TOWARDS
SETTING ENVIRONMENTAL QUALITY OBJECTIVES FOR SOIL

DEVELOPING A SOIL PROTECTION STRATEGY FOR IRELAND

A DISCUSSION DOCUMENT

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A DISCUSSION DOCUMENT

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ISBN: 1-84095-092-7
Price: €13.00 08/02/500

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PREFACE

The Environmental Protection Agency is required under section 75 of the EPA Act, 1992 to specify and publish quality objectives in relation to any environmental medium which the Agency considers reasonable and desirable, for the purposes of environmental protection. Soil, air and water are generally seen as the three main environmental compartments which are essential to life on earth. The quality of air, water and also soil can be determined by comparing a particular property of the medium against a selected standard. The quality of water and air has been assessed for many years using standards such as those specified in EU legislation e.g. Water Framework Directive, Air Framework Directive, Dangerous Substances Directive etc. However, the wide variety of natural soil types and characteristics and range of possible functions and uses makes the development of a soil protection strategy which sets out clear objectives and standards more problematical than developing objectives and standards for other environmental medium such as air or water.

This discussion document assembles existing information on soil resources in Ireland and the pressures and impacts on soil resources. A key recommendation in the report is the need for the development of a soil protection strategy for Ireland, including the development of a national soil quality monitoring programme and the selection of a set of indicators which are representative of soil quality.

The EPA considers it important that this document be presented as a discussion document, so that the views and suggestions of as wide a range of opinions as possible can be canvassed, prior to finalising recommendations. It is therefore hoped that comment and opinion will be expressed by all those wishing to make an input, especially those with interests or responsibilities in the area of soil protection.

Comments on the document and suggestions in relation to the development of a soil protection strategy should be forwarded in writing to: Environmental Management and Planning Division, Environmental Protection Agency, Johnstown Castle Estate, Wexford by 31st August 2002.

1. INTRODUCTION

1.1 BACKGROUND

The Environmental Protection Agency is required under section 75 of the EPA Act, 1992 to specify and publish quality objectives in relation to any environmental medium which the Agency considers reasonable and desirable, for the purposes of environmental protection. The wide variety of natural soil types and characteristics and range of possible functions and uses to which soil can be put makes the specification of quality objectives for soils more challenging than the setting of quality objectives for other environmental media such as air or water. This discussion document is the first step in developing quality objectives for soil. Existing information on soil resources in Ireland is assembled and the pressures and impacts on soil resources are documented. A key recommendation made is the need for the development of a soil protection strategy for Ireland, including the development of a national soil quality monitoring programme and the selection of a set of indicators which are representative of soil quality.

1.2 SOIL

Soil is a biologically active complex mixture of weathered minerals, organic matter, organisms, air and water which provides the foundation for life in terrestrial ecosystems. Soil however, is not merely the sum of minerals, organic matter, water and air but a product of their interactions (Juma, 1999). It can be considered a non-renewable natural resource because it develops over very long timescales. A soil is distinguished from weathered parent material by the vertical differentiation it exhibits due to biological activity, so that the properties that are singled out in most systems of soil classification must be displayed in the soil profile (Wild, 1988).

Soil occurs and is formed in the pedosphere, the envelope where soils occur and soil forming processes are active. Soil only develops where there is a dynamic interaction between the air, water, living organisms and geology. It is these dynamic interactions which contribute to the multiple functions which soils perform. These include supporting plant life and life within the soil, biogeochemical cycling of elements, energy cycles, water storage and exchange and ecosystem productivity.

1.3 THE NEED FOR A SOIL PROTECTION STRATEGY

Recently, the issue of soil, soil degradation and the need for soil protection has been highlighted, particularly in Europe, with the issuing of a communication by the Commission of the European Communities entitled "*Towards a Thematic Strategy for Soil Protection*" (COM(2002) 179 final). Concerns over soil degradation in Europe have also been reported by the European Environment Agency. The Sixth Environment Action Programme of the European Community 2001-2010 identifies soil as a valuable natural resource which takes thousands of years to develop. It acknowledges that soil protection has not been a major policy for the European Union to date. Therefore one of the key objectives of the 6th EU Environment Action Programme is to protect soils against pollution and erosion and this will be achieved through the development of a strategy for soil protection.

The general consensus in Ireland is that soil quality is good overall. However, there is increasing pressure on soil particularly from land use changes, intensification of agriculture, erosion and overgrazing, disposal of organic wastes to soils, afforestation, industry and urbanisation. In addition, untimely or excessive applications of nutrients to soils, in particular phosphorus, has resulted in water quality deterioration, with agriculture reported as the most likely cause of pollution at 45 percent of slightly and moderately polluted river survey locations in Ireland (Lucey *et al*., 1999). This emphasises the important interactions and connectivity between all environmental media and the reason why soil protection should be considered on an equal footing with the protection of air and water in Ireland. The protection of soil quality may pose some unique difficulties e.g. most soil resources are in private ownership, soils perform multiple functions, soil quality monitoring is not undertaken and soil quality standards have not been developed. However, this should not be a deterrent to ensuring that soil quality is maintained or enhanced and protected for future generations.

1.4 AIM AND OBJECTIVE OF A SOIL PROTECTION STRATEGY

The aim of a soil protection strategy is to provide a framework within which soil quality is protected from degradation now and in the future. There is no universally accepted definition of soil quality. However, most definitions stress the importance of the biological, physical and chemical properties of a soil which, combined, enable soils to carry out essential functions. The Soil Science Society of America (SSSA) Ad Hoc committee on soil health proposed that soil quality be defined as " *the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation*" (Karlen *et al*., 1997). This broad definition recognises that the soil ecosystem has multiple roles in the environment and it also encompasses the notion of sustainability. Another definition of soil quality is provided by the Scottish Environment Protection Agency (SEPA) in its recent report on "State of the Environment: Soil Quality" which states "*soil quality refers to the status of a soil which will sustainably support its multiple functions*" (SEPA, 2001). For the purpose of this report soil quality refers to the status of a soil which will support its multiple properties and functions, within natural or managed ecosystem boundaries, in a sustainable manner.

In addition to protecting soil quality through the implementation of best management practices, a soil strategy must develop the mechanisms by which changes in soil quality can be measured and the effectiveness of remedial actions assessed. This requires the development of a **national soil quality monitoring programme** and the selection of a **set of indicators** which are representative of soil quality. A soil monitoring programme must be able to encompass the spatial heterogeneity of soils and their physical, chemical and biological properties. It should be dynamic and able to adapt to developments and changes in our understanding of soil dynamics over time.

2. SOIL QUALITY AND FUNCTIONS

2.1 INTRODUCTION

As stated previously, and for the purpose of this report, soil quality refers to the status of a soil which will support its multiple properties and functions, within natural or managed ecosystem boundaries, in a sustainable manner. Of the three environmental compartments, water, air and soil, the quality of soils is the most difficult to assess in a quantitative way. The quality of a soil is largely defined by the ability of a soils physical, biological and chemical properties to carry out specific or multiple functions. However, soil also has an importance and value in itself not necessarily defined by its managed applications (Doran *et al.*, 1997).

2.2 SOIL FUNCTIONS

Soils functions and uses can be divided into two main areas, ecological and socio-economic. Table 2.1 lists the main soil functions and uses.

TABLE 2.1 SOIL FUNCTIONS

Ecological functions		Socio-economic functions	
Biomass production	- Food production - Renewable energy - Raw materials	Physical medium	- support for built structures such as housing, infrastructure, factories etc. - waste disposal - recreation activities such as sport pitches etc.
Filtering, buffering and transforming action	- Cycling of major elements required by biological systems – C, N, P, S etc. - Regulate and partition water flow - Sorption reactions - Microbial and biochemical transformations	Source of raw material	- quarrying and mining activities supplying sand, gravel. Minerals etc. - supply of water
Biological habitat and gene reserve	- soil biomass – macrofauna, microfauna, and micro-organisms (bacteria, fungi, algae, actinomycetes and protoza) - supporting biological habitat for many plant and animal organisms - gene reserve	Protecting and preserving cultural heritage	- protects archaeological and palaeontological sites - contributes to the appearance of landscape

Blum & Santelises, 1994

Problems arise when developing and implementing soil protection policies because of competition among its concurrent uses. Figure 2.1 illustrates the competition between the six main soil functions and demonstrates the difficulty of developing and implementing a soil protection strategy which will protect soil properties and functions under various land uses (Blum and Santelises, 1994) . For example housing and infrastructure development excludes ecological functions such as biomass production, filtering, buffering and transformation.

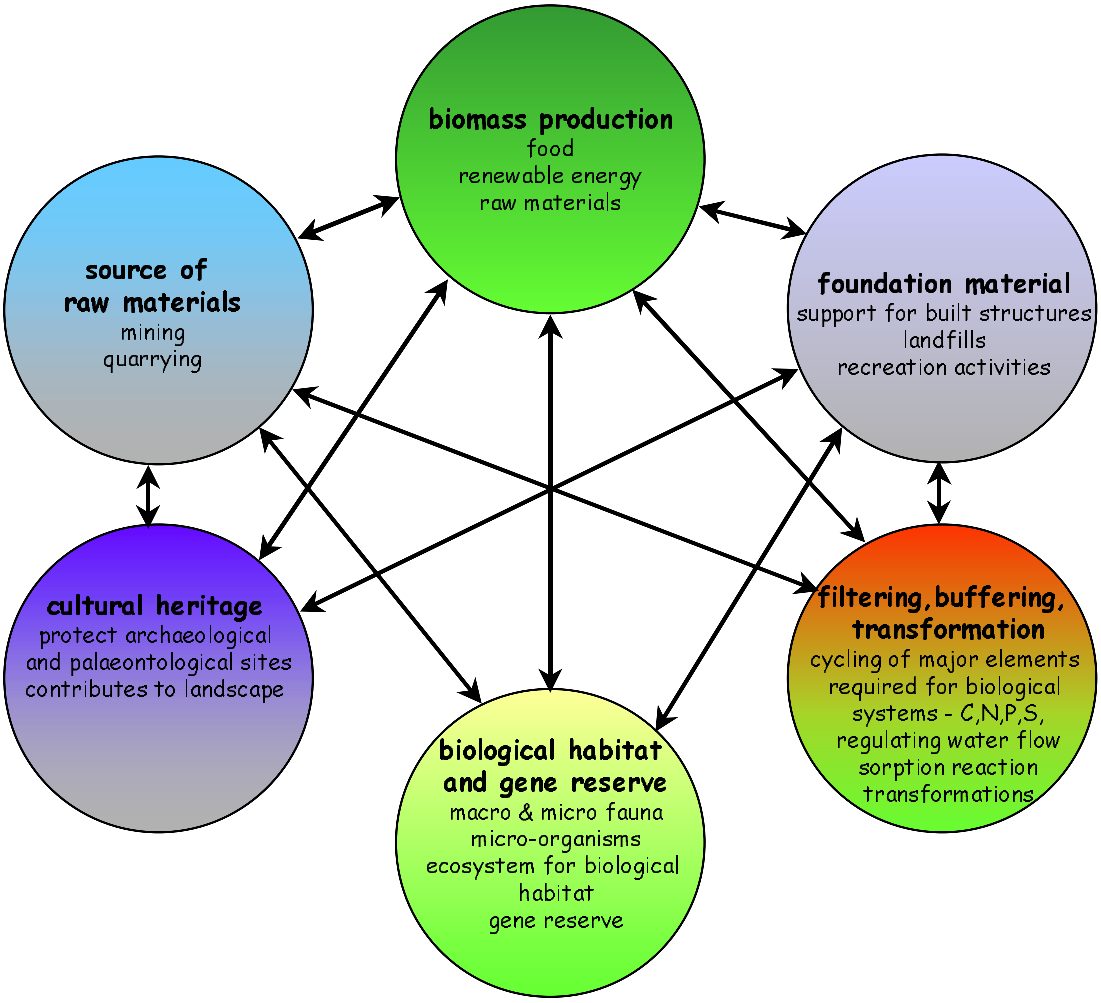


FIGURE 2.1 COMPETITION BETWEEN THE SIX MAIN SOIL FUNCTIONS

As well as safeguarding the potential uses and productive capacities of the soil, the soils intrinsic properties must be safeguarded. Micro-organisms such as bacteria, fungi, earthworms etc. are major agents by which energy, carbon and nutrients such as N, P and S move through soil. Essential parts of the global C, N, P and S and water cycles occur in soil and soil organic matter is a major terrestrial pool for C, N, P and S (Doran *et al.*, 1997). The diversity and activity of micro-organisms present in a soil are strongly influenced by the organic material and nutrients available and also by the soil temperature and moisture content. There are many other aspects to soil, but a recognition of its central importance as an environment facilitating the carbon cycle clarifies the distinction between a soil and a material from which a soil may form (Adams *et al.*, 1994). The land based part of the carbon cycle involves mainly the transformation of atmospheric carbon dioxide into plant material by photosynthesis and the eventual movement of plant and animal remains into the soil. Microbially induced transformations and oxidation return some of this carbon to the atmosphere as carbon dioxide. Soil functions therefore play an important role in controlling carbon dioxide emissions and global warming. It has been estimated, for instance, that the top 30 cm of a hectare of soil contains, on average, 25 tonnes of soil organisms (Blum, 1988).

Soil biomass is defined as the living part of the soil organic matter excluding plant roots and soil animals larger than the largest amoeba (Wild, 1988). Bacteria can be present in very large number, 10^7 to 10^9 bacteria per gram of soil are common numbers. The soil invertebrate fauna of temperate undisturbed habitats comprises several hundred species ranging in size from microscopic protozoa to large earthworms. The total soil faunal biomass can exceed $200 g/m^2$ under conditions which favour earthworms, while for example, land which is under cultivation for tillage crops, the biomass rarely exceeds $50g/m^2$. Larger invertebrates, particularly earthworms, have an important role in maintaining soil fertility through ingestion and reducing plant litter, soil mixing and aeration and the creation of channels which facilitate water and air movement. Smaller invertebrates such as Protozoa, Nematoda, Acari and Collembola play important roles in organic matter mineralisation and nutrient cycling (Strauch & Ballarina, 1991). Without the intermeshing vital processes of the bacteria, actinomycetes, fungi and algae (the microflora), the protozoa and nematode worms (the microfauna), and the collembola, mites and other associated meso-fauna, the soil would become a repository of dead plant remains with no facility for the recycling of vital nutrients such as carbon, nitrogen and phosphorus for plant growth (Wild, 1988).

Different soil types are suitable for a range of different uses depending on their properties. For example, some soils are capable of sustaining high annual yields of grass and cereals while other soils, although their production potential is low, sustain unique flora and habitats which are of national and international importance e.g. Special Areas of Conservation (SACs), Natura 2000, Biogenetic Reserves, Ramsar Convention on Wetlands etc. A soil protection strategy must therefore provide for the protection of soil types, their properties, functions and uses.

Pressures on soil arise as a result of natural processes and human activities. Changes in soil result from both natural processes and human activities which contribute to the dynamic and changing nature of soils. Where natural vegetation has been altered or changed and replaced as a result of human activity, soil continues to support agricultural crops, horticultural crops and forests. Such changes can threaten soil function if they result in the degradation of soils, impairment of ecologically essential soil processes, a reduction in the soils productive capacity or the depletion of soil quality and biodiversity (Gordon *et al.*, 1996). Soil is formed so slowly in nature that it can be considered essentially as a non-renewable resource (Stanners and Bordeau, 1995). Soil erosion is a natural process, it cannot be prevented but it can be reduced to a maximum acceptable rate or soil loss tolerance. Rates of soil erosion can be measured. However, rates of soil formation are so slow they cannot be easily determined. Rates of soil formation throughout the world have been estimated to range from 0.01 to 7.7mm/year with an average rate of 0.1mm/year (Morgan, 1995).

2.3 MAJOR AND TRACE ELEMENTS IN SOILS

Soil is an essential medium for plant growth and for the breakdown and recycling of organic matter. Soil performs this function by supporting plants structurally and supplying elements essential for plant growth. An element is essential to a plant if a deficiency of it makes it impossible for the plant to complete the vegetative or reproductive stages of its life-cycle, the deficiency is specific to the element in question and can be prevented or corrected by supplying this element and the element is directly involved in the nutrition of the plant. Essential elements are generally divided into major elements (or macronutrients) and trace elements (or micronutrients). Trace elements are as important as major elements but are required in lower quantities by plants. The major elements considered essential for plant growth are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium and sulphur. The trace elements are iron, manganese, zinc, boron, molybdenum, chlorine, cobalt, sodium and silicon (Wild, 1988).

In Ireland, the concentrations of elements in soil vary considerably, particularly the level of trace elements which are elements which occur in soils in very small concentrations. Data on the concentration of trace elements in Irish soils is relatively limited. The range in concentration of major and trace elements in non-polluted agricultural soils are given in Table 2.2 and Table 2.3. Higher concentrations may be encountered in the vicinity of ore deposits, in areas where abnormal soil conditions exist and close to industrial areas. Urban soils, including gardens, tend to have much higher levels of heavy metals than soils in rural locations.

TABLE 2.2 TYPICAL RANGE OF MAJOR ELEMENTS IN NON-POLLUTED AGRICULTURAL SOILS

Element	Symbol	Range (g/kg) (Total content)
Aluminium	Al	10 - 80
Calcium	Ca	5 - 30
Iron	Fe	10 - 50
Magnesium	Mg	1- 15
Nitrogen	N	1 - 4
Phosphorus	P	0.2- 2
Potassium	K	1 - 30
Silicon	Si	150 - 400
Sodium	Na	0.5 - 15
Sulphur	S	0.2 - 1.5

McGrath *et al*., 2001.

TABLE 2.3 TYPICAL RANGE OF TRACE ELEMENTS IN NON-POLLUTED AGRICULTURAL SOILS

Element	Symbol	Range (mg/kg) (Total content)
Antimony	Sb	0.2 - 3.0
Arsenic	As	1.0 – 50
Boron	B	20 - 1000
Cadmium	Cd	0.1 - 1
Chlorine	Cl	30 - 300
Chromium	Cr	5 - 250
Cobalt	Co	1 - 25
Copper	Cu	2 - 100
Fluorine	F	20 - 700
Iodine	I	2 - 20
Lead	Pb	2 - 80
Manganese	Mn	20 - 3000
Mercury	Hg	0.03 - 0.8
Molybdenum	Mo	0.2 - 3
Nickel	Ni	0.5 - 100
Selenium	Se	0.2 -2
Thallium	Tl	0.1 - 0.5
Tin	Sn	1 - 40
Uranium	U	1 - 10
Vanadium	V	20 - 250
Zinc	Zn	10 - 200

McGrath *et al*., 2001

3. SOIL RESOURCES IN IRELAND

3.1 INTRODUCTION

Soils vary considerably in their characteristics, depending on the kinds of rocks from which they were formed, the conditions under which they were formed and the length of time which has subsequently elapsed. Soils differ in depth, physical structure, water content, organic matter content and in their chemistry. These differences affect the fertility of the soil, its ability to retain and release substances, its influence on surface waters and groundwater chemistry and the kinds of flora and fauna it supports and contains.

A great variety of soils are found in Ireland and this diversity arises from many factors. The most important of these include:

- a complex geological history which results in a number of different geological strata or units over relatively short distances. However, the dominant rock type is Carboniferous limestone which is widespread in the midlands of the country. Soils which arise from this rock show a wide variety of properties;
- a maritime climate resulting from a warm North Atlantic drift and prevailing winds from the south-west. The mild climate with mean daily temperatures ranging from 4^{o}C in January to 16^{o}C in July/August and mean annual rainfall estimated at between 1,150mm and 1,200mm ensures that soils in Ireland are not affected to a large extent by extreme weather conditions such as freeze thaw action and severe drought;
- the development of soil requires a long time and the majority of soils in Ireland have been developing over the past 15,000 years since the end of the last Ice Age (Gardiner and Radford, 1980). Under natural conditions soils are continually being formed and eroded. In temperate regions the natural tendency of soil development is towards soil acidification and impoverishment and in general all crop production systems accelerate this process (Ball, 1975); and
- different plants interact in different ways with the soil therefore vegetative cover has the potential to affect soil quality and function.

3.2 SOURCES OF INFORMATION ON SOILS

There is no centralised amalgamation of information on soils, soil quality or soil fertility in Ireland, which makes the collection of relevant information difficult. Very little information is available in Ireland on the pressures and impacts of human activities on soil quality. Some of the main sources of information on soil in Ireland include:

1. Soil classification information: An Foras Talúntais undertook a national soil survey programme which commenced in 1959. To date 15 counties have been surveyed or partially surveyed. The soil survey includes information on soil type, land use potential based on identifying limitations for use and suitability for crop types. Information on trace elements is also given.

2. Soil fertility information: Nutrient and Trace Element status in grassland and tillage soils. Teagasc undertakes the analysis of farm soil samples submitted to their laboratory. Approximately 60,000 to 70,000 samples are analysed annually and advice is given in relation to major nutrients i.e. N, P, K and lime requirements and trace elements for both REPS and non-REPS farms.

3. Soil organic carbon content: Information on the organic carbon content is available from sampling and analysis of pasture and tillage soils undertaken by An Foras Talúntais in the 1960s and 1972. 678 samples were taken from pasture soils (Brogan, 1966) and 500 samples were taken from tillage soils (McGrath, 1972).

4. Soil contamination: Organic micro-pollutant and trace element pollution of Irish soils. Teagasc undertook a National Soil Geochemical Survey during the period 1995 to 1996 on a 10 x 10 km grid (McGrath, 1995). A total of 295 samples have been taken to date covering 22 percent of

land base of the Republic of Ireland. The soil samples were analysed for cadmium, chromium, copper, nickel, lead and zinc.

5. Forestry soil yield classification: Teagasc is currently undertaking a national soil survey to assign a yield class for different tree species for each soil type across the country and converting this to forest productivity map. This work on Irish forest soils is being undertaken as part of the Forest Inventory and Planning System (FIPS) and involves the mapping of parent materials and soils. Ten counties (including those partially surveyed by An Foras Talúntais i.e. Cork and Donegal) will be mapped under the FIPS Irish Forest Soils programme accounting for approximately 55 percent of the land area (Forest Service, 1999).

6. Geological Survey of Ireland: The GSI holds extensive information on the quaternary geology of Ireland and mine records database. This contains information in relation to trace element concentration particularly heavy metals in subsoils.

3.3 SOIL CLASSIFICATION IN IRELAND

A soil is distinguished from weathered parent material by the vertical differentiation it exhibits due to biological activity, so that the properties that are singled out in most systems of soil classification must be displayed in the soil profile (Wild, 1988). A soil profile is a vertical face of a soil pit and typically contains bands or layers that are visually different from adjacent horizons. These layers are generally known as soil horizons and occur approximately parallel to the land surface (Gardiner & Radford, 1980). Most soil profiles include three main horizons that are usually identified by the letter A, B and C. The combined A and B horizons constitute the solum or "true soil" whilst C refers to the parent material beneath. Certain soils lack a B horizon and are said to have AC profiles.

Three principal soil forming processes take place in Ireland; leaching; gleisation and calcification. These processes determine many of the soil characteristics and hence their classification (Gardiner & Radford, 1980).

1. Leaching process - soluble constituents are carried down through the soil profile and the soil becomes progressively more acid. Eventually relatively insoluble constituents such as iron, aluminium and humus are washed out (eluviated) from subsurface horizons to deeper horizons. Organic matter may accumulate on the surface and an iron pan may be formed at a lower level in the soil i.e. iron mineral become concentrated in a narrow, hard cemented layer. At this stage, the leaching process may be termed as podzolisation. Most free draining soils in Ireland are affected by this process and therefore require continuous renewal of nutrient and lime to maintain productivity levels.

2. Gleisation; is the soil forming process resulting from water-logging. This may be due to the presence of a high water table or to the impermeable nature of the soil itself. Water movement in the soil is greatly restricted and leaching is limited. As a result of anaerobic conditions in these soils, many soil constituents are converted to their reduced forms resulting in the soils taking on a blue-grey appearance with ochreous mottling the result of reoxidation processes.

3. Calcification is a process resulting in the redistribution of calcium carbonate in the soil profile without complete removal of it. The soils which are affected in this way are located in regions of low rainfall, 750mm of less. Since the rainfall is low the removal of calcium carbonate is prevented. This usually results in the accumulation of carbonate at some point in the profile below the surface. The calcium also tends to keep the fine clay in a granular condition thereby restricting downward movement of the clay. Plants requiring high amounts of bases bring these to the surface and replenish losses of leaching. Although climatic conditions are not dry enough for the calcification process to take place to any great extent in Ireland, this process is an important process in soils classified as Rendzinas and Brown Earths of high base status.

The soils of Ireland have been classified into ten main Great Soil Groups as illustrated in Figure 3.1. The nature of the profile is important in many aspects of soil function and is the basic unit in assessing the true character of the soil. The soil profile usually displays a succession of layers that may differ in properties such as texture, structure, consistency, porosity, chemical constituents, organic matter and biological composition.

Great Groups are soils having the same kind, arrangement and degree of expression of horizons in the soil profile (Gardiner & Radford, 1980). They also have similar soil moisture and temperature regimes and base status.

The ten main Great Soil Groups in Ireland are:

- Podzols - through the leaching process iron and aluminium are removed in solution from the surface horizons as conditions become sufficiently more acidic. Podzols are generally poor acidic soils with high lime and fertiliser requirements. They are usually formed in hill and mountain areas and are often forested. Peaty podzols have an organic surface horizon containing from 20 to 50 percent organic matter.

- Brown Podzolics – are somewhat similar to podzols and have formed under the influence of the podzolisation process. They are less depleted than the podzols and have a good mix of mineral and organic matter in the surface layer. Iron pans have not developed. They generally have a low inherent nutrient status and display good physical characteristics. They are usually devoted to cropping and pasture production.

- Grey Brown Podzolics – are usually formed from a calcareous parent material which counter the effects of leaching. This restricts the podzolisation process. Grey Brown Podzolics are good all purpose soils.

- Brown Earths – are relatively mature well drained mineral soils processing a uniform soil horizon. These soils have not been extensively leached however, some leaching of soluble elements such as calcium and magnesium has occurred. Most Brown Earths occur on lime deficient parent materials and are therefore acid in nature i.e. Acid Brown Earths. Brown Earths can also occur on more lime-rich materials. Brown Earths possess medium soil texture and have good structure and drainage characteristics and are extensively cultivated. They have relatively low nutrient status.

- Gleys – are soils in which the effects of drainage impedance dominate and which have developed under the influence of permanent or intermittent waterlogging. Waterlogging may be due to a high water table giving groundwater gleys, a perched water table due to impervious nature of the soils giving a surface water gley or from seepage or runoff from slopes. Most gleys have poor physical conditions and restricted growth seasons. Peaty gleys have organic horizons containing 20 to 50% organic matter on the surface and are found in wetter conditions.

- Rendzinas – are shallow soils not more than 50cm deep derived from parent material containing 40 percent carbonates. The surface horizon has a strong structure with a neutral or alkaline reaction. Use is often limited by shallowness.

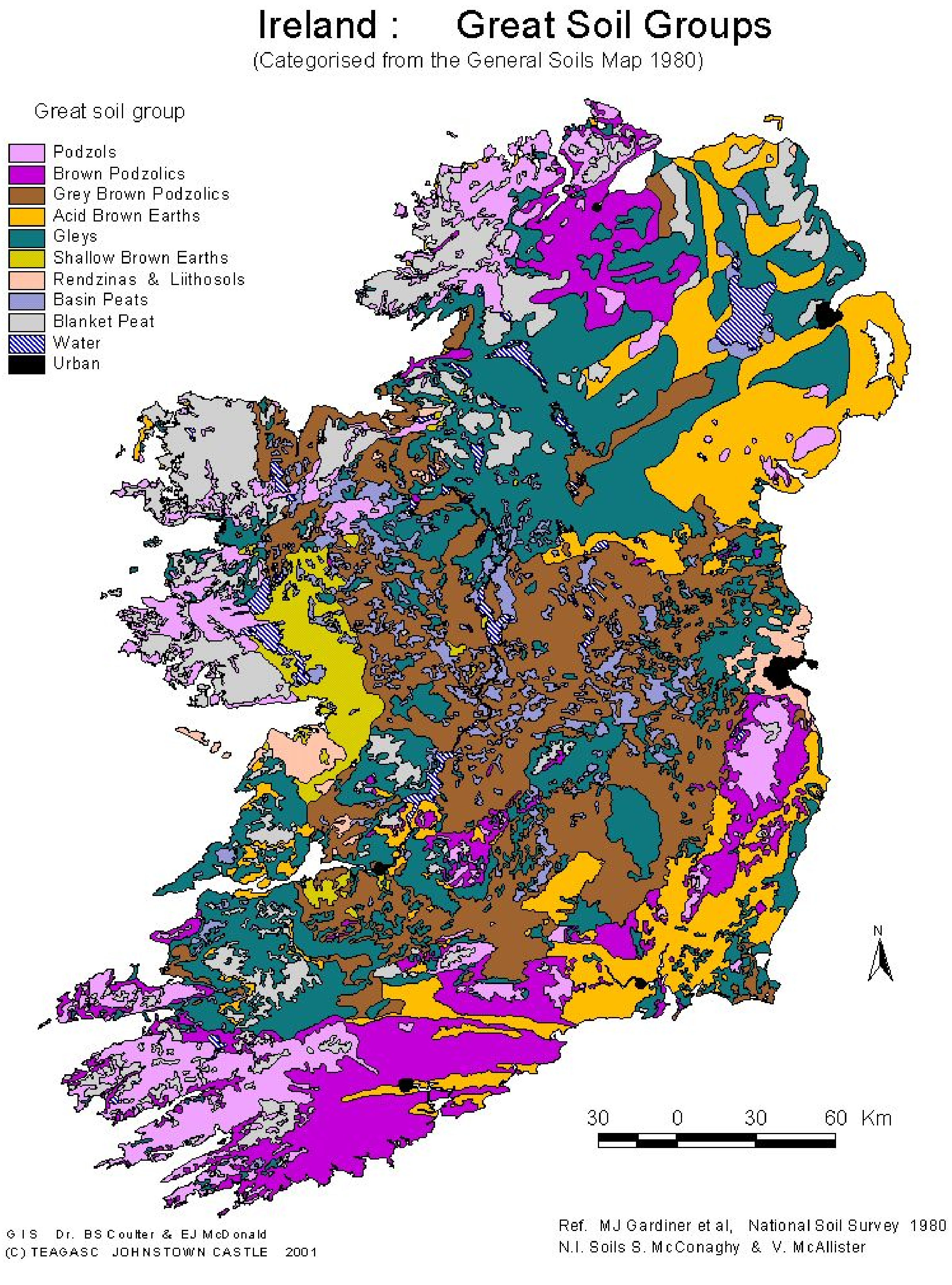
- Regosols – show no distinct horizon development and have the A horizon directly overlying the C horizon. The texture can vary between sand and clays depending on the material from which they are derived and they can be either acid or alkaline. They usually have a wide range or use but can often be subject to flooding.

- Lithosols – are skeletal stony soils, usually overlying solid or shattered bedrock. They often occur in association with podzols on higher ground. Bare rock outcroppings are common and many have steep slopes.

- Blanket Peats – Peats are characterised by having a high organic matter content, usually over 30 percent and are at least 30 cm deep. Blanket peat (or climatic peat) accumulates in areas of high rainfall and humidity predominately in the west and upper part of mountain ranges. Poor drainage and adverse physical conditions limit their agricultural use.

- Basin peats have formed in lake basins, hollows or river valleys or where the sub-soil is impermeable. Two types of basin peats are recognised, raised bogs and fen peats. Fen peats are formed under the influence of base rich groundwater. The agricultural use of basin peats can be increased following drainage and reclamation works.

FIGURE 3.1 GREAT SOIL GROUPS OF IRELAND



Below the Great Soil Group category, soils may be classified into 'series' and subsequently into 'phases'. The series is defined as a 'collection of soil individuals essentially uniform in differentiating characteristics and in arrangement of horizons' (Gardiner & Radford, 1980). A soil series is usually named after the area in which it is most widely distributed or in which it is best expressed e.g. Clonroche series in Wexford. Detailed maps show soil phases or series but more generalised maps may only be able to show associations of soils due to limitations of scale. The soil association is not a soil classification category but a mapping unit. It consists of two or more soils, usually formed from the same type of parent material, which are associated on the landscape in a particular pattern e.g. a well drained Brown Earth which occurs on the more favourable topographic positions and a poorly drained Gley soil occurring in the depression. There are 44 Soil Associations included in the legend of the soil map of Ireland and these are further grouped into five physiographic divisions (Gardiner & Radford, 1980). These physiographic divisions are listed in Table 3.1.

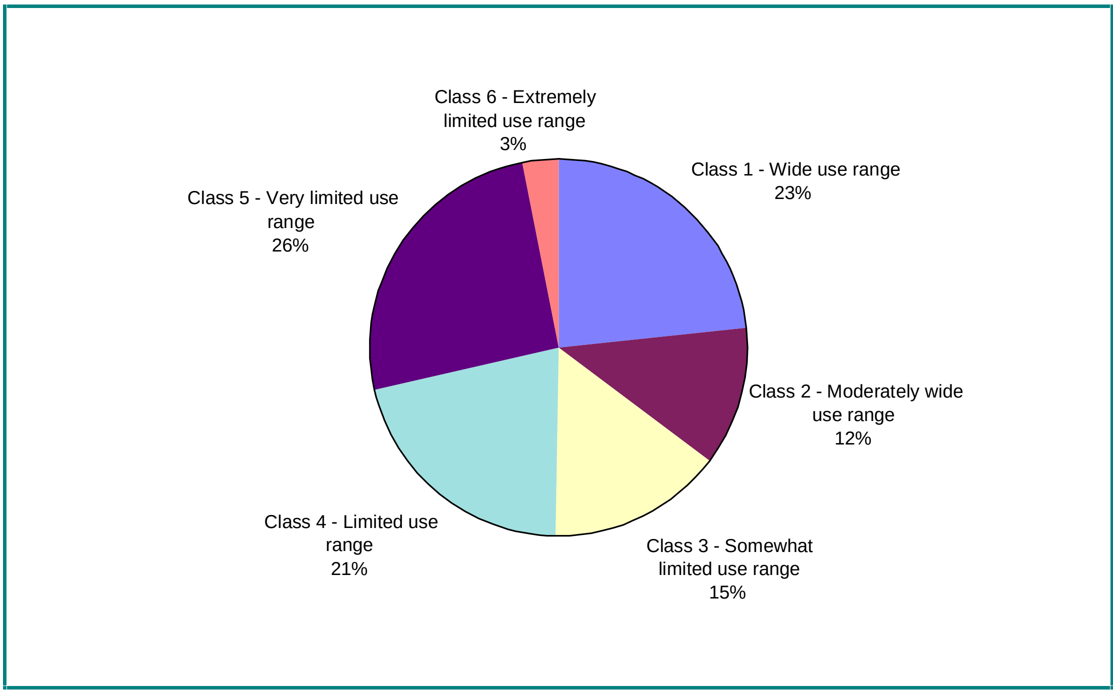
TABLE 3.1 PHYSIOGRAPHIC DIVISIONS AND EXTENT OF DIFFERENT SOILS

Physiographic Division	% Total Land Area
Mountain and Hill Soils	16
Hill Soils	6
Rolling Lowland	31
Drumlin Soils	11
Undulating Lowland Soils	36

Gardiner and Radford, 1980

3.4 AGRICULTURAL LAND USE

The information obtained from the Soil Map of Ireland has been used to determine a suitable range of uses for the various soil types. Land use range is a qualitative method by which the range of potential agricultural uses to which soils are suited are expressed. The range of classes vary from Class 1 which has a wide use range to Class 6 which has an extremely limited use range. The limitations imposed on use include slope, altitude, poor drainage, shallow soils and/or coarse texture. The percentages of each of the use range classes are illustrated in Figure 3.2.



Gardiner & Radford, 1980

FIGURE 3.2 POTENTIAL AGRICULTURAL LAND USE

3.5 LAND COVER AND LAND USE

The Republic of Ireland covers a surface area of approximately seven million hectares or 70,285 km^2. Lakes, rivers and tideways occupy an area of 140,000 ha representing two percent of the surface area. The principal sources of information on land cover and use in Ireland include Central Statistics Office, Department of Agriculture, Food and Rural Development (DAFRD), the Department of Marine and Natural Resources Forest Service, Dúchas, the Heritage Service and European Environment Agency CORINE Land Cover database.

3.5.1 CORINE LAND COVER

The European Environment Information and Observation Network (EIONET) was established by the European Environment Agency to provide consistent, reliable and comparable data across Europe. To obtain data on changing land cover in Europe the CORINE Land Cover database was established. The first CORINE land cover inventory was based on satellite imagery taken during 1989-1990. The CORINE land cover database was based on the allocation of land cover types to one of 44 standard pan-European land cover classes. It was recognised that the CORINE database underestimated land under forestry and that there are conceptual differences between land use and land cover. There is a proposal to update the CORINE Land Cover (Ireland) database using satellite imagery taken during 2000-2001. Figure 3.3 illustrates the percentage of land cover that is classified under the Level 1 nomenclature for CORINE Land Cover.

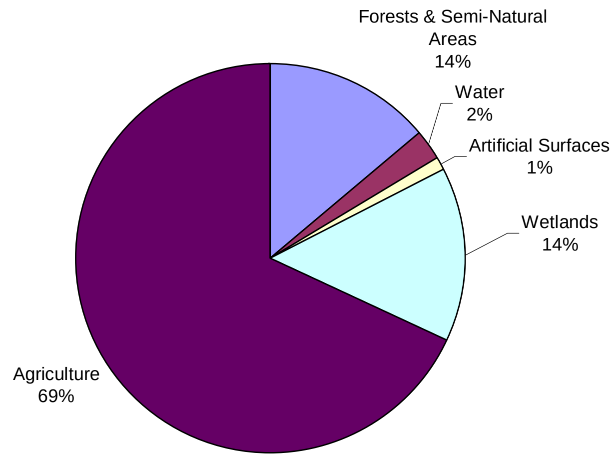


FIGURE 3.3 CORINE LAND COVER

3.5.2 AGRICULTURAL LAND USE

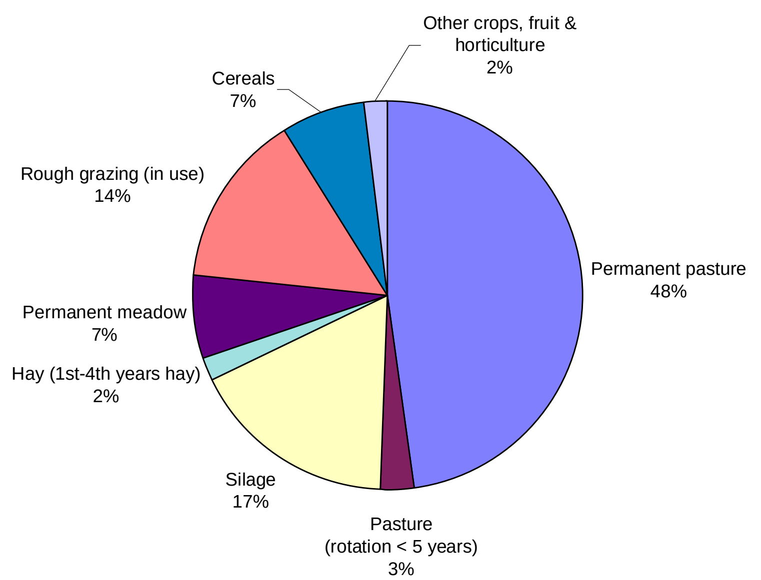
The 1991 Census of Agriculture provides the most recent detailed comprehensive information on land use in relation to agricultural production in Ireland. All farms where the agricultural area used was at least 1 hectare were covered in the 1991 Census. Censuses carried out since then have been based on a representative sample of 15,900 farms. The principal land use categories used in this survey were tillage (including all cereals, root and green crops, fruits and horticulture), silage, hay, pasture and rough grazing in use. The total area under all these categories combined is referred to as the agricultural area utilised (AAU) and amounted to over 4.4 million hectares or accounted for 64.4 percent of the land area (i.e. total land area in Ireland is approximately 6.8 million hectares). Table 3.2 shows the agricultural land use categories for 1991.

TABLE 3.2 AGRICULTURAL LAND USES 1991

Land Use	Hectares
Permanent pasture	2,118,804
Silage	764,651
Rough Grazing in Use	641,919
Permanent meadow	314,856
Cereals	301,524
Pasture (rotation <5 years)	130,631
Other crops, fruit & horticulture	90,166
Hay (1^{st} to 4^{th} years)	79,204
Total AAU	**4,441,755**

CSO, 1991

Commonage which refers to land on which two or more farmers have grazing rights amounts to 426,500 hectares and covers 6.2 percent of the surface area. This land is not included under the CSO definition of AAU. Commonage tends to be located mostly in upland areas where factors such as poor drainage, steep slopes and high altitude restrict agricultural potential. Grassland accounts for over 91% of the agricultural area utilised. The importance of grassland in Ireland stems from the favourable climatic conditions which allows for a prolonged grass growing season, soil limitation factors and the traditional importance of livestock production to the economy (Lafferty *et al.*, 1999). Figure 3.4 illustrates the percentage of land in the various land use categories.



CSO, 1991

FIGURE 3.4 AGRICULTURAL LAND USE 1991

As agriculture occupies over two thirds of the land area a breakdown of the types of crops produced and the numbers of livestock reared on Irish soils will give an indication of the current use of Irish soils and the likely pressures and impacts on soils from various agricultural activities. Over 90% of the area farmed in Ireland is under grassland with 68% being under permanent grassland or rough grazing. Soils under permanent grassland are generally less prone to erosion and have generally higher levels of organic matter, which promotes good soil structure.

The Department of Agriculture, Food and Rural Development has developed the Land Parcel Identification System (LPIS) to provide a numeric identification system for all agricultural parcels which are the subject of an Area Aid application, as required under EU legislation. Approximately 80% of total agricultural land is covered under LPIS.

3.5.3 FORESTRY LAND USE

Mixed woodlands were once a natural feature of Ireland and the decline in the natural forest cover was a slow process that started with small scale clearing. As agriculture developed, large areas of woodland were burnt and cut down to provide land for grazing and crops. By the turn of the nineteenth century forest covered just one percent of the land area.

Ireland's forest area now comprises approximately 634,117 hectares or 9.2% (figures for 1999) of the total land area. Most of this forest has been established since 1950, with significant increases in the rate of planting in the private sector since 1989. Forestry has been recognised by the European Union as having a major role to play both in the reform of the Common Agricultural Policy (CAP) and in the wider context of rural development. Forest cover as a percentage of total land area is increasing at a rate of a third of one percent every year and is probably the most significant changing land use.

The Afforestation Grant and Forest Premium Schemes, introduced under Council Regulation 2080/92, are part of the accompanying measures to CAP reform, support the afforestation of agricultural land. These schemes aim to increase forest cover in Ireland to 17 percent by 2030 (or 1.2 million hectares), an objective which will require the annual planting of 20,000 hectares from 2001 to 2030. These are financed by the CAP Reform Accompanying Measures and are administered by the Department of Marine and Natural Resources through the Forest Service. These schemes aim to reduce agricultural surpluses, provide more varied sources of income for farmers and develop rural economies. Levels of grant aid vary with the types of land being afforested and the species of trees. Virtually no afforestation is undertaken without grant and premium support.

Traditionally forestry was restricted to low productivity acid soils not suitable to agriculture. However, under the current Afforestation Grant Scheme and Forestry Premium Scheme, better quality land and soils are being planted. In addition greater emphasis is being placed on multi-purpose use i.e. nature conservation and habitat protection, natural regeneration, recreation and educational opportunities, provision of employment opportunities in rural areas, providing alternative landuse etc. Current policy focuses on farm forestry, which is now the largest single component of the forestry programme.

The Forest Service, Department of Marine and Natural Resources has recently developed a new national forest inventory called Forestry Inventory and Planning System (FIPS). The first national forest inventory was completed for 1998. This inventory will be supplemented with additional information obtained through the current financial schemes i.e. Afforestation Grant Scheme and Forestry Premium Scheme. It is expected that a full update will be undertaken at five yearly intervals. FIPS records all forest parcel areas greater than 0.2 hectares in size and splits them into twenty categories based on species makeup. Of the total land area under forestry in 1999 i.e. 634,117 hectares, 62 percent is state owned with the remaining 38 percent in private ownership. Figure 3.5 gives a breakdown of the species composition of the national forest cover for 1999 (Forest Service 1999). The predominant trees used in afforestation are conifer trees particularly Sitka spruce. Approximately 85 percent of the current forest cover is conifer with the remaining 15 percent made up of mixed broadleaves, if the categories 'mixed forest' and 'cleared' are equally apportioned between broadleaves and conifers. 'Mixed forest' is used as a category to describe forest areas where there is less than 80 percent broadleaves or conifers in the stand. 'Cleared' includes recent reforestation and afforestation.

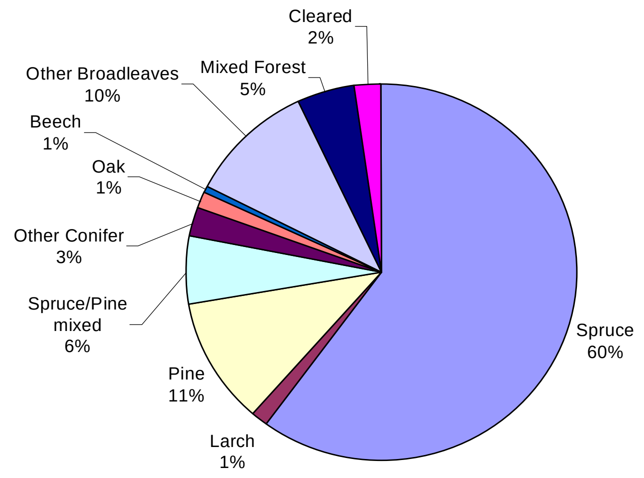


FIGURE 3.5 SPECIES COMPOSITION OF NATIONAL FOREST COVER, 1999

In 1999, approximately 12,700 hectares of land were afforested of which over 93% is under private ownership. Full time and part time farmers accounted for 85 percent of 12,700 hectares afforested in 1999.

3.5.4 PROTECTED AREAS OF LAND

Ireland has a rich geological heritage and owes much of its natural distinctiveness to this unique geology. The Quaternary era, with its glaciations and post-glacial stages, has most shaped the present landscape and its flora and fauna. Under EU and national legislation, many habitats are given protection e.g. European Communities (Natural Habitats) Regulations, 1997 and the Wildlife Acts 1976 and 2000. The Department of Arts, Heritage, Gaeltacht and the Islands (DADGI) distinguish two categories of protected area in Ireland:

- One comprising sites set aside primarily for nature conservation, which are generally unpopulated with no significant economic activities e.g. National Parks and Nature Reserves; and
- A much larger category of sites which are designated at a national level i.e. Natural Heritage Areas (NHAs) and a European level i.e. Special Protection Areas (SPAs)/Special Areas of Conservation (SACs). These areas are designated for their biodiversity importance but where sustainable economic activities also take place.

In recent years progress has been made in establishing, or proposing for designation, a range of protected areas (i.e. NHAs, SPAs and SACs) for biodiversity. Approximately 1,100 sites of national ecological or geological importance have been proposed by Dúchas for designation as NHAs. NHAs will provide the base area upon which all other designations may be superimposed. The Wildlife (Amendment) Act 2000 which came into force in July 2001 now provides statutory protection for NHAs (Clenaghan *et al.*, 2000). The categories of protected areas are listed in Table 3.3.

TABLE 3.3 SURFACE AREA DESIGNATED FOR CONSERVATION

Category	Objectives	Area Covered (ha)	Number of sites
Nature reserves	Conservation of flora, fauna and habitats	18,095	78
Special protection areas (SPAs)	Conservation of bird species and habitats of European importance	230,000	109
Special areas of conservation (SACs)	Conservation flora, fauna and habitats of European importance	~650,000	400
Natural Heritage Areas (NHAs)	Protection of flora, fauna, habitats and geological sites of national importance	~750,000	1,100+
National Parks	Nature conservation and public use and appreciation	56,987	6

4. PRESSURES AND IMPACTS ON SOIL RESOURCES

4.1 INTRODUCTION

Changes in soils result from both natural processes and human activities which contribute to their dynamic and evolving nature (Gordon *et al*., 1996). Such changes are matters of concern if they result in the physical, biological or chemical degradation of soils. This can result in the impairment of ecologically essential soil processes, the reduction in productive capacity, the depletion of soil quality and biodiversity and the direct loss of soil. Many of the changes arise as a result of pressures from human activities which can affect the physical, biological and chemical components of soils.

The main pressures on soil resources in Ireland arise from the following sectors:

- intensive agriculture and organic waste disposal;
- forestry;
- industry;
- peat extraction; and
- urbanisation and infrastructure development.

These activities can lead to soil degradation including loss of organic matter, decline in soil fertility, acidification, loss of soil stability, increasing soil erosion, soil compaction, contamination, loss of biodiversity and loss of soil to buildings and infrastructure. Many of these activities which affect soil functions also have the potential to cause deleterious effects on air and water environments.

4.2 AGRICULTURE

Agriculture is the primary land use in Ireland accounting for approximately 4.9 million hectares (including upland pasture and commonage areas) out of a total land area of 6.9 million hectares. Grassland (pasture, hay and silage) accounts for 70 percent of land use or over 91 percent of the agricultural area utilised (AAU). Of the 91 percent of the AAU under grass over 75 percent is under permanent grass i.e. permanent pasture, permanent meadow and rough grazing in use (CSO, 1991).

Trends since 1970 show that while the area under grass has remained more or less unchanged, the proportion of arable land has decreased and the area under forestry has increased (DoE, 1997). Major changes have taken place since 1973 when Ireland joined the EEC under the influence of the Common Agricultural Policy (CAP). Animal and crop production systems have intensified under CAP. This intensification has resulted in increased volumes of slurry, a switch from hay based systems to silage based systems and increases in the use of chemical fertilisers and pesticides.

Agricultural land-use activities that have the potential to cause soil quality degradation and impact on the water and air environments include:

- poor fertiliser management on farm including application of excessive nutrients, inadequate storage and inappropriate timing of nutrient applications e.g. applying nutrient to frozen or water saturated soils or during non-growing season and inadequate storage. Poor nutrient management results in the loss of nutrients from soil to water which causes eutrophication of streams and rivers;

- high stocking densities leading to overgrazing and soil erosion particularly on vulnerable soil types e.g. blanket peats;

- poaching and soil compaction resulting from extension of grazing season and trafficking when soils are near saturation. This can also result in water quality deterioration;

- disposal of non-farm produced organic wastes such as sewage sludge and wastes from animal, food and drink processing industries. These wastes have the potential to cause soil and water quality deterioration.

- more frequent ploughing of permanent grassland and semi-natural grasslands resulting in loss of organic matter and mineralisation of nitrogen which has the potential to impact on water quality and release of CO_2 to the atmosphere; and

- increased soil erosion under modern intensive arable production systems.

4.2.1 APPLICATION OF AGRICULTURAL ORGANIC WASTES TO SOIL

The essence of good nutrient management planning and fertiliser use is to ensure that the necessary quantities of the essential crop nutrients are available when required for uptake by crop, and that losses to the environment are prevented or minimised (MAFF, 2000). Where good agronomic practice is not implemented, and where the storage and application of organic fertilisers is poor, these practices can lead to significant negative impacts on the environment. These negative impacts include; the leaching of nitrate from soil to groundwater; surface loss or runoff of soluble phosphorus in soils or organic manures or movement of P enriched clay to drainage channels; and losses of ammonia or nitrogen oxides from chemical or organic fertilisers to the atmosphere (Coulter, 2001).

The EPA estimate that a total of 132 million tonnes of organic wastes was applied to agricultural land in 1998, of which 130.7 million tonnes arose from agriculture and 1.3 million from agri-industry and sewage sludge (Brogan *et al.*, 2001). Approximately 63.2 million tonnes of agricultural wastes i.e. animal slurry, farmyard manure, effluent etc. are collected annually from the various farm enterprises and require subsequent management (i.e. collection, storage and application to land) with the remaining 67.5 million tonnes deposited directly by grazing animals.

The EPA calculated a national phosphorus balance for agriculture based on figures for 1998. These calculations indicate that there was a surplus of between 11 to 14 kgs of P applied to every hectare farmed in 1998 if the surplus is spread uniformly across the AAU. This indicates that nutrients are being applied in excess of crop requirement. The disposal of organic wastes to land has the potential to impact on soil, water and air quality (Carton and Magette, 1998).

The impact of animal wastes on soil biomass can be both positive or negative depending on rate and frequency of application. Soil decomposers are often food limited, and animal wastes can have direct stimulatory effect by increasing food supply. However, heavy applications of semi-liquid slurry can adversely affect the soil community, such effects being oxygen depletion, high levels of ammonia and soluble salts, and various organic decomposition products.

Table 4.1 lists benefits and potential negative impacts arising from the landspreading of slurry and wastes generated by agriculture.

TABLE 4.1 THE BENEFITS AND POTENTIAL NEGATIVE IMPACTS OF LANDSPREADING SLURRIES AND WASTES ARISING FROM AGRICULTURE

Type	Benefits	Negative impacts on soils	Other negative impacts
Cattle and sheep slurry	• supply of N, P, K • supply of organic matter	▪ high application rates can cause surface caking ▪ applying under wet soil conditions causes soil smearing and compaction	- untimely and/or excessive applications to soil can cause runoff and eutrophication of watercourses - high BOD (17,000 mg/litre) causes deoxygenation of water - odour problems - NH_3 emissions contributing to acidification and eutrophication - potential spread of pathogens such as cryptosporidium, salmonella, campylobacter, *E.coli*
Pig and Poultry	• supply of N, P,K • supply of organic matter	▪ high application rates can cause surface caking ▪ applying under wet soil conditions causes soil smearing and compaction	- untimely and/or excessive applications can cause runoff and eutrophication of watercourses - high BOD (25,000 to 35,000 mg/litre) causes deoxygenation of water - possible contamination of water supplies by pathogens - disease implications (*Salmonella*) as slurry usually not spread on the producing farm - odour problems
Silage effluent	• low nutrient content	▪ acidic and can cause scorching of vegetation	- high BOD (65,000 mg/litre) causes deoxygenation of water courses - fish kills
Spent mushroom compost	• supply of N, P and K and organic matter to soils	▪ potential high salt content leading to increases in soil electrical conductivity which can reduce the availability of soil water for plant uptake ▪ pesticide residues e.g. diazinon, lindane - a persistent organo-chlorine insecticide	- water quality problems arise due to poor disposal practices - BOD, nutrient content and pesticide residues
Dirty waters	• low nutrient content	▪ Large volumes generated on farm all year around. Often applied during unfavourable weather conditions causing water logging of soils ▪ Anaerobic soil conditions	- water quality problems arise where applied under unfavourable weather and soil conditions due to BOD, N and P content - soak-away pits potential for direct discharge to groundwater
Spent sheep dip	• none	▪ potential effects on soil organisms due to toxic effects	- sheep dips are very toxic to river life particularly synthetic pyrethroids (SP). SP formulations are about 100 times more toxic to aquatic insects than

			organophosphate (OP) formulations

4.2.2 SOIL DEGRADATION ARISING FROM AGRICULTURAL ACTIVITIES

Irreversible or only slowly reversible physical damage to soils is defined as soil degradation (MAFF, 1998). Soil compaction, soil erosion by wind or water, deep cultivation and mixing of soil and loss of topsoil are all forms of soil degradation which cause physical damage and loss of soil.

Compaction in soil occurs as a result of loads being applied to the soil surface, particularly during unfavourable weather and soil conditions e.g. grazing animals or using agricultural and other machinery when soils are too wet, high stocking rates in wet weather, out-wintering particularly around feeding areas, extended grazing seasons, strip grazing etc. Soil porosity and permeability are reduced, soil strength increases and many changes to soil properties and functions are induced (Soane and van Ouwerkerk, 1998). Soil compaction caused by machinery or livestock restricts root growth and reduces infiltration of water into and through the soil profile. This in turn can lead to an increase in run-off from soils, flooding and transfer of nutrients to surface waters. As air is restricted in the soil this interferes with biological activity and root growth which affects nutrient cycling in the soil and nutrient and water uptake by plants.

Soil erosion is a two phase process consisting of the detachment of individual particles from the soil mass and their transport by erosive agents such as running water and wind (Morgan, 1995). Plants generally protect the soil against erosion but significant problems can occur on soils used for grazing animals and tillage. The risk of soil erosion is also increased where levels of organic matter in mineral soils are low. The practice of burning vegetation on hill and mountain areas to encourage regrowth of vegetation increases the risk of soil erosion particularly on steep slopes in exposed areas.

Increases in sheep numbers grazing on the upland peatlands particularly in the West and North West of Ireland has lead to overgrazing of natural vegetation making these soils more susceptible to erosion. Soil erosion from blanket peats in upland areas which experience high rainfall (c. 2,500mm/annum) and windy conditions is a natural phenomenon. However, the rate of erosion is exacerbated by overgrazing of the natural vegetation leading to increased risk of soil erosion. The amount of soil loss in tonnes/ha/yr has not been quantified in detail, however, some research undertaken in Ireland would indicate soil losses ranging from 0.37 mm average annual loss to 2.628 mm of peat over the sub-catchment used in the research (Walsh *et al.*, 2000). Where severe overgrazing has occurred, the natural blanket peat has totally eroded exposing the underlying geological material.

There is now considerable evidence to show that the susceptibility of soils to erosion has increased under the modern system of high-powered farming techniques (Conry, 1997). The techniques which are contributing to increases in soil erosion include: ditch removal and field enlargement; increased use of high powered traction systems which tend to plough up and down slopes rather than across; increased use of tramlines; reduction in use of manures and green manuring; and the reclamation of upland areas.

Under arable cropping, soil erosion can occur at any stage of crop growth or any time of the year, provided the conditions suitable for erosion are present. These include: lack of ground cover vegetation; loose fluffy and very fine seed bed conditions; intense rainfall over short periods accompanied by high winds; steep slopes and excessive runoff from higher ground (Conry, 1997). Where deep cultivations are undertaken this can also result in the loss of topsoil through mixing with subsoil particularly on soils with shallow topsoils.

4.2.3 PESTICIDE USE AND DISPOSAL

Pesticides used in agriculture include insecticides, molluscicides, fungicides, herbicides, growth regulators and seed treatments which are manufactured from a wide range of chemicals. These chemical have the potential to impact on soil and water environments. Concerns have been raised that repeated applications of pesticides to soil may result in their accumulation in soil. Pesticides may

also affect non-target species directly and predators indirectly by damaging their food supply (SEPA, 2001).
Many soil micro-organisms have the ability to degrade complex chemical compounds including pesticides however, there have been few studies into the long-term effects of pesticides on soil quality. One long-term study showed that repeated pesticide applications were either rapidly degraded in the soil or were bound to soil organic matter and made biologically inactive. There is very little information available in Ireland on the level of pesticide residues in soils and their impact on soil quality. The National Waste Database Report estimates that 19,000 tonnes of spent sheep dip was generated in 1998 which is disposed by landspreading (EPA, 2000).

The active ingredients in sheep dip include either organophosphorus compounds or synthetic pyrethroids. Organophosphorus compounds (OPs) are harmful to human health and are toxic to the aquatic environment. Synthetic pyrethroids are extremely toxic to the aquatic environment and it has been estimated that these are about 100 times more toxic than OPs. Sheep dip chemicals are not readily leached from soils. Soil properties, which are important in determining their ability to adsorb sheep dip chemicals include, soil texture, pH and drainage characteristics. In relation to the protection of groundwater, depth of subsoil and presence of preferential flowpaths are also important. The impacts of OPs compounds on soils are not well know. However, a recent review undertaken on behalf of SEPA, suggests that due to their rapid breakdown and low availability, impacts on microbial processes and on the microbial community are unlikely in the short-term (SEPA, 2001).

4.3 FORESTRY

Under a cool temperate west maritime climate in Ireland, the natural tendency in soil development is towards soil acidification. Soils which are under forestry and which are currently being afforested reflect a legacy of human interference and changing climatic conditions over centuries, with some upland areas suffering significant degradation as a result of this interference (Farrell, 1997). With the current forest policy proposal to increase the current land cover under forest from 8 % in 1995 to 17% by the year 2030 an understanding of the potential impacts, both beneficial and adverse is necessary. Forestry has the potential to cause negative environmental impacts on soil and water throughout its life cycle from afforestation through to harvesting and replanting.

4.3.1 QUANTIFYING IMPACTS OF PLANTATION FORESTRY ON SOILS

Most of today's plantation forests in Ireland were established to meet the primary objective of timber production. Management systems and grant schemes were developed to meet this objective neglecting, in many circumstances, wider environmental issues such as soil and water quality protection. It is important to emphasise that forestry, like agriculture, is an economic activity and that plantation forests are artificial ecosystems established for the purpose of supplying timber, which also have the potential to supply a range of beneficial uses such as habitat conservation, amenity, biological diversity etc.

Soil type and location are important factors in determining what land is afforested and the trees species that are planted. Historically, plantation forestry occurred on peaty podzols, podzols and blanket peats. Over 40 % of plantation forestry in Ireland occur on peatlands. The development of peatlands for forestry begins a process of peat subsidence and oxidation, which immediately threatens the integrity of the peat soil (Farrell *et al.*, 1996). Thin acid soils which are afforested are poorly buffered and cannot ameliorate against the effects of organic matter and nutrient loss during harvest and the influence of acidifying processes which take place over time. In the past ten years there has been a move away from the planting on peaty podzols, podzols and blanket peats to more fertile soils. This change has occurred as a result of the realisation that these soil types were not capable of producing commercial crops. However, it is important to remember that the impact of conifer plantations on soils will vary with soil type, site location and crop species. Two of the most significant impacts arising as a result of forestry practices on soil are acidification and erosion. Table 4.2 lists some of the impacts/potential impacts on soils and water arising during a plantation forest rotation cycle.

4.3.2 SOIL ACIDIFICATION

Soil acidification is a natural process and all crop production accelerates this process however, the acidifying effects of agricultural crops can be corrected by lime applications. The soil acidification process is accelerated as a result of anthropogenic activities including the production of atmospheric pollutants, sulphur dioxide (SO_2) and nitrogen oxides (NO_x) arising from fossil fuel combustion. The tree canopy is a much more efficient collector of particulate and aerosol material from the atmosphere than low lying grass or heathers. Conifer tress in upland areas seem to be very efficient at capturing aerosols in occult precipitation i.e. mist, fog and cloud. This occult precipitation has higher concentration of pollutants and non-pollutants than rain or snow (Hornung *et al.*, 1987). Anthropogenic acidification occurs where the atmospheric deposition of strong acid anions, sulphate and nitrate exceeds the buffering capacity of the soil. It is generally the weakly acid or neutral soils which are more prone to acidification because they have low reserves of weatherable minerals which can offset acid inputs (Trudgill, 1988).

Plantation forestry in upland catchment areas alters natural recycling processes and this can result in an increase in the rate of acidification of the soils and vegetation. Biomass storage tends to decrease as an ecosystem matures. In a young stand of trees the growth rates are higher hence the nutrient uptake is greater. As the trees mature this uptake of nutrients slows down. The forestry rotation cycle causes continual disturbance of the ecosystem involving biomass harvesting and replanting with young vigorous trees. This will ultimately lead to soil impoverishment. The method of harvesting will also determine the quantity of cations removed i.e. total tree removal or partial with branches remaining in-situ or used to aid extraction and haulage. Drainage may also cause increased rates of acidification. The disturbance caused to soils by drainage may result in increased organic matter decomposition particularly in peaty soils and blanket peats. Drainage of peats and peaty soils results in the oxidation of acid minerals, which can form acids in solution.

4.3.3 SOIL EROSION

Soil erosion is also a natural process. However, accelerated rates of erosion can result from plantation forestry particularly at establishment and during harvesting and replanting. The construction of forest roads can contribute significantly to soil erosion particularly where planting has occurred on steep slopes and in forestry establishment and management practices.

Plantation forestry has the potential to cause soil erosion and soil compaction. Site preparation, tree planting, thinning, clearfelling and replanting have the potential to cause soil degradation. The operations most likely to cause soil erosion and compaction include drainage and ploughing, road construction, harvesting and replanting. Afforestation in upland areas has a pronounced effect on the timing and quantity of runoff, with peak discharges increasing and the duration of storm hydrographs shortening which results in increased soil erosion (Gee and Stoner, 1988). Three to four fold increases in sediment loadings as a result of afforestation appear to be common in established uplands forest in the UK (Soutar, 1989).

Before trees are planted the ground usually has to be ploughed and drained. The type of ploughing carried out depends on soil type and site location. Ploughing and drainage of afforestation sites involves mixing of topsoil and subsoil and thereby exposing soil to the atmosphere. This result in soils drying out and increase in soil loss through erosion. Soil properties and soil functions are altered as a result.

The method of harvesting, the machinery used and the construction of roadways contribute to soil erosion and compaction during felling. It is also difficult to distinguish between the impacts resulting from the harvesting operations and the removal of the tree canopy itself. The suppression of ground cover at canopy closure, results in a reduction in vegetation cover which is replaced by the formation of a leaf litter layer. The removal of the canopy at harvesting causes an increase in the quantity and intensity of precipitation reaching the forest floor. Some work carried out on the impacts of clearfelling in the USA showed that 15% of logged areas suffered deep soil disturbance as a result of tractor logging whereas cable logging produced the same degree of disturbance on only 1.9% of the area (Van Hook *et al.*, 1982). Other studies have indicated that soil losses are greater for clearfelling than for selective felling. Losses would also be higher where total crop removal is practised i.e. removing all woody biomass from the harvested areas.

Clear -felling is the most widely practised method of harvesting undertaken in Ireland. Large blocks of forests are felled in a single coup due mainly as a consequence of the uniform age structure of plantation forests in Ireland and the risk of windthrow.

The Forestry Act, 1946 requires that forests which are felled must be replanted. The ground preparation required will depend on the harvesting method employed on the previous crop. The risk of soil erosion and compaction may be greater for replanting than afforestation as soils generally lack good ground cover under forestry, particularly conifers.

TABLE 4.2 IMPACT OF FORESTRY ON SOIL AND WATER RESOURCES

Stage in forestry cycle	Forestry practice and tree development	Impact on Soil	Other impacts
Establishment Years 0-5	▪ Ground preparations including drainage and cultivation and road construction	– soil erosion – increased organic matter decomposition – increased biological activity causing the formation of organic acids – soil compaction	· increased sedimentation in water courses · alter flow regime in water courses · increase nitrate leaching and phosphate runoff to watercourses · loss of indigenous vegetation
Mid-rotation Years 5-30	▪ Impacts of trees at canopy closure include acidification and water interception. ▪ Thinning operations, road and drainage maintenance.	– filtering of air pollutants by canopy resulting in increased rate of acidification of soils – conifer needles add to soil acidity – soil erosion during construction of roads and rides – loss of organic matter – altered soil structure and soil fertility	· acidification of watercourses · reduced soil pH increases mobility of toxic elements e.g. Al^{3+} to aquatic ecosystems · sedimentation of watercourses · N and P losses to water · reduced water quantity · increased shading reduces habitat diversity
Harvesting Years 30 plus	▪ Removal of vegetation cover ▪ Tree felling, removal and transport of timber	– soil erosion of bare soils – damage to soil structure – soil compaction – loss of organic matter – reduced soil fertility – reduced soil buffering capacity as cations removed in biomass harvesting – soil compaction	· sedimentation of water courses · increased nitrate leaching · increased surface water runoff · loss of diversity in aquatic ecosystems · reduced soil pH increases mobility of toxic elements e.g. Al^{3+} to aquatic ecosystems

4.4 INDUSTRY

The industrial and municipal sector in Ireland places pressures on soil, water and air environments. The main pressures and impacts which arise from this sector and which affect soil include:

- Atmospheric deposition;
- Industrial organic waste disposal to soils such as blood, offal, sewage sludge, biological treatment plants, dredging wastes etc;
- Disposal of wastes from mining activities, municipal waste disposal to landfill and other industrial activities which result in soil contamination by heavy metals or organic micro-pollutants; and
- Direct loss of soils as a result of quarrying and mining activities.

4.4.1 ATMOSPHERIC DEPOSITION

Deposition resulting from the emissions of sulphur dioxide (SO_2) and nitrogen oxides (NO_x) and ammonia (NH_3) can lead to the acidification of soils and surface waters and may cause nitrogen saturation in terrestrial ecosystems (Stapleton *et al.*, 2000). Anthropogenic emissions of sulphur and nitrogen oxides that are mainly from fossil fuel combustion have lead to increased acidity of aerosol particles, cloud water and precipitation in and around industrial regions during the past century (Aherne *et al.*, 2000 a). Power stations, residential and commercial properties, industry and transport in Ireland account for approximately 175,000 tonnes of SO_2 and 120,000 tonnes of NO_x emitted to the atmosphere in 1998. Emissions of ammonia are also a cause for concern as ammonia can be converted to nitrate by ecosystem processes. The agricultural sectors accounts for virtually all (99.5%) of the ammonia emissions. SO_2 and NO_x emitted to the atmosphere are transformed into sulphates and nitrates, which then react with moisture in the air or on the soil surface forming acids e.g. sulphuric and nitric acid. Emissions of SO_2 and NO_x which emanate mainly from combustion sources showed a general decrease from 1990 through 1995 but have since increased. This rise can be attributed to the marked increase in the combustion of petrol and diesel since 1995 (Stapleton *et al.*, 2000).

Acid rain causes numerous deleterious effects on soils, plant life and the aquatic environment. Acid rain interferes with nutrient recycling in the soil by suppressing microbial decomposition of organic matter and may also inhibit the formation of nitrogen fixing bacteria in the soil. Acid rain can accelerate the process of leaching of nutrients such as calcium, potassium and magnesium thereby reducing availability of these nutrients for plant growth. The leaching of these nutrients will lead to soil acidification over time. Acid rain can also interfere with plant photosynthesis and carbohydrate production and increases the potential for uptake of toxic substances by plants. In aquatic ecosystems, low pH can lead to fish kills, destruction of eggs, impairment of reproductive cycle etc. and disruption to the food chain. In addition, toxic elements such as aluminium become more available and are leached to the aquatic environment. Long term acidification may lead to damage to trees, extinction of plant species and extermination of fish species (Aherne *et al.*, 2000a).

The concept of critical loads is used to determine the impact of anthropogenic pollutants on soil and water environments. The definition of the critical load for sulphur and nitrogen acidity for an ecosystem is " the highest deposition of acidifying compounds that will not cause chemical changes leading to long term harmful effects on ecosystem structure and function" (Nilsson and Grennfelt, 1988). The basic idea of critical load concept is balance the deposition than an ecosystem is exposed to, with the capacity of this ecosystem to buffer the input.

The Forest Ecosystem Research Group in UCD carried out critical load mapping in Ireland using a mass balance approach (Aherne *et al.*, 2000b). Exceedance of critical loads of actual acidity were calculated by subtracting critical loads from potential acid deposition. Deposition has a strong east-west gradient, with highest mapped values in the Dublin and Wicklow mountains and lowest values in the west. The only exceedance of concern occurs on the middle east coast due to a combination of low critical loads and high potential acid deposition. Figure 4.1 illustrates where critical loads of actual acidity measured in $mol_c\ ha^{-1}\ year^{-1}$ are exceeded. The critical load is exceeded on 2% of the mapped soils, which equates to approximately 1500 km^2. This would suggest overall exceedance of actual acidity is quite low under present conditions however, land cover effects were not considered and their inclusion may indicate a more widespread threat of acidification (Aherne *et al.,* 2000b).

The atmospheric nitrogen load to terrestrial ecosystems, such as forests and peatlands, has increased dramatically over the past number of years. The main sources are NOx from combustion processes and NH_3 from agricultural activities. Although terrestrial ecosystems may accumulate considerable amounts of nitrogen in biomass and soil organic matter there is increasing concern that they may become overloaded or saturated with nitrogen from atmospheric deposition. Nitrogen saturation has at least three serious environmental impacts: on soil chemistry and water; plant species composition and productivity; and on fluxes of greenhouse gases. In Ireland it has been estimated that critical loads of nutrient nitrogen are in the range of 8 –25 kgs N ha^{-1} . Total nitrogen deposition shows a strong east-west gradient with the lowest deposition being in the west at 2 kg N ha^{-1} and the highest in the east at 20 kg N ha^{-1}. The critical loads for nutrient N were exceeded on approximately 15% of the mapped area (Aherne *et al*., 2000b). The highest exceedances occur in the Dublin and Wicklow mountains, due to a combination of low critical loads and high nitrogen deposition.

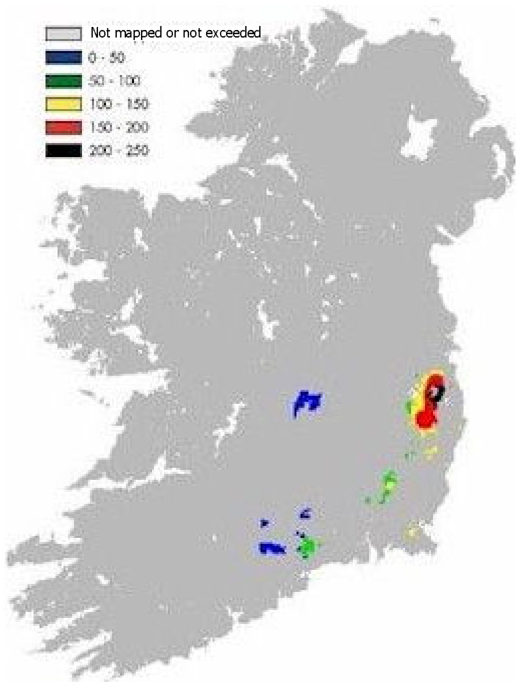


FIGURE 4.1 EXCEEDANCE OF CRITICAL LOADS OF ACTUAL ACIDITY

4.4.2 INDUSTRIAL ORGANIC WASTE DISPOSAL

Much of the organic waste arising from the industrial sector, particularly the agri-food sector, is disposed of to agricultural land by landspreading. Some information is available on the potential benefits and negative impacts of these types of waste on soils however, unlike agricultural organic wastes such as cattle slurry where the benefits are well know, very little agronomic information is available in relation to industrial organic wastes. The application of many of these wastes to agricultural land does not represent nutrient recycling and certain practices such as the application of blood or offal to land should be prohibited.

The types and estimated quantities of wastes arising from industry which are disposed of to agricultural land by landspreading are given in Table 4.3.

TABLE 4.3 ORGANIC WASTES ARISING FROM INDUSTRY FOR DISPOSAL BY LANDSPREADING

Industrial/municipal waste types	Tonnes wet weight	Tonnes of dry solids	Tonnes N	Tonnes P
Animal slaughterings	206,616	17,769	1,694	310
Food processing	998,049	81,840	3,493	1,197
Industrial biological	30,833	2,590	80	67
Water treatment plant	1,793	373	4	2
Wastewater treatment	104,350	4,174	208	125
Septic tanks	971	34	2	1
Total industrial/municipal wastes arising in 1997	1,342,612	106,780	5,481	1,702

Fehily, Timoney & Co., 1998

Where these wastes are spread onto land it is important to consider the origin and processing of such wastes in assessing their potential impacts on soil, water and air. Table 4.4 list the types of wastes arising and the potential problems associated with the application of these wastes to land.

TABLE 4.4 POTENTIAL PROBLEMS ASSOCIATED WITH LANDSPREADING ORGANIC INDUSTRIAL WASTES

Waste type	Properties of waste	Negative impacts on soil	Other negative impacts
• sludge from biological treatment plants	▪ high nutrient and BOD content	- over-application can cause anaerobic soil conditions	· crop growth problems · water quality
• salty wastes	▪ salt in the form of sodium and potassium chloride	- soil structural damage - high soil electrical conductivity - reduce availability of soil water for plant uptake	· can be toxic to plant growth · induce artificial drought conditions · water quality
• oily wastes (above 4% fat or oil content)	▪ can have high N content	- oil coats soil particles and prohibits water uptake by plants - can cause anaerobic conditions in soils	· plants become stunted and die-back · scum develops on surface of the soil · water quality · odours
• brewery and distillery wastes	▪ high BOD, low in plant nutrients	- short term impacts if waste undergoes further fermentation resulting in low pH	· water quality
• vegetable matter/washings	▪ nutrient content variable and wastes are dilute (c. 1% dry solids)		· potential to spread pests and diseases e.g. potato cyst nematode, eelworm
• blood and gut	▪ high fertiliser	- potential high salt content leading to	· potential for disease transmission

Waste type	Properties of waste	Negative impacts on soil	Other negative impacts
contents	value	increases in soil electrical conductivity - anaerobic soil conditions - possible impacts on soil organisms	· odours · water quality
• water treatment sludge	▪ low content of major plant nutrients, good sulphur content	- high aluminium levels which can become toxic if applied to soil with low pH when it causes induced phosphate deficiency - possible impacts on soil organisms	· possible effects on ruminant animals if grazing land where get a build up of Fe or Al levels · water quality
• sewage sludge from waste water treatment plants	▪ good source on N and P, % DS depending on treatment process	- high levels of heavy metals - Cd, Cu, Ni, Pb, Zn , Hg can cause build up of heavy metals in soils - possible impacts on soil organisms ?	· water quality impacts · pathogens · heavy metals could cause toxicity problems for ruminants or induce trace element deficiencies · odour problems

4.4.3 INDUSTRIAL CONTAMINATED SOIL

Ireland's relatively late arrival into the industrial age means that contaminated land problems in Ireland are significantly smaller than those of other European Countries. Soil contamination generally arises as a result of spillages, leaks and improper handling of raw materials, manufactured goods and waste products. Examples of most of the common types of land contamination are to be found in Ireland including old gasworks sites, old waste disposal sites, old mining sites and associated tailing ponds and leaking underground storage tanks.

To date no specific national survey has been carried out to identify and register contaminated sites in Ireland. However, the most common types of facilities and activities likely to give rise to contamination in Ireland are listed below and can be found in both urban/industrialised areas and rural locations:

- old gasworks sites;
- closed and existing waste disposal sites;
- old mining sites and tailings ponds;
- old fertiliser plants;
- petroleum storage sites;
- dockyards;
- chemical industries;
- timber treatment facilities;
- tanneries;

- agricultural/horticultural practices including inappropriate application of pesticides, public sheep dipping baths, landspreading of sewage and industrial sludge and spent sheep dip;
- railway land, especially depots; and
- scrap yards and car breakers.

Estimates from a preliminary assessment of contaminated sites in Ireland would indicate that there are approximately 2000 sites which are causing or have the potential to cause environmental pollution (Brogan *et al*., 1999).

4.4.4 LOSS OF SOIL DUE TO QUARRYING AND MINING ACTIVITIES

Quarrying and mining activities result in the direct loss of soil during their development and operation. The amount of soil loss is dependent upon the method of operation e.g. open-cast versus underground. Mining activities also have the potential to cause soil and surface water or groundwater contamination. Large quantities of heavy metal enriched wastes are generated which are usually disposed of to land. Acid rock drainage and acid mine drainage also poses significant problems to the aquatic environments. Very little information is currently available in Ireland on the quantity of soil lost to these operations and also their impacts on soil, water and air environments. Most existing mining operations and all new mines now require an integrated pollution control licence (IPC).

Large quantities of aggregates are required each year by the construction industry. The consumption of aggregates is now estimated at 50 million tonnes per annum in Ireland. Approximately 35 million tonnes of aggregates are obtained from hard rock quarry by drilling and blasting and around 15 million tonnes of sand and gravel are extracted by direct digging from pits (Stapleton *et al.,* 2000). These extraction processes invariably lead to soil loss and or degradation.

4.5 PEATLAND EXTRACTION

4.5.1 INTRODUCTION TO PEATLANDS

Peat is a soil that is made up of the partially decomposed remains of dead plants which have accumulated at the surface in areas of poor drainage and under conditions of high rainfall and humidity. Peat accumulates in areas where the rate of plant production exceeds the rate of plant decomposition. Complete plant decomposition is prevented in areas where water logging occurs. There are two major peatland types in Ireland, fen peats and bogs. Bogs can be further divided into blanket bogs and raised bogs. Blanket bogs can be further divided into Atlantic or lowland blanket bog (below 200m) and mountain blanket bog (above 200m).

In the lowlands, peat formed on lake beds or in water logged depressions which were fed by mineral rich groundwater. Over time plant remains accumulated and formed a layer of peat on the lake bed which built up and became colonised by plants. These peats are know as fen peats and can be up to two metres deep. Raised bogs developed over fen peats when the roots of plants growing on the surface are no longer in contact with the rich groundwater. At this stage the only source of nutrients comes from rainfall. As a result, plants tolerant of low nutrient status invade the peat such as *Sphagnum* mosses and acidic conditions prevail resulting in the development of raised bogs (Foss and O’Connell, 1996). Raised bogs occur mostly in the midland countries of Kildare, Laois, Offaly, Roscommon, Longford, Tipperary, Westmeath, east Mayo and east Galway.

In the West of Ireland where rainfall exceeds 1250mm and falls on more than 250 days per year blanket bog has developed. Initially, peat formation was confined to shallow lakes and wet depressions however this acid peat spread out to cover large areas. Heavy rainfall caused minerals to be washed out such as iron which when deposited lower down the slopes formed an iron pan resulting in water logging and the spread of the blanket bog. Lowland blanket bog is best developed in south Connemara and north west Mayo with mountain blanket bog covering the higher areas (Cross, 1990). The differences between fens, raised and blanket bogs are summarised in Table 4.5.

TABLE 4.5 PROPERTIES OF FENS, RAISED BOGS AND BLANKET BOGS

Property	Fen	Raised Bog	Blanket Bog
Average depth	2 metres	6 to 7 metres	3.5 metres
Average Age	10,000 years plus with most fens being replaced by raised bogs	10,000 years	4,000- 7,000 years
Location	midlands	midlands	western lowlands and mountains
Rainfall	800-900 mm	800-900 mm	> 1,200mm
pH	7 - 8	3.5	4.2
Formation	in lake basins	in lake basins	on mineral soils
Vegetation	rushes, sedges, grasses, orchids, trees and shrubs	shrubby appearance with heathers, cotton grasses, deer grass, Sphagnum mosses	grassy appearance with purple moor grass, carnation sedge, bog asphodel. With increasing altitude bilberry and crowberry become more abundant

Foss and O'Connell, 1996

4.5.2 PRESSURE ON PEATLAND RESOURCES

Around the 1640's peatlands covered more than 17% or 1,178,798 hectares of the land surface of the Republic of Ireland of which 311,300 hectares were classified as raised bogs and 744,990 hectares as blanket bog (O'Leary and Gormley, 1998). However, from the mid 1940's the area of intact peatlands has been seriously depleted. It has been estimated in 1996 that only 23,628 hectares of intact raised bog and 143,248 hectares of intact blanket bog remains. The decline in the area of peatland of conservation importance has arisen as a result of human exploitation of the resource.

Factors which have contributed to this decline includes:

- the introduction of large-scale mechanised turf extraction schemes in the 1940's;
- afforestation schemes in the 1950's;
- intensification of agriculture particularly following entry in the European Community in 1973; and
- land reclamation particularly drainage.

The most serious impact of mechanised peat extraction has been on the Midlands raised bogs accounting for a loss of 20% of the resource in less than 50 years (Cross, 1990). Drainage removes water from the peat and lowers the water table exposing the upper layers to the air. This destroys the upper layer of the bog where living sphagnum mosses grow which are the main contributors to peat formation. The vegetation changes from a peat moss dominated community to a vegetation type dominated by dry bog species such as heathers. The bog as a result loses its peat forming capacity. Existing peat extraction activities require an Integrated Pollution Control Licence from the EPA and new activities require an Environmental Impact Assessment to be carried and an IPC licence prior to the commencement of the peat extraction.

Grazing pressure by sheep on blanket bogs, particularly in western counties has resulted in severe erosion and complete loss of habitat with bedrock becoming exposed in many areas. Many factors appear to give rise to this problem including the subsidisation of agriculture in less-favoured areas (i.e. EU Ewe Premium grants and Sheep Headage Scheme in Disadvantaged areas), high rainfall and the relatively recent dramatic increase in sheep flock sizes during the eighties when total sheep numbers rose by over five million representing a 330% increase in numbers for the period 1980-1990 (Lee, 1995). The worst affected areas appear to be in Galway and Mayo where over one fifth of the national sheep flock is currently found.

Heavy grazing by sheep on peat substrates eventually culminates in a reduction in heather cover, an increase in the cover of mat grass (*Nardus stricta*) (Bleasdale, 1998). Where the vegetation cover has been removed the peat becomes exposed to erosion by wind, rain and freeze thaw action. This ultimately leads to the direct loss of peat, loss of productivity and loss of habitats that are important at national and international levels. As well as the direct loss of soils, the eroding peat impacts on water quality and fishery productivity of streams and rivers draining from these hill areas. Erosion has led to siltation of lakes and rivers, the development of peat-algal complexes on river beds and increased peat staining and turbidity of waters. The erosion of the peats also results in the degradation of the landscape giving the peatlands a pronounced bare and black appearance which may have the potential to impact directly on the tourist industry in the region.

In response to overgrazing and soil erosion, the Department of Agriculture, Food and Rural Development (DAFRD) and Dúchas, the Heritage Service of Department of Arts, Heritage, Gaeltacht and the Islands (DAHGI) have undertaken an assessment of the overgrazing problem on the peatland and upland resources in all commonages in Ireland. Agri-environmental plans have been produced for almost every commonage and these plans known as “Commonage Framework Plan” will be used to produce individual farm plans which are compatible with the overall strategy of the framework plan to reduce soil degradation. The Commonage Framework Plans were launched in February 2002 with more than 2000 agri-environmental plans being produced which covers ninety percent of commonage land in fifteen counties. Over 500,000 ha of commonage land has been assessed and recommendations have been made in relation to destocking rates where required. The destocking figures range from zero to 100 percent depending on the townland and commonage involved and destocking is to be applied from 2003. Commonage Framework Plans will be applied through the Rural Environment Protection Scheme or DAHGI.

4.6 URBANISATION AND INFRASTRUCTURE DEVELOPMENT

Soil is lost annually through the rezoning of agricultural land for development purposes. The number of hectares, which are rezoned annually on a countrywide basis is not known, nor is the quantity of soil loss through surface sealing. Urban environments have greatly changed in Ireland with the centre of cities and towns being subjected to depopulation with growth focused on the periphery of these areas. With urban expansion, agricultural land surrounding cities and towns as well as green areas within them are subjected to increasing pressures. An EU study on Urban environmental issues provides some information on the extent and impact of urbanisation in Dublin (Critchley, 1999). In the intervening period from 1956 to 1998, residential area in Dublin doubled and the area used for road networks increased by a factor of 10. This has resulted in a reduction of agricultural, forestry and semi-natural areas around Dublin of approximately 15%. While this increase in urbanisation may not have resulted in total loss of soils in the area, it is likely that a significant proportion of the soil in this area has been sealed over and therefore lost from future use. The types of soils lost and therefore their land-use potential is not known. Information in relation to surface sealing in other parts of the country is not available. This gap in information on surface sealing needs to be addressed as one of the issues requiring further evaluation and possible research.

5. SOIL PROTECTION STRATEGY

5.1 INTRODUCTION

A soil protection strategy needs to be developed in Ireland to ensure the protection of soil, soil properties and soil functions now and for future generations. There are many elements which need to be considered when developing such a strategy and this chapter endeavours to set out a broad outline of what should be included.

The main elements of a strategy for soil protection include:

1. Identifying and reviewing sources of available information on soils that already exist in Ireland, and assess this information to see if they can provide useful historical information in relation to soil and changes which may have occurred in soil quality over time.
2. Identifying and selecting a set of national soil quality indicators that will be used to monitor soil quality, both spatially and temporally.
3. Developing a set of standards that will be used to assess soil quality in relation to monitoring results from soil quality indicators.
4. Designing and establishing a soil quality monitoring network, which can be applied across a wide range of soil types under different land uses, which monitors soil quality changes over time.
5. Developing a code of good practice for soil, which identifies pressures and impacts on soils and outlines best practice in relation to sustainable soil management under different land uses.

5.2 IDENTIFY AND REVIEW EXISTING INFORMATION ON SOILS IN IRELAND

An attempt has been made in this document to identify current sources of information on soils in Ireland. Further historical information may be available. Where this is identified through the consultation process of this document, it should be assessed in relation to providing information on soil quality and changes over time e.g. what information is currently available, what does this tell us about soil quality changes over time and under different land uses and pressures, etc. There appears to be a significant amount of information on soil types in Ireland, the suitability of soil types for various land uses such as agriculture and afforestation and on soil fertility levels in relation to agricultural production. There is also limited information available on trace element concentration. There appears to be poor and or fragmented information on physical degradation and none on soil biological properties. The establishment of a series of permanent national soil quality monitoring sites should address the gaps in information that currently exist and be able to monitor soil quality changes over time.

5.3 DEVELOP A SET OF KEY SOIL QUALITY INDICATORS

A set of key soil quality indicators which can measure changes in soil quality needs to be selected. These indicators must be capable of informing policy makers, regulators and soil users so that questions such as “what is soil quality like in Ireland, is it good, is it bad and how is it changing over time” can be answered. Soil quality assessment includes measurement of the state of soil and judgements about suitability made by society. “Good” or “bad” soil quality has two components (a) a scientific understanding of the state of soil resources supporting soil functions and, (b) decisions made by society on the intended use for the soil. The concept of “good” or “bad” quality will depend upon the fitness for use i.e. is the soil well matched for a particular land use (Sparling and Schipper, 1998) and also on the status of the soil relative to a particular standard (Larson and Pierce, 1994).

The multiple properties, functions and uses of soil make the selection of a set of key soil quality indicators a difficult task. There are many countries that are currently in the process of selecting appropriate indicators to measure changes in soil quality over time. Some countries, for example New Zealand have selected and carried out trials to assess the usefulness of the selected indicators in measuring soil quality changes. In selecting a set of soil quality indicators for use in New Zealand, a research team suggested that the characteristics which soil quality indicators were required to demonstrate could be divided into six broad categories (Sparling and Schipper, 1998). They suggested that soil quality indicators must be:

- Interpretable – the indices need to be meaningful so that differences between land uses or soil types can be interpreted.
- Transferable – measurements cannot be taken from all soil types under all land uses, therefore the soil properties, which are measured, should not be specific to a particular land use or soil type but should apply at all sites.
- Simple to measure and cost-effective – soil properties need to be relatively simple to measure so that large numbers of samples from a range of sites can be processed. The cost of analysis must be weighed against the information provided.
- Acceptable – soil properties need to be scientifically robust and accepted by national and international communities.
- Sensitive – soil properties need to be responsive to differences in land use, soil types and climate.
- Archive data – useful to be able to use existing archived data on soil quality if available.

The selection of a set of soil quality indicators should be based on soil physical, biological and chemical properties and be relayed to soil functions. A wide range of soil quality indicators have been suggested by many people working in the area, however, there is no international consensus on a definitive set of soil quality indicators. Table 5.1 list examples of soil quality indicators that should be considered when developing a national set of soil quality monitoring indicators for Ireland. Various countries and organisations including the UK, New Zealand and European Environment Agency (EEA) have carried out research and have identified some of the following as possible indicators for assessing soil quality over time.

TABLE 5.1 EXAMPLES OF SOIL QUALITY INDICATORS

Indicator	Soil property/soil function
Soil organic carbon content	Biomass production, filtering and buffering, soil structure, formation of soil aggregates, soil fertility, ability to retain water etc.
Cation exchange capacity	Filtering and buffering capacity and nutrient reserve
Base saturation	Filtering and buffering capacity and indicates reserves left in the soil to buffer against acidity
Soil pH	Acidity or alkalinity of soil and influences land use, biomass production and biodiversity
Olsens P or Morgans P	Plant available P, and also indicator of soil fertility status and potential for biomass production. Links to potential for water eutrophication
Microbial biomass	Size of microbial populations and indicates the potential for soil to recycle organic matter and nutrients, relevant to soil fertility and indicates the activity level within a soil Ability to transform chemicals
Soil macro and micro fauna and flora	Biodiversity, soil health, soil fertility
Soil N mineralisation potential	Availability of N reserve, indicates activity of soil microbial biomass, relevant to soil fertility
Soil bulk density	Measure of the porosity and compaction of soil, physical environment for roots and soil

Indicator	Soil property/soil function
	organisms
Particle size distribution	Physical environment for roots
Macroporosity and readily available water	Indicates the number of larger pores in the soil which are important for soil aeration and storage of plant-available water
Area of land lost to urbanisation and development	Loss of soil
Sediment load to water courses	Soil erosion and loss of soil functions
Heavy metal concentration in soils	Anthropogenic soil contamination, possible loss of soil functions.

Once soil quality indicators are selected and then monitored over time, the monitoring results must be compared against a particular standard for an assessment to be made i.e. is soil quality good, stable or declining. Standards for soil quality assessment will have to be developed to assess the status of soils relative to a particular standard so that monitoring results from soil quality indicators can be communicated to the various stakeholders i.e. soil quality is improving or declining over time.

5.4 SOIL QUALITY MONITORING NETWORK

An effective soil monitoring network will provide information which is required to understand the extent, diversity and quality of soils and how these are changing over time. The sites selected for inclusion in the national soil quality monitoring network must be able to represent the diversity in soils types, soil properties, soil functions, and land use and be able to measure the impact, if any, of soil management practices on soil quality over time. Where soil management practices have been altered and improved in response to soil monitoring results, the soil quality monitoring programme must be able to measure the effectiveness of the implementation of best practice. The establishment of a series of permanent national soil quality monitoring sites provides a sound platform upon which decisions on soil quality management can be taken. Soil quality changes can be monitored and the effectiveness of measures (including regulatory), that are implemented to improve soil quality can be assessed. It is important that the information obtained can be integrated with other environmental monitoring information.

The selection of the most appropriate soil quality monitoring sites should be undertaken through a consultative process with relevant organisations, scientists and stakeholders. It is important that key land uses and soil types, which are perceived at being under the greatest risk of decline in soil quality, are included in the list of sites. In addition, the inclusion of matching soil types under different land uses should be included as this will enable the measurement of the impact of land management practices on soil quality over time. Where gaps are identified in relation to particular soil types and land management practices these should also be addressed in the national soil quality monitoring programme. It is important that appropriate timescales are used to monitor soil quality changes. Many soil properties change very slowly up to a point and then changes can occur quite rapidly once a particular threshold has been reached. In addition to the above the private ownership of soil may also lead to practical difficulties in relation to access to monitored sites over time.

5.5 DEVELOP A CODE OF GOOD PRACTICE FOR SOIL MANAGEMENT

A code of good practice needs to be developed which gives advice in relation to soil management practices which should be adopted by all sectors which have the potential to impact on soil quality. This code will give the best practice in relation to soil management and will transverse all sectors providing guidance in relation to the sustainable management of soils. The code should address the physical, chemical and biological properties of soils and advise on how to avoid harmful practices. It should also provide advice on the management of degraded soils.

The implementation of a code of good practice for soils which outlines sustainable land management practices and increased awareness of the importance of soil should lead to the maintenance of good soil quality and recommend preventative actions in addition to remedial measures for soil quality.

5.6 RECENT DEVELOPMENTS AT EU LEVEL

The need to develop a more coherent approach to the protection of soils has been recognised at European level and has resulted in the establishment of such bodies as the European Soil Bureau (ESB), the European Soil Forum (ESF) and European Environment Agency (EEA) Topic Centre on the Terrestrial Environment (ETC/TE).
There has been a shift in focus at European level from policies relating mainly to the agricultural sector to policies based on environmental protection. The key soil issues, which have been identified at the European level, include erosion and desertification, industrial contamination, diffuse pollution including organic waste disposal and air deposition, soil loss through urbanisation, soils and climate change, soil biodiversity and salinisation.

At the EU level, comprehensive community policies exist for water and air protection but not for soils. In order to address this gap, the 6th Environment Action Programme of the EU contains a commitment by the European Commission to develop a thematic strategy for soil. The main objective of the strategy for soil is to raise the political importance of soil issues at a European level so that soil protection receives adequate attention. With this in mind the Commission of the European Communities issued a COM document (COM(2002) 179 final) entitled "*Towards a Thematic Strategy for Soil Protection*" in April 2002. The purpose of the Communication is to build on the political commitment to develop a thematic strategy for soil over time which will be based on the precautionary principal. In the long-term it recommends the establishment of a legislative basis for soil monitoring so that a knowledge based approach can be established aimed at delivering soil protection.

5.7 RECOMMENDATIONS

The EPA recommends that the main elements of a soil protection strategy as discussed should be implemented. The main elements of the work required are:

1. Identify and review sources of available information on soils that already exist in Ireland, including information on existing soil monitoring programmes and assess to see if existing information can provide valuable historical information in relation to soil quality.
2. Identify and select a set of national soil quality indicators that will be used to monitor soil quality, both spatially and temporally.
3. Develop a set of standards that will be used to assess soil quality in relation to monitoring results from soil quality indicators.
4. Design and establish a soil quality monitoring network, which can be applied across a wide range of soil types under different land uses, which monitors soil quality changes over time.
5. Develop a code of good practice for soil, which identifies pressures and impacts on soils and outlines best practice in relation to sustainable soil management under different land uses.

The main elements of the work would be to review existing information, identify and select a limited set of soil quality indicators, establish a set of standards to assess soil quality in relation to the chosen indicators, design and make recommendations in relation to the establishment of a national soil quality monitoring network and to develop code of good practice for soils.

The above work should be undertaken in tandem with developments at the European level. It is important therefore that evolving developments at the EU level are considered during the development of a soil protection strategy for Ireland. Ireland should therefore take an active role in participating in the development of a European Framework on Soil Protection.

6. REFERENCES

- Adams, W.A. and Gibbs, R.J. 1994. *Natural turf for sport and amenity*. CAB International, Wallingford, UK.
- Aherne, J. and Farrell, E.P. 2000 a. *Critical loads and levels: Determination and mapping of critical loads for sulphur and nitrogen and critical loads for ozone in Ireland: Literature Review.* EPA, Wexford, Ireland.
- Aherne, J. and Farrell, E.P. 2000 b. *Critical loads and levels: Determination and mapping of critical loads for sulphur and nitrogen and critical loads for ozone in Ireland: Final Report.* EPA, Wexford, Ireland.
- Ball, D.F. 1975. Process of soil degradation: a pedological point of view. In: Evans, J.G., Limbrey, S. And Cleere, H. (eds.) *The effect of Man on the Landscape: the Highland Zone*. Council of British Archaeology Research Report No.11.
- Bleasdale, A. 1998. Overgrazing in the West of Ireland - assessing solutions. In: O'Leary, G. and Gormley, F. (eds.) *Towards a Conservation Strategy for the Bogs of Ireland*. Irish Peatland Conservation Council, Dublin, Ireland.
- Blum, W.E.H 1988. Problems of Soil Conservation. Nature and Environment Series, 39. Council of Europe, Strasbourg.
- Blum, W.E.H. and Santelises, A.A. 1994. A concept of sustainability and resilience based on soil functions: the role of ISSS in promoting sustainable land use. In: Greenland, D.J. and Szabolcs, I. (eds.) *Soil Resilience and Sustainable Land Use*. CAB International, Oxon, UK.
- Brogan, J., Carty, G., Crowe, M., Leech, B. 1999. Policy Framework for Contaminated Sites - Ireland. In: Ferguson, C. and Kasamas, H. (eds.) *Risk Assessment for Contaminated Sites in Europe: Volume 2 Policy Frameworks*. LQM Press, Nottingham, UK.
- Brogan, J., Crowe, M. and Carty, C. 2001. *Developing a National Phosphorus balance for Agriculture in Ireland: A Discussion Document*. EPA, Johnstown Castle, Co. Wexford.
- Brogan, J.C. 1966. Organic Carbon in Irish pasture soils. Irish Journal of Agricultural Research, Vol. 5, No. 2, 1966.
- Carton, O.T. and Magette, W.L. 1998. Teagasc Manure Management Guidelines with special reference to Intensive Agricultural Enterprises. In: Carton, O. (ed.) *Draft Guidelines for nutrient use in Intensive Agricultural Enterprises*. Teagasc, Wexford.
- Central Statistics Office. 1991. *Census of Agriculture, June 1991 – Detailed Results*. CSO, Dublin.
- Clenaghan, C. and Crowe, M. 2000. Managing and Protecting the Environment, In: Stapleton, L., Lehane, M. and Toner, P. (eds.) *Ireland's Environment : A millennium report*. Environmental Protection Agency, Wexford, Ireland.
- Conry, M.J. 1997. *Weather hazards in tillage cropping*. Paper presented to Irish Meteorological Society, April, 1997. Teagasc, Co.Carlow.
- Coulter, B. 2001. *Nutrient Advice and Trace Element Advice for Grassland and Tillage Crops*. Teagasc, Johnstown Castle Research Centre, Wexford.
- Critchley, M. 1999. *Monitoring Urban Dynamics (Murbandy) – Dublin.* Final report prepared by ERA-Maptec Ltd for the European Commission, Joint Research Centre. ERA-Maptec Ltd. Dublin.
- Cross, J.R. 1990. *The raised bogs of Ireland, their Ecology, Status and Conservation*. Stationary Office, Dublin.

- Department of Agriculture, Food and Forestry. 1996. *Growing for the Future: A strategic plan for the Development of the Forestry Sector in Ireland*. Government Publication Office, Dublin. Ireland.
- Department of Agriculture, Food and Rural Development. 2000a. *CAP Rural Development Plan 2000-2006*. Government Publications, Dublin.
- Department of Agriculture, Food and Rural Development. 2000b. *Agri-Environmental Specification for REPS 2000*. DAFRD, Dublin.
- Department of Agriculture, Food and Rural Development. 2001. *Good Farming Practice*. DAFRD, Dublin, 2001.
- Department of the Environment. 1997. *Sustainable Development: A Strategy for Ireland*. Government Publications, Dublin 2.
- Department of Environment and Department of Agriculture, Food and Forestry. 1996. *Code of Good Agricultural Practice to Protect Waters from Pollution by Nitrates*. Government Publications, Dublin.
- Doran, J.W., and Safley, M. 1997. Defining and Assessing Soil health and Sustainable Productivity. In: Pankhurst, C.E., Doube, B.M. and Gupta, V.V.S.R. (eds), *Biological Indicators of Soil Health*. CABI Publishing, Oxon, UK.
- Environmental Protection Agency. 2000. *National Waste Database Report 1998*. EPA, Johnstown Castle Estate, Wexford.
- Fehily, Timoney & Co. 1998. *Inventory of Non-hazardous Sludges in Ireland*. Prepared by Fehily Timoney and Co. on behalf of the Department of Environment and Local Government, Dublin.
- Farrell, E.P. 1997. Managing our Forests for the Future. *Journal of Irish Forestry*, Vol 54, No. 1, 1997, pp 38-44.
- Farrell, E.P., Cunningham, D.A. and Collins, J.F. (1996) Impacts of Pre-Twentieth Century Deforestation on Soil Development: A View Based on Current Evidence. In: Giller, P.S. and Myers, A.A. (eds) *Disturbance and recovery in ecological systems*. Dublin Royal Irish Academy, Dublin.
- Forest Service. 1999. *Forest Inventory and Planning System*. Forest Service, Department of Marine and Natural Resources, Wexford.
- Forest Service. 2000. *Code of Best Forest Practice – Ireland*. Forest Service, Dublin.
- Foss, P. and O'Connell, C. 1998. *The IPPC Peatland Conservation Management Handbook*. IPPC, Dublin.
- Gardiner, M.J. and Radford, T. 1980. *Soil Associations of Ireland and their land use potential*. An Foras Talúntais, Dublin.
- Gee, A and Stoner, J. 1988. The effects of afforestation and acid deposition on water quality and ecology in upland Wales. In: Usher, M and Thompson, M. (eds) *Ecological Change in the Uplands*. Blackwell, Oxford, UK.
- Gordon, J.E., Gubbins, N., Taylor, A.G. and McKirdy, A.P. 1996. Soils and Sustainability: A Natural Heritage Perspective. In: Taylor, A.G., Gordon, J.E. and Usher, M.B., (eds) *Soils, sustainability and the Natural Heritage*. Scottish Natural Heritage, HMSO, Edinburgh.
- Hornung, M., Stevens, P.A. and Reynolds, B. (1987) The effects of Forestry on soils, soil water and surface water chemistry. In : *Good, J. (ed) 1987 Environmental Aspects of plantation Forestry in Wales*. NERC, Grange-over Sands, Cumbria, UK.
- Juma, N.G. 1999. T*he Pedosphere and Its Dynamics: What is a soil?: 1.6 Major components of soil* [on line]. Available http//www.pedosphere.com /(22/02/2001).

- Karlen, D.L., Mausbach, M.J., Doran, J.W., Cline, R.G., Harris, R.F. and Schuman, G.E. 1997. Soil quality: a concept, definition, and framework for evaluation. *Soil Science Society of America Journal* 61, pp4-10.

- Larson, W.E. and Pierce, F.J. 1994. The Dynamics of Soil Quality as a Measure of Sustainable Management. In (eds.) Doran, J.D., Coleman, D.C., Bezdicek, D.F. and Stewart, B.A. *Defining soil quality for a sustainable environment*. SSA, Madison, USA.

- Lafferty, S., Commins, P. and Walsh, J.A. 1999. *Irish Agriculture in Transition – A Census Atlas of Agriculture in the Republic of Ireland.* Teagasc, Dublin 4.

- Lee, 1995. Some aspects of sustainability in relation to Agriculture in Ireland. In: Convery, F. and Feehan, J. (eds.). *Assessing sustainability in Ireland.* Environmental Institute, UCD, Dublin.

- Lucey, J., Bowman, J.J., Clabby, K.J., Cunnigham, P., Lehane, M., MácCarthaigh, M., McGarrigle, M. L. and Toner, P.F. 1999. *Water Quality in Ireland 1995-1997*. EPS, Wexford, Ireland

- McGrath, D. 1972. Frequency distribution of the percentage of Organic Carbon in Irish Soils. *Irish Journal of Agricultural Research*, Vol.12, No.1, 1973.
- McGrath, D. 1995. *Organic micropollutant and trace element pollution of Irish soils*. The Science of the Total Environment 164 (1995) 125-133. Elservier Science, Oxford, UK.
- McGrath, D., Carton, O.T., Diamond, S., O'Sullivan, A.M., Murphy, W.E., Rogers, P.A.M., Parle, P.J. and Byrne, E. 2001. Soil, herbage, feed and water. In: *Investigation of Animal Health Problems at Askeaton, Co. Limerick.* EPA, Johnstown Castle Estate, Wexford.
- Ministry of Agriculture, Fisheries and Food and Welsh Office of Agriculture Department. 1998. *Code of Good Agricultural Practice for the Protection of Soil*. MAFF, London, UK.

- Ministry of Agriculture, Fisheries and Food. 2000. *Fertiliser recommendations for Agricultural and Horticultural* (RB209). Stationary Office, London.

- Morgan, R.P.C. 1995. *Soil erosion and Conservation*. Longman Limited, Essex, England.

- Nilsson, J. and Greenfelt, P. 1988. (eds) *Critical loads for sulphur and nitrogen. Miljörapport 1988:15*. Nordic Council of Ministers. Copenhagen, 418 pp.

- O'Leary,G. and Gormley, F. 1998. *Towards a Conservation Strategy for the Bogs of Ireland*. Irish Peatland Conservation Council, Dublin.

- Organisation for Economic Co-Operation and Development. 1998. *The Environmental Effects of Reforming Agricultural Policies*. OECD Publications, Paris, France.

- Organisation for Economic Co-Operation and Development. 1998. *Agriculture and the Environment: Issues and Policies*. OECD Publications, Paris, France.

- Scottish Environment Protection Agency. 2001. *State of the Environment: Soil Quality Report*. SEPA, Stirling, Scotland.

- Soane, B.D., and van Ouwerkerk. 1998. Soil compaction: A Global threat to Sustainable Land Use. In: Blume, H.P., Eger, H., Fleischhauer, E., Hebel, A., Reij, C. and Steiner, K.G. (eds) *Towards Sustainable Land Use: furthering co-operation between people and institutions.* Vol.1 Advances in Geogeology 31, Catena Verlag GMBH, Reiskirchen, Germany.

- Soutar, R. 1989. Afforestation and sediment yields in British Fresh Waters. In: *Soil Use and Management*. Vol 5, No. 2, pp 82-86.

- Sparling, G. and Schipper, L. 1998. *Soil Quality Monitoring in New Zealand: Concepts, Approached and Interpretation (Technical report LCR 9798/060).* Landcare Research, Hamilton, New Zealand.

- Stanners, D. and Bourdeau, P., (eds). 1995. *Europe's Environment: The Dorbis Assessment*. European Environment Agency, Copenhagen.

- Stapleton, L., Lehane, M. and Toner, P. 2000. *Ireland's Environment : A millennium report*. Environmental Protection Agency, Wexford, Ireland.
- Straunch, D. and Ballarini, G. 1991. Hygienic aspects. From European Colloquim - Scientific Basis for an Environmentally Safe and Efficient Management of Livestock Farming, held in Mantova, Italy, 12 to 15th November 1991.
- Trudgill, S. 1988. *Soil and Vegetation Systems*. Oxford University Press, New York, USA.
- Van Hook, R.I., Johnson, D.W., West, D.C. and Mann, L.K. 1982. Environmental effects of harvesting forests for energy. In: *International Journal of Forest Ecology and Management*, Vol. 4, pp 79-94.
- Walsh, M., Mulqueen, J., Grennan, E., Rodgers, M., Marren, N., Guinan, L., Nixon, D. and Collins, J.F. 2000. *Evaluation of the Impact of Livestock on the Hill Environment. Teagasc End of Project Report: Sheep Series No.10. Project No.4043*. Teagasc, Sheep Research Centre, Athenry, Co.Galway.
- Wild, A. 1988. *Russell's soil condition and plant growth*. Longman Scientific & Technical, Harlow, Essex, UK.

APPENDIX A
EXISTING LEGISLATION AND POLICIES ON SOIL PROTECTION

A.1 INTRODUCTION

Legislation relating directly to soils and soil protection is poorly developed at both national and European level. Very little legislation relates directly to soil protection and in many cases air or water legislation affords protection indirectly to soils. In addition to primary legislation, agreements, protocols and codes of good practice have been developed in relation to soil protection both at European and international levels.

Soil protection policies at European and National level have been fragmented and in most cases the focus of these policies and legislation has been to give protection to other environmental medium such as water and air. The protection of soils to date has been achieved through a series of separate instruments such as standards in relation to the use of sewage sludge, the nitrates directive and agri-environmental measures under the Common Agricultural Policy. The main direct and indirect policy measures addressing soil protection are given below indicating the sector or medium, which is addressed, and the principal aims of the policy.

A.2 SOIL CHARTERS

A.2.1 WORLD SOIL CHARTER ADOPTED BY THE FAO OF THE UNITED NATIONS (1981)

The Food and Agriculture Organisation of the United Nations adopted a World Soil Charter to ensure sustainable use of the worlds soil resources. It recommends that decisions about land use management be made for long-term advantage rather than for short-term gains and that farming practices should permit sustainable or improving levels of production. The Charter identified the need to develop land use policies and legislation, compile inventories of soil resources and to develop educational programmes and research on soil conservation.

The charter aims to:

- establish a set of principles for rational use of the worlds soils and protect them against irreversible degradation; and
- calls on governments and institutions to pursue programmes of soil conservation and reclamation.

A.2.2 EUROPEAN SOIL CHARTER (RESOLUTION (72) 19) ADOPTED BY THE COMMITTEE OF MINISTERS FOR THE EUROPEAN COUNCIL (1972)

The European Committee for the Conservation of Nature and Natural Resources of the Council of Europe prepared the European Soil Charter in response to growing concerns over soil degradation across Europe. The Charter emphasises soil as a non-renewable natural resource that develops slowly over time but is easily destroyed. Soils should be managed so as to protect their multi-functional roles and land management practices should be adopted to ensure soil quality preservation.

The charter aims to address soil protection and identifies key issues in the area which include:
- soil is a limited resource essential for life on earth and must be protected;
- soils are easily destroyed;
- the properties of soils determine their suitability for various uses;
- marginal lands offer special opportunities for nature reserves, reafforestation etc.;
- farmers and foresters must adopt management practices which preserve the quality of soils;
- soils must be protected against erosion and pollution;
- urban development must be planned and impacts on adjacent lands must be minimised;
- an inventory of soil resources should be undertaken;

- soils, through research and education should be brought forward into the public domain; and
- countries should develop proper policy on soil conservation.

A.3 EU LEGISLATION

A.3.1. COMMITTEE OF MINISTERS FOR THE EUROPEAN COUNCIL RECOMMENDATION NO.R (92) 8 ON SOIL PROTECTION 1992.

This EU recommendation addresses issues such as heavy metal contamination of soils, acid deposition, acidification, eutrophication of water courses and physical degradation of soils. The recommendation highlighted the need for explicit soil protection policy. Some European countries such as the Netherlands, Germany and Switzerland have developed specific legislation to deal with soil protection, the maintenance of soils multifunctionality and soil contamination. In response to growing concerns over increasing rates of soil degradation and alarm at the speed at which soil resources have deteriorated in recent years, the Committee of Ministers for the European Council drew up guidelines on soil policy formulation.

It recommends that soil policy should be guided by three principles that are divided into:

- Fundamental principles
  - soil protection should be integrated into environmental protection and long-term development policies
  - soils should be recognised as a non-renewable resource of vital importance and its multi-functional roles should be recognised
  - soil protection should be considered in all other policies e.g. agricultural, forestry, urbanisation etc.
  - public participation is encouraged

- Soil management principles
  - soils should be regarded as a limited resource
  - integrated soil management requires the co-ordination of soil quality measures

- Operational (or functional) principles
  - soil and land use should allow the soil to perform several functions at once i.e. filter, buffer, transformer, biological habitat and genetic reserve alongside uses associated with human activities
  - the reversibility use: whenever possible, land use should cause only reversible changes in the soil

A.3.2 SEWAGE SLUDGE DIRECTIVE

The purpose of the sewage sludge directive (i.e. Council Directive on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture (86/278/EEC) is two fold. Firstly, to ensure that human beings, animals, plants and the environment are safeguarded against the possibility of harmful effects from the uncontrolled spreading of sewage sludge on agricultural land and secondly, to promote the correct use of sewage sludge on such land. The directive and regulation sets maximum values for concentrations of heavy metals in soils and maximum values for heavy metals in sewage sludge above which sewage sludge application to agricultural land is prohibited. Sewage sludge application is banned where the concentration of one or more heavy metals exceeds the limit laid down at national level. Table A.1 summarises the maximum values for concentrations of heavy metals in soil. Where the pH of the soil is consistently higher than 7, the values may be exceeded by not more than 50%, provided there is no resulting hazard to human health, the environment or, in particular, groundwater.

TABLE A.1 MAXIMUM CONCENTRATION OF HEAVY METALS IN SOIL

Parameter	Maximum value (mg/kg of dry matter)
Cadmium	1
Copper	50
Nickel	30
Lead	50
Zinc	150
Mercury	1

The Directive and regulation also set restrictions on the use untreated sludge, restrictions on crop types and restrictions after application. Each Local Authority must establish and maintain a sludge register on the quantities produced and supplied for use in Agriculture in their functional areas. The Directive was transposed into Irish law by the European Communities (Use of Sewage Sludge in Agriculture) Regulations, 1991 (SI No. 183 of 1991) which was replaced by the Waste Management (Use of Sewage Sludge in Agriculture) Regulations, 1998 (SI No. 148 of 1998).

A.3.3 NITRATES DIRECTIVE

The Nitrates Directive (Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agriculture) seeks to reduce or prevent the pollution of waters (groundwater, surface freshwater, estuaries, coastal and marine waters) by the application and storage of chemical fertilisers and manures on farmland. It aims to protect drinking water supplies and to prevent ecological damage resulting from eutrophication of fresh and marine waters. To date no areas in Ireland have been designated as Nitrate Vulnerable Zones (NVZ).

The Nitrates Directive requires member states to:

- Identify water that is affected or could be affected by nitrates. The definition of water includes surface waters, groundwater, estuaries, and coastal and marine waters;
- To establish a code of good agricultural practice to be implemented by farmers on a voluntary basis for all waters; and
- To develop and implement action programmes to reduce and prevent pollution of waters by nitrates. Action programmes must include enforceable rules i.e. regulations.

Action programmes under the Nitrates Directive must impose limits on the amount of livestock manure that can be applied per hectare. The maximum amounts are 210 kgs ha^{-1} $year^{-1}$ of organic N for the first four years and 170kgs ha^{-1} yr^{-1} of organic N thereafter. Member states may seek a derogation from these limits. The Directive requires that action programmes be implemented in relation to the whole territory of a Member State or to areas designated by Member States as vulnerable zones.

A.3.4 HABITATS DIRECTIVE

Concern over the deterioration of various habitat types and extinction and declining numbers of species of flora and fauna throughout Europe lead to the adoption of the Habitats Directive (Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild fauna and flora). The aim of the Directive is to contribute to the maintenance of biodiversity through the conservation of natural habitats and of wild fauna and flora. The Directive aims at establishing a 'favourable conservation status' for habitat types and species selected as being important within the Community. 'Favourable conservation status' is broadly defined for both habitats and species by reference to such factors as species population dynamics, trends in the natural range of species and habitats and that these areas are stable or expanding, etc. Natural habitats are defined as "terrestrial or aquatic areas distinguished by geographic, abiotic, and biotic features, whether entirely natural or semi-natural".

The measures proposed under the Directive are to maintain and/or restore favourable conservation status. Annex I lists 168 habitat types, with 42 of these identified as priority habitats which are currently in danger of becoming extinct. Annex II lists animal and plant species of community interest whose conservation requires the designation of SAC's.

The Habitats Directive extends many of the protection mechanisms established by the Birds Directive (79/409/EEC) and imposes obligations similar to those laid down in the Berne Convention on the Conservation of European Wildlife and Natural Habitats. The Directive also contributes to the implementation of Convention on Biological diversity signed at the UN conference on Environment and Development in Rio de Janeiro in 1992. The Habitats Directive was transposed into Irish law by the European Communities (Natural Habitats) Regulation, 1997 (SI No. 94 of 1997).

Special Areas of Conservation (SAC's) and Special Protection Areas (SPA's) designated under the Birds Directive will establish a coherent European ecological network of sites of Community importance and shall come under the title Natura 2000.

A.3.5 COUNCIL DIRECTIVE ON ENVIRONMENTAL IMPACT ASSESSMENT

Council Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment embodies the preventative approach to environmental protection. It requires that before a governmental body gives consent, certain development projects likely to have significant effects on the environment are subjected to an environmental impact assessment. Directive 97/11/EC subsequently amended directive 85/337. These directives were transposed into Irish Law by and the various regulations and are cited collectively as the European Communities (Environmental Impact Assessment) Regulations 1989 to 1998.

Projects listed in the First Schedule of SI No. 349 of 1989 require an Environmental Impact Assessment (EIA), whereas some discretion over the requirement to prepare an EIA is given to member states for projects listed in the Second Schedule. The Second Schedule also outlines what information should be contained in an Environmental Impact Statement (EIS). The EIS must give a description of the likely significant direct or indirect impacts of a development on soil, water, air, flora, fauna, climate, landscape, human beings etc. Where significant adverse effects are identified, measures to avoid, reduce or remedy these effects must be developed. Major development activities most likely to cause significant impacts on soils are listed in the Directive including agriculture, infrastructure development, the extractive industry and waste disposal activities. The activities covered under agriculture include the use of uncultivated land or semi-natural areas for intensive agriculture, water management projects for agriculture, initial afforestation, land reclamation and intensive pig and poultry rearing installations. The extractive industry includes activities such as extraction of peat, minerals and stone, sand, gravel and clay.

A.3.6 WATER FRAMEWORK DIRECTIVE

Directive 2000/60/EC establishing a framework for Community action in the field of water policy came into force on the 22nd December 2000. The purpose of the directive, commonly known as the Water Framework Directive (WFD), is to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater which prevents further deterioration and protects and enhances the status of aquatic ecosystems. It also aims to promote the sustainable use of water and to ensure enhanced protection and improvement of the aquatic environment by reducing discharges and emissions and losses of priority hazardous substances. In addition the Directive aims to contribute to the mitigation of the effects of floods and droughts.

In the WFD subsoil is referred to under the definition of groundwater i.e. groundwater is defined as " *all water which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil*". In addition the WFD requires member states to identify the individual river basins and assign them to river basin districts. River basin districts are the management units through which the objectives of the directive shall be met. Annex VII of the WFD sets out elements that need to be covered in river basin management plans. One of the main elements requires a summary of significant pressures and impacts of human activity on the status of surface water and groundwater including estimation of point source pollution and diffuse source pollution, including a summary of land use. The hydrological linkage between soils and water requires that measures taken to achieve good quality water status must also promote quality soil management practices.

A.4 NATIONAL LEGISLATION

A.4.1 LOCAL GOVERNMENT (WATER POLLUTION) ACTS, 1977-1990

The Local Government Water Pollution Acts 1977-1990 and associated regulations provides for the management of water quality and the prevention of water pollution and the licensing of trade and sewage effluents in Ireland. The regulation of certain agricultural activities including the collection, storage, treatment and disposal of any polluting matter on land for the purpose of agriculture, horticulture or forestry are covered. The application and/or injection of silage effluent, animal slurry, manure, fertiliser, pesticides or other polluting matter to land or growing crops are controlled under section 21 of the Local Government (Water Pollution) (Amendment) Act, 1990.

Local authorities have powers under this legislation to make byelaws in relation to prevention of environmental pollution from agricultural activities. Local authorities have further powers under section 21 of the Local Government (Water Pollution) (Amendment) Act, 1990 as amended by section 66 of Waste Management Act, 1990 to require the preparation of nutrient management plans by owners/occupiers of lands where certain agricultural activities are carried out. Nutrient management planning provides an operational framework for the agronomically efficient and environmentally safe use of organic fertilisers, organic wastes and chemical fertilisers.

A.4.2 LOCAL GOVERNMENT (WATER POLLUTION) ACT, 1977 (WATER QUALITY STANDARDS FOR PHOSPHORUS) REGULATIONS (SI NO. 258 OF 1998)

These regulations have been introduced under the requirements of Council Directive 76/646 i.e. the Dangerous Substances Directive to deal with the increasing problem of eutrophication of rivers and lakes in Ireland. The regulations require that water quality be maintained or improved by reference to biological quality rating/trophic status or phosphorus concentration.

Where water quality is deemed unpolluted (rivers) or satisfactory (lakes) the regulations require that the existing biological quality of rivers and lakes be maintained at the same level as assigned by the EPA during the period 1995-1997. The biological quality is based on the trophic status (level of enrichment) for lakes and the Q value system for rivers. Where quality has been found to be unsatisfactory, the regulations require that the water be improved by the 31 December 2007 at the latest for waters surveyed in the period 1995-1997 and within a maximum timeframe of ten years for waters surveyed after 1997. The degree of improvement required is based on the existing quality and standards prescribed by the regulation. Local authorities have primary responsibility for ensuring that the standards set by the Regulations are met.

Run-off of phosphorus from soils to waters has been identified as one of the main contributing factors to water quality deterioration. There is very strong evidence to suggest that nutrient loss from agriculture, including farmyards, is now the single biggest source of pollution problems in Ireland's rivers (Lucey *et al.,* 2000). Siltation and other effects due primarily to soil erosion from overgrazing by sheep and bog and forestry development are responsible for much of the slight to moderate pollution caused in the west of Ireland.

A.4.3 EPA ACT, 1992 AND ASSOCIATED REGULATIONS

One of the primary aims of the EPA Act, 1992 was to improve environmental protection and pollution control in Ireland. The EPA Act defines environmental protection and environmental pollution and in relation to soils states "*environmental pollution means - the disposal of waste in a manner which would endanger human health or harm the environment and in particular - create a risk to waters, atmosphere, **land, soil**, plants or animals*".

The EPA Act also provided for the introduction of an integrated pollution control licensing system for industrial activities. In relation to soil the activities of importance would include those involved in waste disposal to soils via landfill or landspreading including:

- mining activities and peat extraction;
- energy production and ash disposal;
- intensive agriculture (pig and poultry);
- food and drink (including the manufacture of vegetable and animal fats and oils, dairy products, sugar, fish meal and oils, the slaughtering and rendering of animals; and
- fell mongering.

Activities applying for an IPC licence must provide information on their manufacturing processes and waste disposal operations and give details on emissions made to ground and assess their impacts. In addition existing and /or new activities are required to give details on all know historical pollution incidents which have occurred on site and where appropriate provide an assessment of ground and groundwater contamination of the site. The EPA is prevented from granting a licence or revised licence unless it is satisfied that any emission from the activity does not result in the contravention of any relevant air and/or water standard and any relevant standard for an environmental medium prescribed under the European Communities Act, 1972.

The EPA is required under section 75 of the EPA Act, 1992 to specify and publish quality objectives in relation to any environmental medium for the purposes of environmental protection. This document represents the first step in fulfilling the EPAs requirement under this section of the Act, for soil.

A.4.5 WASTE MANAGEMENT, 1996 ACT AND ASSOCIATED REGULATIONS

The primary aim of the Waste Management Act, 1996 is the prevention, management and control of waste. The Act establishes a licensing and permitting system for waste disposal and recovery activities such as landfills, transfer stations, hazardous waste facilities, composting facilities and landspreading. The Act confers powers and responsibility on both the EPA and Local Authorities relating to environmental pollution arising as a result of waste disposal and waste recovery activities. The granting of a waste licence is prohibited if any emission from an activity contravenes any relevant environmental standard for a medium (includes soil, land, water and atmosphere). In addition existing and/or new activities applying for a waste licence are required to provide details on all known historical pollution incidents which have occurred on-site and where appropriate provide an assessment of ground and groundwater contamination on-site.

Section 22 of the Act requires each local authority to prepare a Waste Management Plan (WMP) detailing its approach to waste prevention, minimisation, recovery and disposal of waste within its functional area. The Waste Management (Planning) Regulations, 1997 (SI No. 137) require that the plan should specify the quantities of wastes arising within their functional areas. Contaminated soil is a category of waste which is required to be quantified and the nature of contamination should be specified.

The EPA was required to prepare a National Hazardous Waste Management Plan (NHWMP) under section 26 of the Act. The plan was published in 2001 and provides for the establishment of a framework for the management of sites, which have been used for the disposal of hazardous waste.

Certain landspreading activities are dealt with under various sections of the Act and associated regulations. The main provisions include the exemption under section 51 for the recovery of sludges and agricultural waste from the requirement to hold a waste licence or permit. Waste types exempted include residual sludge from sewage treatment plants and septic tanks, faecal matter of animal and poultry origin in the form of manure or slurry and blood of animal and poultry origin. All other waste types, which are applied to land either on a recovery or disposal basis, require either a permit from the local authority or a waste licence from the EPA.

The EPA is of the opinion that the application to blood to land and soil under any circumstances cannot be considered a recovery activity due to the risk of environmental pollution and the potential risk to animal and human health. The Agency has recommended that blood arising from activities requiring an IPC licence must be sent for rendering. Under the IPC licensing system, no blood can be applied to land even by injection.

A.5 POLICIES AND CODES OF GOOD PRACTICE

A.5.1 COMMON AGRICULTURAL POLICY AND AGRI-ENVIRONMENT MEASURES

The Common Agricultural Policy (CAP) was conceived to address the problems of food shortages and under development following the Second World War. Under the CAP technological advances and price/production supports have dramatically increased farming productivity. This has resulted in food surpluses with many of the production-linked supports contributing to environmental problems in the EU.

Policy reforms in recent years have tended to lead to a reduction in supports linked to production, which together with a growing share of environmentally-targeted budgetary payments to farmers, have the potential to improve environmental performance in agriculture (*OECD, 1998*). Other policy measures include reductions in market price support and input subsidies and increases in direct income payments. Three specific measures, an “agri-environmental” regulation, a forestry scheme and an early retirement scheme accompanied the 1992 CAP reforms. ‘*Council Regulation (EEC) No 2078/92 on agricultural production methods compatible with the requirements of the protection of the environment and the maintenance of the countryside*’ was adopted in June 1992 and implemented in Ireland through the Rural Environment Protection Scheme (REPS).

The Agenda 2000 Agreement of March 1999 provides the framework for all structural activities throughout the EU for the period 2000-2006. In relation to agricultural the framework is built around the importance of improving competitiveness of the agricultural and agri-food sector. This will be achieved through a programme of phased reduction in price supports for beef, milk and arable crops with compensation paid to farmers in the form of direct income support. In addition, the need for an integrated rural policy, including the environment, to accompany the reform process has been recognised and built into the national CAP Rural Development Plan, which was approved recently by the EU Commission and forms part of the National Development Plan 2000-2006. The CAP Rural Development Plan provides four support measures covering early retirement, compensatory allowances, agri-environment and afforestation. These measures will help improve agricultural structure, support farm incomes and enhance the environment through an agri-environmental programme i.e. REPS and sustainably managed afforestation programme, compatible with the protection of the environment. The objectives for each measure are taken from Council Regulation (EC) No. 1257/99 (DAFRD, 2000a).

A.5.2 RURAL ENVIRONMENT PROTECTION SCHEME (REPS)

The Rural Environment Protection Scheme was launched in June 1994 and approximately 45,000 farmers are currently participating in REPS, which represents about 1.5 million hectares of land being farmed under REPS guidelines. It is anticipated the numbers participating will increase over the coming years particularly as a result of recent revisions to provide for increased payments to farmers in Natural Heritage Areas and commonages. The objective of REPS is to establish farming practices and production methods which reflect the increasing concern for conservation, landscape protection and wider environmental problems; to protect wildlife habitats and endangered species of flora and fauna and to produce quality food in an extensive and environmentally friendly manner. The agri-environmental measures specified under REPS should aim to achieve environmental benefits over and above those achieved through the application of good farming practices.

There are eleven basic agri-environmental measures which farmers participating in REPS must comply with. These include measures in relation to nutrient management planning, grassland management, protection and maintenance of watercourses and wells; reducing the use of pesticide, herbicides and fertilisers, retaining wildlife habitats, maintaining farm and field boundaries, protecting archaeological features etc. In addition, Supplementary Measure A was introduced to deal specifically with farmers in REPS whose land is designated as a Target Area. Target areas are lands, which have been designated or proposed as NHAs, SACs or SPAs and commonages. Additional supplementary measures were introduced under the REPS scheme to resolve specific environmental problems such as long-term set-aside of riparian zones, organic farming (CR 2092/91) and rearing of local breeds in danger of extinction (DAFRD, 2000b).

Participating countries are required to monitor the changes carried out by REPS farmers and to evaluate the effectiveness of the measures with respect to environmental, agricultural and socio-economic objectives (CR 747/96). A recent Government evaluation of REPS indicated that it was having positive effects including a reduction in the use of fertiliser on farms and increased awareness of environmentally sensitive farming practices. However, the review does identify the need for better evaluation procedures and indicators (Stapleton *et al.,* 2000). The lack of adequate baseline information in REPS plans and the absence of a formal countrywide environmental monitoring programme of representative farms make it difficult to assess the environmental benefits of REPS on a national basis.

A.5.3 CODE OF GOOD AGRICULTURAL PRACTICE TO PROTECT WATERS FROM POLLUTION BY NITRATES

The preparation of a Code of Good Agricultural Practice to protect waters from pollution by nitrates was a requirement under the Nitrates Directive (DoE and DAFF, 1996). The Code was required to cover measures listed in Annex II of the Directive such as timing of fertiliser applications, restrictions on applications to steep ground, waterlogged, frozen ground and proximity to watercourses. Recommendations on the rate of application of both chemical and organic fertilisers to minimise loss to the aquatic environment should also be included. The inclusion of additional items such as nutrient management planning on a farm by farm basis and crop rotation was optional. The Code of Good Practice is to be implemented by farmers on a voluntary basis in all areas other than designated vulnerable zones.

The aim of the voluntary code is to promote sustainable farm practices while maintaining high water quality standards. Water quality standards are assesses by Local Authorities. Where nitrates levels rise close to or above 50 mg/l, the areas of land draining into the affected waters will be designated as vulnerable zones.

The code is essentially a list of good farming practices which, if applied, will benefit the farmer and the environment. It makes recommendation on good farming practices in relation to:

- storage of animal manures, soiled water and silage effluent;
- timing and application rates for organic and chemical fertilisers;
- additional precautions to prevent water pollution; and
- nutrient management.

The code specifies recommendations on stocking rates and application of organic nitrogen to land. In areas supporting high stocking rates and where nitrate concentrations in water are less than 20mg/l and where there is no evidence of eutrophication, the amount of livestock manure applied to land each year, including by the animals themselves does not exceed 250kg/ha/yr. In all other areas the maximum applied should not exceed 210kg/ha/yr. The maximum hydraulic loading per single application should not exceed $50m^3$ per hectare or $25m^3$ in karst areas.

A.5.4 GOOD FARMING PRACTICE

Reforms to CAP and recent negotiations of Agenda 2000, have placed increasing emphasis on environmental concerns in agriculture. The EU has attached environmental requirements to various EU schemes, including:

- Arable aid;

- Disadvantaged Area Compensatory Allowances Scheme;
- Installation Aid Scheme;
- Livestock Premia Schemes e.g. suckler cow, ewe and special beef premium etc.;
- On-farm investment schemes e.g. investment aid for farm waste management etc.;
- REPS; and
- Scheme of early retirement (transferees).

Under EU Regulations the DAFRD is required to implement Good Farming Practice (GFP). In response to this requirement, the DAFRD have prepared a booklet on GFP which outlines key aspects of good farming practice which farmers are required to implement on their farms (DAFRD, 2001). Good farming practice is defined as " common-sense farming which cares for the environment and meets minimum hygiene and animal welfare standards". There are penalties for non-compliance with GFP, which take the form of reductions in payments or non-payment of EU subsidies.

Some of the key environmental aspects of GFP include nutrient management, grassland management, protecting watercourses and wells, maintaining wildlife habitats, protecting archaeological features and careful use of pesticides and chemicals including chemical fertilisers and oils. In relation to soil protection and degradation, GFP advises that farmers are required to adopt grassland management practices, which avoid severe poaching, overgrazing, and soil erosion.

A.5.5 CODE OF BEST FOREST PRACTICE

The aim of the Code of Best Forest Practice is to provide guidance at the operational level to ensure sustainable development of the Forestry Sector in Ireland. The main objective of the strategic plan for forestry sector is " to develop forestry to a scale and in a manner which maximises its contribution to national economic and social well-being on a sustainable basis and which is compatible with the protection of the environment" (DAFF, 1996). It describes all forest operations and the appropriate manner in which they should be carried out to ensure the implementation of sustainable forest management.

In the Code, emphasis is placed on ensuring the various environmental, economic and social forest values are recognised throughout the forest life-cycle and that adverse impacts associated with of forest operations are avoided, minimised and monitored (Forest Service, 2000). The forest values which have been identified in the code, and which should be safeguarded during the planning and management of forest operations include:

- Environmental values - soil, water quality, landscape, ecological and scientific values, cultural and archaeological values, biodiversity and forest protection and health;
- Economic values- sustained productivity and commercial viability; and
- Social values – rural development and farm forestry, amenity and recreation, safety and other community values.

The Code of Best Forest Practice provides guidance and best practice in relation to the forest operations throughout the forest cycle. In relation to environmental protection, the Code identifies potential adverse impacts of afforestation and reforestation and recommends best practice at each stage of the cycle. The potential for soil degradation is highlighted in the Code particularly during operations such as site preparation for afforestation, thinning, final harvesting, forest road construction and reforestation.

In addition to the Code, five Environmental Guidelines relating to water quality, archaeology, landscape, biodiversity and harvesting have been developed. Adherence to the Guidelines is a condition of grant aid and felling licence approval and is the mechanism by which the Forest Service will ensure that the environmental aspects of sustainable forest management are implemented. The five Environmental Guidelines are:

1. Forestry and Water Quality
2. Forest Harvesting and Environment
3. Forestry and Archaeology
4. Forestry and Landscape

5. Forest Biodiversity

The Guidelines on water quality and harvesting emphasis the potential for soil degradation and deterioration to the aquatic environment and recommend best practice to avoid and/or minimise such impacts.