewhat coherent. If squeezed when moist, a cast can be formed that bears careful handling without breaking.

Loam: A loam has roughly equal proportions of sand, silt and clay. If squeezed when moist, a cast is formed which can be handled quite freely without breaking.

Silt loam: A silt loam contains a moderate amount of sand, a relatively small amount of clay and more than half the particles of silt size. A cast can be formed which can be freely handled without breaking, but when moistened and squeezed between thumb and finger it does not "ribbon" but gives a broken appearance.

Clay loam: A clay loam contains more clay than a loam and usually breaks into clods or lumps that are hard when dry. In the moist state it is plastic and can be formed into a cast which can withstand considerable handling. When kneaded in the hand, it does not crumble readily, but tends to work into a heavy compact mass.

Clay: A clay has a preponderance of finer particles, contains more clay than a clay loam and usually forms hard lumps or clods when dry, but is quite plastic and sticky when wet. When pinched out between thumb and finger in the moist state it forms a long, flexible "ribbon".

General Grouping of Soil Textural Classes

Often it is convenient to refer to texture in terms of broad groups of textural classes. Although the terms "heavy" and "light" have been used for a long time in referring to fine- and coarse-textured soils, respectively, the terms are confusing as they do not bear any relation to the weight of the soil; the terms arose from the relative traction power required for ploughing. An outline of acceptable terms is as follows:-

General Terms		**Basic soil textural class**
Sandy	Coarse-textured	Sands
		Loamy sands
	Moderately coarse-textured	Sandy loams
Loamy	Medium-textured	Loams
	Silt loams	
	Silts	
	Moderately fine-textured	Clay loams
		Sandy clay loams
		Silty clay loams
Clayey	Fine-textured	Sandy clays
		Clays

Structure
Soil structure refers to the aggregation of primary soil particles into compound particles, which are separated from adjoining aggregates by surfaces of weakness. An individual natural soil aggregate is called a ped.

The productivity of a soil and its response to management depend on its structure to a large extent. Soil structure influences pore space, aeration, drainage conditions, root development and ease of working. Soils with aggregates of spheroidal shape have a greater pore space between peds, are more permeable and are more desirable generally than soils that are massive or coarsely blocky.

Field descriptions of soil structure indicate the shape, arrangement, size, distinctness and durability of the aggregates. Shape and arrangement of peds are designated as type of soil structure, size of peds, as class; and degree of distinctness, as grade.

Type
There are four primary types of structure:

(a) *Platy* - with particles arranged around a plane and faces generally horizontal.

(b) *Prismlike* - with particles arranged around a vertical line and bounded by relatively flat vertical surfaces

(c) *Blocklike* - with particles arranged around a point and bounded by relatively flat or curved surfaces that are not accommodated to the adjoining aggregates.

(d) *Spheroidal* - with particles arranged around a point and bounded by curved or very irregular surfaces that are not accommodated to the adjoining aggregates

Each of the last three types has two subtypes.

Under prismlike, the two subtypes are prismatic (without rounded upper ends) and columnar (with rounded ends). The two subtypes of blocklike are angular blocky (with sharp-angled faces) and sub-angular blocky (with rounded faces). Spheroidal is subdivided into granular (relatively non-porous) and crumb (very porous).

Class
Five size-classes are recognised in each type. The size limits of these vary for the four primary types given. A type description is generally qualified by one of the following class distinctions; very fine, fine, medium, coarse and very coarse.

Grade

Grade is the degree of aggregation or strength of the structure. In field practice, it is determined mainly by noting the durability of the aggregates and the relative proportions of aggregated and non-aggregated material when the aggregates are disturbed or gently crushed.

Terms for grade of structure are as follows:

0 *Structureless* - No observable aggregation. This condition is described as massive if coherent and single grain (if non-coherent, free flowing).

1 *Weak* - Poorly formed indistinct peds which, when disturbed, break down into a mixture comprising some complete peds, many broken units and much non-aggregated material.

2 *Moderate* - Many well-formed, moderately durable peds that are not so apparent in the undisturbed soil. When disturbed, however, a mixture of many complete peds, some broken peds and a little non-aggregated material is evident.

3 *Strong* - Structure characterised by peds that are well formed in undisturbed soil, and that survive displacement to the extent that when disturbed, soil material consists mainly of entire peds, with few broken peds and a little non-aggregated material.

The appropriate terms describing type, class and grade of structure are combined in that order to give the structural description, e.g. moderate, medium sub-angular blocky; weak, fine crumb.

Porosity

Porosity of a soil is conditioned by the shape, size and abundance of the various channels, passages and other soil cavities which are included under the general name of soil pores. In this bulletin, porosity refers mainly to the voids between the soil structural units, which is strictly the structural porosity. Soil porosity is influenced largely by type of structure; it is also influenced by rooting and by the activity of earthworms and other soil macro-organisms.

Porosity determines, to a large extent, the permeability rate in the soil and the air-to-water ratio prevailing and is thus of considerable importance with regard to soil aeration and the drainage regime.

Consistence

Soil consistence is an expression of the degree and kind of cohesion and adhesion or the resistance to deformation and rupture that obtains in a soil. Interrelated with texture and structure, and strongly influenced by the moisture condition of the soil, this characteristic is most important in developing a good tilth under cultivation practices. The evaluation of soil consistence is usually considered at three levels of soil moisture - wet, moist and dry, even though Irish soils are seldom dry enough to exhibit dry consistence.

Consistence when wet

A *Stickiness:* Stickiness expresses the extent of adhesion to other objects. To evaluate this feature in the field, soil material is pressed between thumb and finger and its degree of adhesion noted. Degrees of stickiness are expressed as follows:

0 *Non-sticky:* On release after pressure, practically no soil material adheres to thumb or finger.

1 *Slightly sticky:* After pressure, soil material adheres to thumb and finger but comes off one or the other rather clearly.

2 *Sticky:* After pressure, soil material adheres to both thumb and finger and tends to stretch somewhat and pull apart rather than pull free from either digit.

3 *Very sticky:* After pressure, soil material adheres strongly to both thumb and finger and is decidedly stretched when they are separated.

B *Plasticity:* Plasticity is the ability to change shape continuously under applied stress and to retain the impressed shape on removal of the stress. To evaluate in the field, the soil material is rolled between thumb and finger to form a "wire".

0 *Non-plastic:* No wire formable.

1 *Slightly plastic:* Wire formable; soil mass easily deformed.

2 *Plastic:* Wire formable; moderate pressure required to deform soil mass.

3 *Very plastic:* Wire formable; much pressure required to deform soil mass.

Consistence when moist

To evaluate in the field, an attempt is made to crush in the hand a mass of soil that appears moist.

0 *Loose:* noncoherent.

1 *Very friable:* Soil material crushes under very gentle pressure but tends to cohere when pressed together.

2 *Friable:* Soil material crushes easily under gentle to moderate pressure between thumb and finger and tends to cohere when pressed together.

3 *Firm:* Soil material crushes under moderate pressure between thumb and finger but resistance is distinctly noticeable.

4 *Very firm:* Soil material crushes under strong pressure; barely crushable between thumb and finger.

Consistence when dry

To evaluate, an air-dry mass of soil is broken in the hand.

0 *Loose:* Noncoherent

1 *Soft:* Soil is fragile and breaks to powder or individual grains under very slight pressure.

2 *Hard:* Soil can be broken easily in the hands but it is barely breakable between thumb and finger.

3 *Very hard:* Can normally be broken in the hands but only with difficulty.

Cementation

Cementation of soil material refers to a brittle, hard consistence caused by various cementing substances. Different degrees of cementation occur, mainly in natural pan layers - iron pans, fragipans.

1 *Weakly cemented:* Cemented mass is brittle but harder than that which can be shattered in the hand.

2 *Strongly cemented:* Cemented mass is brittle but harder than that which can be shattered in the hand; it is easily shattered by hammer.

3 *Indurated:* Very strongly cemented; brittle; does not soften when moistened and is so extremely hard that a sharp blow with a hammer is required for breakage.

Chemical Analyses

pH

pH is a measure of soil acidity or alkalinity. A soil having a pH of 7.6 to 8.3 is moderately alkaline; pH 7.1 to 7.5, slightly alkaline; pH 7.0, neutral; pH 6.6 to 6.9, nearly neutral; pH 6.0 to 6.5, slightly acid; pH 5.3 to 5.9, moderately acid; pH 4.6 to 5.2, strongly acid; and pH below 4.5, very acid.

Total Neutralising Value (TNV)

This is an index of the level of carbonates present in a soil. These carbonates modify the solubility of other nutrients. Soils showing positive TNV values in the surface horizons contain adequate or excess neutralising materials and are not in need of liming.

Carbon and Nitrogen

The level of organic carbon indicates the amount of organic matter in a soil (C X 1.72 = organic matter). The content and nature of organic matter are of fundamental importance. Due to its high cation exchange capacity, organic matter acts as a reservoir for plant nutrients, which are gradually released to meet the requirements of the growing plant. At the same time, acid humus supplements the supply by influencing the extraction of nutrients from the mineral fraction of soils. Organic matter creates favourable physical conditions for crop growth; it promotes granulation of structure by reducing plasticity, influences cohesion and increases the water-holding capacity of the soil. Organic matter in the surface also influences the temperature of soils and, thus, seasonal growth.

Depending on organic carbon content, soils are classified as follows: over 30%, peats; 20 to 30%, peaty; 10 to 20%, slightly peaty; and those with 7 to 10% are usually referred to as "organic". In the case of the terms "peaty", "slightly peaty" and "organic", the mineral textural class is included in the definition of the soil, e.g., peaty sandy loam; slightly peaty clay loam; organic loam. The surface horizon of mineral soils in Ireland normally contains 3 to 6% organic carbon.

Nitrogen, which is normally present in soils in relatively small amounts, is extremely important as a plant nutrient. It is easily leached from the soil and supplies need to be constantly replenished. The ratio of carbon to nitrogen (C/N ratio) indicates generally the degree of decomposition of organic matter; a ratio between 8 and 15 is considered satisfactory and indicates conditions favourable to microbial activity. Ratios higher than 15 are associated with a slower decomposition rate and with the accumulation of raw organic matter or, in more extreme cases, with peat development, and are indicative of unfavourable conditions for microbial activity.

Free Iron

A localised accumulation of free iron in a soil profile (Bir horizon), as is evident in Brown-podzolic and Podzol soils, indicates that leaching and podzolising processes have been operative. On the other hand, a uniform distribution of free iron throughout a profile, as is the case in the Brown Earths, indicates that the soils have not been strongly leached.

Summary of Analytical Methods

Particle Size Analysis: Determined by the International Pipette method as described by Kilmer and Alexander (1949), using sodium hexametaphosphate as dispersing agent.

pH: Determined on 1/2 soil/water suspension using a glass electrode.

Total Neutralising Value (TNV): Determined on HC1 extract using phenolphthalein as indicator and titrating against NaOH. CaCO^ is used as a 100% standard.

Organic Carbon: Estimated by the Walkley-Black dichromate oxidation method as described by Jackson (1958), modified for colorimetric estimation. Values are read off on a Spekker Absorptiometer using Orange Filter No. 607. A recovery factor of 1.1 was used.

Total Nitrogen: Estimated by a modification of the method of Piper (1950) by digesting soil with concentrated H_9S0_4 using selenium as a catalyst, distilling into boric acid and titrating with HO.

Free Iron: Extracted with buffered sodium hydrosulphite (Mehra and Jackson, 1960). Fe determined colorimetrically using o-phenanthroline.

Physical Measurements

Monolith excavation

The field methodology involved excavating monolith columns from the profile at the selected sites and sampled at 100 mm increments down the column. Samples were coated with paraffin wax and transported to the laboratory. Values determined in the laboratory included bulk density, with and without corrections for gravel and stone content, non-capillary air space, capillary air space and moisture contents at pF values 0.1, 1.3, 1.78, 2, 2.6, 3.0 and 4.2. A sand bath is used for suction measurements up to pF 2.0 and a pressure plate apparatus for the higher suctions, (Modern suction equivalents are expressed in kilopascals 1, 2, 6, 10, 40, 100, and 1500 kPa).

Non-capillary pore space

Non-capillary pore space (NCP) is by convention that fraction of soil porosity with larger diameter pores that drain at 60 cm soil water tension. This tension is equivalent to a negative soil water pressure of -58.84 hPa or a soil water potential of -5.88J/kg. NCP can also be referred to as gravitationally drainable porosity. Again by convention the arbitrary 60 cm soil water tension is assumed to be the tension reached by top soils in the field 2-3 days after saturating rain or irrigation and where gravitational drainage has occurred.

Available water pore space volume

Available water pore space volume (capacity), is the percentage pore volume between pore diameters corresponding to 60 and 15,000 cm tension, when saturated with water. The arbitrary 15,000 cm soil water tension (pF 4.2) (Negative pore water pressure -1.5Mpa approx ° 1.5MJ/kg approx soil water potential) is assumed to be the upper tension limit above which common plants will suffer severe wilting. In practice the "wilting point" is plant specific.

Saturation water content

Saturation water content is the water content when the total porosity is filled with water. Therefore both total porosity (%vol)and saturation water content (%vol) are numerically identical. Samples for saturation measurement are de-aired under partial vacuum. Water tension is taken to be zero and cannot be shown on the pF log scale, thus the broken x-axis

Analytical methodology for peat samples (Lynn *et al.*, 1974)

Sample preparation for the determination of the saturated sodium pyrophosphate extract colour and fibre is carried out as follows: A sample of peat is rolled in a paper towel to a cigar shape to remove excess moisture. The sample once rolled in the towel is removed and cut into 1-cm sections. These sections have an approximate bulk density of 0.18 to 0.3 g/cc and a moisture content (dry weight basis) of 300 and 500%.

Saturated Pyrophosphate Extract colour (SPEC)
A 5 ml sample of peat material is mixed in with a saturated solution of sodium pyrophosphate and left to stand overnight at room temperature. Next morning the mixture is thoroughly stirred and a 5-cm strip of chromatographic paper inserted vertically with tweezers and allowed to saturate with solution. The strip is removed, the soiled end cut off with scissors, blotted damp dry and colour comparison made with the Munsell Chart.

Fibre content -field methodology
The amount of fibre and its resistance to deformation is an important characteristic of organic soils. Fibre content is determined in the unrubbed and rubbed condition under field and laboratory conditions. In the field the estimation is based on examining a freshly broken peat face with a 10x hand lens and estimating the proportions of fibres present. To determine the rubbed state the peat sample is deformed in the hand by rubbing, then moulded into a ball and then cracked open and an estimation made of the proportions of fibres remaining. The accuracy of the field method is based on field experience and correlation with laboratory determinations.

Fibre content - laboratory methodology
The fibre content is determined by packing the peat sample into a 5 ml syringe adjusted to 2.5 ml by removing half of the barrel in a longitudinal section. When packing the syringe ensure that all excess air is driven out of the sample and the sample is just saturated without expressing any water. Once this stage is complete, the sample is transferred to a 100-mesh sieve and washed under tap water until the effluent is clear, the Excess water is removed and the syringe repacked to similar moisture content. The volume as unrubbed fibre is noted. The sample is removed and gently rubbed between the forefinger over the sieve and under running water until the effluent is clear. The syringe repacked to similar moisture content and the volume read as rubbed fibre.

Rubbed fibre contents of 20 and less and a (value-chroma) of 3 and less are classified as sapric rubbed fibre values of 20 - 80 and (value-chroma) between 3 and 6 are classed as hemic materials and rubbed fibre values >80 (value-chroma) of >5 are classified as fibric.

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