SUSTAINABLE DEVELOPMENT OF SOILS IN WESTERN EUROPE-AN OVERVIEW

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INTRODUCTION

In December 1989 the United Nations General Assembly called for a global meeting to discuss and devise strategies to halt and reverse the effects of environmental degradation. Following the adoption of Agenda 21 by the United Nations Conference on Environment and Development in June 1992 (United Nations 1992), increasing focus has been given to sustainable development. Agenda 21 called on governments to prepare national strategies for sustainable development and to report on actions to implement them, on the problems faced and on other relevant environmental issues. Perhaps more than any other single initiative, it has led to a rigorous investigation into the extent that mankind is damaging the environment, the potential effects of such damage and the overall sustainability of the use being made of the planet. Much attention is now being been given to the sustainability of the natural resources, of which the soil is one of the three most important.

Two aspects of soils need to be considered in respect to sustainable development. Firstly, there is increasing recognition that the major soil functions (Table 1, Bullock and Gregory, 1991a) should be protected i.e. sustainable development of the soil resource itself. Secondly, there is a strong link between soil properties and processes, the use that is made of the soil and the wider environment, e.g. in relation to water quality, greenhouse gases. It is necessary to understand and manage this link to achieve sustainable development.

This paper summarises the problems that have emerged and are emerging in the sustainability of the soils of Western Europe and identifies some of the changes that may be necessary to maintain the soils at an adequate standard for future generations.

THREATS TO THE SOIL RESOURCE

There are five main sources to the problems that are affecting the soils of Western Europe and which jeopardise their sustainability (Bullock and Thompson, 1996).

Legacy of industry: The 18th and 19th centuries saw huge industrial expansion, particularly of heavy industry which was demanding of natural resources and used large amounts of fossil fuels. One of the consequences of this, in evidence over the last 200 years, has been acid rain caused mainly by atmospheric emissions from chimneys. It means that for decades soils in many parts of Western Europe have been leached by rainwater with a pH of around 4, and this has had important repercussions

Table 1. Soil Funtions.

Economic	Food crops, energy crops, timber. Sand, gravel, minerals. Foundations for buildings and roads.
Ecological	Nutrient supply, cycling, storage. Ecological habitats. Cycling of water and air.
Biological	Habitat for soil fauna and microflora. Gene bank. Food for groundfeeders, e.g. birds.
Hydrological	Water storage, flow control, absorption, and amelioration.
Pollutant Control	Source and sink for pollutants. Waste disposal medium.
Gaseous Exchanges	Source and sink for greenhouse gases.
Landscape and Cultural Heritage	Indicator of landscape evolution. Preservation of archaeological and palaentological material.

for soil functions and the wider environment, especially the quality of surface water.

The other main legacy of industry is contaminated land. Most West European countries have numerous sites contaminated to varying degrees by industrial use (de Haan, 1987). In the UK, for example, estimates of the area of contaminated land have ranged from 50,000-200,000 ha (almost 1% of Britain) implying that the number of contaminated sites may be in the order of 100,000 (Royal Commission on Environmental Pollution, 1996; (House of Commons, 1991). The uncertainty about the exact number reflects how poorly documented such sites are.

In addition to these industrial sources of contamination is that associated with the major industrial accidents, the best known of which is the Chernobyl nuclear accident. This left a cumulative deposition of Cs-137 across Europe (Stanners and Bourdeau, 1995), the effects of which are still being felt in that the use of some affected land is still restricted.

The built environment: Countries of Western Europe have experienced significant increases in population in the last 100 years although in the last decade the rate of increase has greatly reduced. One of the effects of this population increase has been the increased demand for housing, roads and the extension of urban development, which in turn has led to increasing amounts of land being taken for building. Soils that are built on usually lose all their functionality, apart from acting as a foundation for the built environment in its various forms (Bullock and Gregory, 1991b). In the UK about 1 per cent of land is lost per decade to urbanisation.

1994). Soil erosion by which particulate matter is moved from the land to off-field sources, such as lakes and rivers, is seen as a key transport mechanism for P to water. There appears to be less movement of P once it is within the soil, though there is some evidence that once threshold levels are exceeded, P in the soil may be mobilised and transported within the soil medium. Heckrath et al., 1995 showed that up to 60 mg extractable P/kg soil, hardly any P could be detected in the water leaving the soil profile, whereas at levels above 60 mgP/kg soil there was a rapid and linear increase in P, mainly as dissolved P in proportion to soil P concentrations. Some soils in Western Europe are saturated with P, e.g. The Netherlands where 80% are estimated to be so (Stanners and Bourdeau, 1995). The fact that large amounts of P have been added to soils over the last 50 years and the fact that both overland and within-soil mechanisms exist for its transfer make it a difficult nutrient to manage.

The EC drinking water directive (EC, 1980) specifies the minimum quality requirements for drinking water supply. The minimum admissible concentration (MAC) of any pesticide in drinking water is set at 0.1μg l^{-1} for individual compounds and 0.5 μg l as the combined total for all compounds. Pesticides can affect soil functions, particularly the biological one, and since they are subject to movement in the soil with water or attached to particles there are various mechanisms by which they can be transferred to the wider environment. However, in Western Europe there is little evidence that the soil functions are being damaged by the use of pesticides. For example, Bromilow et al., (1966) found no evidence of long term pesticide treatments damaging soil fertility or harming the effects of measured microbial problems. There is abundant evidence that pesticides can be transferred through the soil profile to water courses and aquifers and there are many examples of this in Western Europe (e.g. Suett et al., 1996). Management of pesticides in soils is hindered by the fact that there are several hundred different compounds with different behaviour patterns, e.g. some are strongly adsorbed and others weakly so. Their behaviour is also influenced by the time of application and the crop to which they are applied. Their safe management on soils can be difficult to achieve and much research is currently being expended on application management. Pesticides have been used extensively in the last few years but the European legislation combined with better understanding of the fate and behaviour of the compounds means that there are fewer incidents of pollution.

ADAPTATIONS AND MITIGATIONS REQUIRED TO IMPROVE THE SUSTAINABLE DEVELOPMENT OF WESTERN EUROPEAN SOILS

As pointed out by van Lynden (1994), there are two principal approaches to controlling soil degradation: (i) to seek to identify the source of the problem and take steps to change the source so as to diminish or remove the problem; (ii) to aim to treat the adverse effects where they occur with a view to reducing the extent of the problem. Treating the source of the problem has much to recommend it since it is preventative by nature though initially at least it may be expensive. It also lends itself to a more integrated approach to pollution and degradation control because a single source can give rise to more than one form of degradation. For example, emissions of N from industrial sources can contribute to acid rain as well as deposition of unwanted nitrogen on sites of special scientific interest. Treating the adverse effects on the soil as they occur is a trouble shooting approach and may be subject to reoccurrence of the problems because the causes have not been addressed. Much is now known about the nature of the soil degradation problems in Western Europe. There now needs to be a strategic plan on the part of West European governments, supported by the European Environment Agency to implement

changes to the sources sufficient to bring soil degradation under control.

Industrial influences

Much is already being done to reduce the impact of industry on the soil resource. Following the Rio Summit, nations were charged with bringing about a reduction in emissions. Several countries in western Europe are working to a set strategy for such reductions and improvements are already being recognised. According to Stanners and Bourdeau (1995), most West European countries have demonstrated reductions in SO_2 omissions in the last decade. No such reductions have been identified in respect to NO_x a matter of concern in view of the estimate of Grennfelt et al., (1994) that nitrogen deposition contributes 30-80% of the acidity of the Netherlands, for example. It is extremely important that emissions continue to be reduced so that damage to the soil resource from this standpoint is limited. Reduction in emissions are essential if acid rain and other unwanted and unregulated additions to soils are to be controlled at an acceptable level.

There is now a much greater awareness of the potential damage to soils, and in turn to plants, fauna and humans, from contaminants. The somewhat carefree approach to the release of contaminants to soils has been replaced by increasing regulation to prevent the deposition of contaminants on soils. For example, the European Environment Agency is now in place and there are more or less strong national Environment Agencies setting legislation or monitoring the observance of it. Thus, new contamination is likely to be less frequent than in the past and be more related to accidents than to ignorance and lack of care. The problem remains, however, that most of the existing contaminated sites are difficult and costly to decontaminate to an acceptable level whereby the soil can be expected to regain most or all of their functions. In most countries of Western Europe there is no comprehensive inventory of existing sites so that the scale, extent and severity of contamination is not well known. This should be redressed and be one of the responsibilities of the European Environment Agency. It is important to know the location, contaminants and risk sites even if clean-up is never attempted.

Agricultural and Forestry Influences

As pointed out earlier, agricultural practice, particularly in the last 50 years has had a major influence on the soil resources of Western Europe and has been responsible for both good and bad effects. The major good effect has been in the maintenance of nutrition of the soils. By and large the nutritional aspects of soils, particularly under arable agriculture, has been well catered for. Both the pH and levels of N, P and K have been maintained at least at adequate levels and in many cases fertiliser and lime surplus to crop needs have even been applied.

Several of the problems are associated, at least in part, with deterioration in the levels of organic matter which have contributed to increasing structural instability leading to capping and compaction and to increasing soil erosion, which in turn effects the movement of soil nutrients and pesticides off-field to water courses. Insufficient is known about the extent to which soil biodiversity is affected by lower levels of organic matter but it would be surprising if it was not. It is thus extremely important for organic matter levels to be maintained at a reasonable level. This can be achieved in a number of ways: rotation with crops which provide abundant residues, rather than adopting monoculture; incorporation of straw and other crop residues e.g. instead of burning stubble; addition of waste materials to the soil. With respect to the latter there will be huge pressure on the land of Western Europe to accept waste, now that deposition at sea is to be banned from 1998. Relatively little is known about the effect of the different forms of waste in soils and their

value as organic matter once they are in the soil. It will be essential for research programmes to be developed which specifically address this need for knowledge. Alongside the need for research is also the need for legislation which protects the soil from undesirable forms of waste application. Provided the above needs are met, there is significant potential for the use of waste on land to improve the organic matter content and this should receive the support of national governments by appropriate funding for research that will initially be necessary, pump priming to get the ideas taken up and legislation to prevent damage being done to the soil by inappropriate use of waste. Maintaining healthy levels of organic matter in soils must be a cornerstone of soil quality maintenance and sustainable soil development.

Improvements in organic matter levels will go some way to improving soil structure and lessening compaction. Natural compaction is difficult to improve. It usually involves deep cultivation of the soil with heavy machinery. Man-made compaction is easier to redeem because it is mainly, though not solely, damage to the topsoil and hence more easily available to machinery for disturbance of the compaction. The principal man-made compaction damage is by agricultural machinery working the land when the soil moisture content is too high and by overstocking of the land by livestock again when the soil is too wet. A combination of maintenance of organic matter levels and choice of farming systems that free the farmer or other land user from working the soil when it is too wet would remove most of the problems of man-made soil compaction. Similarly, where land is used for livestock, the number of livestock should be appropriate to the soil type and moisture conditions to avoid compaction from overstocking.

There is little doubt that soil erosion is an increasing problem in Western Europe. No country can afford to have its resources degraded beyond redemption. It has been difficult to get policy makers to accept that erosion is a major issue to be dealt with. However, the fact that erosion is now being seen as a primary mechanism for the movement of would be pollutants from land to water is causing concern and may now lead to the European Environment Agency calling for legislation to reduce erosion.

The causes of erosion are generally known and in most of Western Europe it would be possible to prescribe agricultural systems suitable for particular areas of land. This now needs to be done for vulnerable landscapes. Using the now considerable knowledge of the soils of Western Europe, it is possible to identify the problem areas and with the support of models such as EUROSEM for predicting the likelihood of erosion (Morgan et al., in press a & b) and the vast knowledge internationally of soil conservation methods, agricultural systems adapted to these vulnerable landscapes need to be introduced. The Common Agricultural Policy has been responsible to a large extent for the increase in soil erosion because it encouraged well subsidised crops to be grown on land that was unsuitable for the particular crops because of its vulnerability to erosion. It will be interesting to see the extent to which CAP will be modified in ways that will check the increase in soil erosion. The information base is largely in place - it now needs the driving force of a policy.

Acidification is not a major problem in most of Western Europe where the land is being used for agriculture. The main problems are on forested lands where few if any liming measures are carried out and there is, therefore, little compensation for the acidifying effects of acid rain and the largely coniferous plantations that are established. An added problem is that the buffering capacity of many of these soils is very low and hence is their resistance to various forms of degradation. Now that the emissions leading to acid rain are being addressed, one of the major acidifying influences is being reduced. Further improvements could be brought about by introducing mixed plantations which contain a proportion of less acidifying species although the drawback of using less acidifying deciduous

species is that in the climate of Western Europe they are slow growing and hence uneconomic in a commercial sense. Increasingly, there is information available on soil types and their properties and it should be possible to afforest and reafforest with species better suited to the native soil properties, more than has been the case in the past.

One of the major areas of concern at present is the fate and behaviour of chemicals applied to the soil, particularly nitrates, phosphates and pesticides. The soil is an important regulator of this fate and behaviour. With respect to nitrates while the vulnerability of soils to leaking nitrates to aquifers can readily be predicted, there is then the need to modify the amounts of nitrates fertiliser added particularly to the vulnerable soils. In some West European countries already Nitrate Vulnerable Zones have been identified and the amounts of nitrate fertiliser that can be added has been regulated in these zones.

The solution is not a simple one since yield and economic return are greatly dependent on the ability to use nitrogen fertiliser. Much research has been undertaken in recent years to investigate changes in management of agricultural systems to limit the losses of nitrate. Examples include improvements to the timing of nitrogen applications in relation to crop needs, the use of cover crops such as rye, turnips, white mustard, forage rape and the management of manures.

Most phosphate transfer from land to other parts of the environment results mainly from soil erosion. Hence measures that will reduce erosion will benefit reductions in loss of phosphorus from the land. Some leaching of phosphorus can take place in the soil (Heckrath et al., 1995) but early indications are that it is associated with high levels of phosphorus, higher than are usually found in most soils. Further research needs to be undertaken to verify this. A combination of erosion prevention measures and a regime which seeks to restrict the amounts of phosphorus applied to actual crop needs would reduce the current problems with respect to phosphorus transfer in the environment.

Pesticide fate and behaviour is more complex than that of phosphorus or nitrogen and a wider range of factors control it. To understand the fate and behaviour of pesticides in soils, it is essential to understand the properties and processes related to the soils in which pesticides are to be applied. Applications should be crop, land management and soil specific. If the inter-relationships of these factors are well understood, there is the opportunity for more precise prescriptions for the application of pesticides which would be expected to reduce the problem of pesticides in ground and surface waters.

CONCLUSIONS

There are a number of fundamental requirements for the successful sustainable management of West European soils:

a. a good understanding of the nature of the soils and their properties.
b. strong national soil/land databases which can be regularly added to and which provide the basic information on which to develop a sustainable soil development policy and put it into practice.
c. a knowledge of soil quality, and the soil quality requirements for the particular land uses. This will involve identifying the important parameters that indicate soil quality and the ability to be able to monitor changes in these parameters over time and under different types of land use. There is a major weakness currently in that very little trend data occurs for the soils of Western Europe. Most such data are restricted to experimental farms, and national overviews are lacking.
d. a much better understanding of the effect of particular types of land use and management practice on the soil i.e. what is the impact over a year, a decade, a century or other set of suitable time scales.

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