SOILS AND LAND USE PLANNING

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PREFACE

This book is based on an introductory course on applied pedology which I have taught at St David's University College, Lampeter, and at the University of Strathclyde, Glasgow. The aim of the course is to demonstrate to middle-level students how soil information can aid land use planning. The need for a short text on this topic is very apparent since none is available and relevant literature is scattered throughout a wide range of journals and reports. In the preparation for this book I became aware of the marked differences between various countries in the application of soil information to planning and thus I began to discern the need for a short text designed to encourage the broader use of soil survey data. It is thus very much the hope that the book will be useful not only to geography or other environmental science students interested in the application of pedology, but also to planners and members of planning committees who make decisions about the use of land.

I wish to thank all the authors who kindly sent me reprints of their work. In particular I am grateful to Mr R. Grant, Soil Survey of Scotland for providing the annotated aerial photograph for Fig. 2.1, and to Mr L. Lynch, Soil Conservation Service, New South Wales, for Figs 3.3 and 3.4. My study visit to the Netherlands in preparation for this book was made possible by financial assistance from the Carnegie Trust for the Universities of Scotland and from the University of Strathclyde. In the Netherlands I benefited from discussions with Professor A. P. A. Vink, Dr J. C. F. M. Haans and other members of the Soil Survey Institute. I am grateful to Mr C. J. M. Kraanen who arranged the details of my visit. I thank my co-editor, Dr J. A. Dawson, for his encouragement and comments on a draft of the text. Dr E. M. Bridges very kindly read the text for me and offered useful suggestions. Despite the help from all these friends, I alone am responsible for any errors or misrepresentations.

I am grateful to the secretarial services in the Department of Geography, University of Strathclyde, and in particular to Mrs M. MacLeod. The diagrams were drawn by the cartographers in this department and I wish to thank especially Mrs M. Walker for all her help. It is with pleasure that I also record the friendly collaboration with Mr I. Stevenson of Longman, not only with this book, but also with all the others in the series. In conclusion I acknowledge with affection all the support of my wife, Caroline, who has maintained domestic normality over recent months despite my sometimes erratic and remote behaviour and has also found time to correct and improve my English.

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April 1979

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INTRODUCTION

The ever increasing pressure on land means that planning decisions ought to be made only after comprehensive analysis of all relevant factors. In terms of land use one such factor is the nature of the soil. This is most obvious in agriculture, but the assessment of soil conditions is also very relevant to the planning of other land uses, for example forestry and recreation. The long-standing emphasis of soil science has been on agriculture, but in recent years there has been a distinct broadening in application of the subject. The aim of this short book is to present an integrated review of soil assessment procedures based primarily upon the work which has been done in Western Europe, North America, Australia and New Zealand. The topic is very clearly one in applied geography since the focus is on methods of physical resource assessment relevant to land use planning. The hope is that this book demonstrates to geography and other environmental science students the application of soil expertise to the planning and management of land use. The intention is also to indicate to planners and to others who make land use decisions the types of useful information which soil scientists can provide.

As will be demonstrated in this book, the awareness of soil properties and how soils vary in space can be of tremendous advantage in the design of a land use plan. The incorporation of a soil input to planning has several merits. The ultimate costs of a plan can be better estimated if the physical difficulties are known; it is ecologically and aesthetically desirable for the design of an area to blend in with its natural environmental base, and when pressures are great on land, conservation demands that land most suitable to particular uses is retained for such purposes. In countries such as the Netherlands, Australia, Canada and the USA, there seems to be an awareness of the application of soil data to planning. In the Netherlands this is because of the extreme pressures on a limited land area as well as a strong national tradition in applied science. In Britain there is still much work to be done to publicise the importance and usefulness of soil to planning in the broadest sense.

The dominant theme in this book is how soil survey information can be interpreted and presented in a form helpful to land use planning. The book is designed for use on middle and upper university and polytechnic courses. The assumption is that the reader has completed a foundation course in physical geography or environmental science which included consideration of the basic nature and properties of soils. Readers without such backgrounds are referred to introductory texts such as those by Bridges (1977), Briggs (1977), Bunting (1972), Courtney and Trudgill (1976), Cruickshank (1972), FitzPatrick (1974), Jacks (1954) and Russell (1957). An introduction to British soils is given by Curtis, Courtney and Trudgill (1976). More advanced texts on soil science are provided by Brady (1974), FitzPatrick (1971), Foth and Turk (1972) and Russell (1973). Overall guidance on the literature of soil geography is given by Bridges (1977). Readers not familiar with soil survey work are urged to study any recent soil map and associated memoir produced by a national soil survey. Such a memoir not only describes the types of soil within the mapped area, but also the techniques used in the survey and usually some assessment of the various soils for land use purposes.

As will become apparent, there is a very wide literature dealing with the assessment of soils but there are few texts on the subject. Brook (1975) has compiled a bibliography of selected references for the period 1960 to 1972. The first major monograph was written by Jacks (1946), but this was not followed until the text by Bartelli *et al*. in 1966. It was only in the 1960s that techniques of land assessment began to be widely developed, tested and applied to different planning problems – reflected in the Bartelli *et al.* text and in a major symposium held in Canberra in 1966 which resulted in the volume by Stewart (1968). The first definitive text written by one author is by Vink (1975); another major contribution is by Young (1976), although this study is focused on the humid tropical environment. Whyte (1976) also draws together much of the material, but with an emphasis on South-East Asia. Another relevant text is by Mitchell (1973), though the emphasis in this book is on terrain analysis. An advanced text dealing very much with the principles and methodology of land evaluation is provided by Beek (1978).

A conference organised by the Agricultural Development and Advisory Service and the Soil Survey of England and Wales discussed the application of soil data to a variety of planning situations (Ministry of Agriculture, Fisheries and Food, 1974). A comprehensive review monograph on land classifications has been written by Olson (1974); review papers are provided by Trudgill and Briggs (1977) and Young (1978). A special issue of the journal *Photogrammetria* in 1970 was devoted to the topic of terrain classification and evaluation whilst the journal *Geoderma* focused attention on the non-agricultural applications of soil surveys (Simonson, 1974). The Welsh Soils Discussion Group devoted their conference papers in 1975–76 to the theme of soil survey interpretation and use and these papers have subsequently been published (Davidson, 1976a). A conference held at Cornell University has resulted in a useful publication entitled *Soil resource inventories* (1977). Albers, Krul and van Lanen (1975) compare various West European land classification systems.

This brief summary of the literature dealing with the subject in general terms is sufficient to illustrate the intensity of research effort and the virtual absence of introductory texts. The intention of this book is to fill this gap at least partially. Every attempt has been made to refer to all major publications concerned with soils and land use planning, but the vast number of research papers and reports necessitated a rather selective approach. Apologies are offered to scientists whose work is not referred to in this book. One danger in a book of this type is that full comprehension is only possible if the reader follows up a large number of the references. This is clearly undesirable from the undergraduate viewpoint and thus an outline is given wherever possible of most referenced publications. Nevertheless the reader would obviously benefit from following up references and also seeking out new publications by the use of such abstracting journals as *Soils and Fertilizers* and *Geoabstracts*.

In no way is this a book on planning, nor is its aim to make planners applied pedologists. Instead the hope is to show students of soils how their subject can be applied to land use planning and to indicate to planners the contribution which pedologists can make to their work. In this latter situation it is essential for planners to know the types of questions which a pedologist can tackle and thus it is important for planners to be aware of the spectrum of techniques at the disposal of the applied pedologist.

CONTENTS

CHAPTER 1
SOIL RESOURCES AND PRESSURE ON LAND

'With increasing pressure on land, and a wakening political and popular awareness of environmental qualities, data on soil resources have become valuable tools in planning.' M. Ćirić (1975, p. 2)

1.1 INTRODUCTION

To a very large extent, research in soil science has been motivated by land use problems and this is particularly the case with the production of soil maps. Thus, soil science is clearly a practical or applied subject. This is not to deny that many soil scientists pursue research into topics which may appear to be extremely theoretical and remote from land use problems, but the underlying assumption is that such investigations can aid an understanding of pedogenic processes and may thus lead to practical benefits. In Britain serious interest in soil conditions first arose with the agricultural improvement movement in the eighteenth and early nineteenth centuries. During this period a series of county agricultural reports were produced by the first Board of Agriculture. For example, Keith (1811) was the first to produce a rudimentary soil map for Aberdeenshire; he also provided detailed descriptions of methods of land improvement and management which were in part conditioned by soil characteristics. In Britain during the nineteenth century the main advances in soil science were in agricultural chemistry and soil bacteriology – again orientated to the practical issue of soil fertility.

The foundations of *pedology* as a distinct subject area within soil science were established in the latter half of the nineteenth century by Vasilii Dokuchaev and his co-workers in Russia. In a strict sense pedology is the study of soils as they naturally occur in terms of their profile characteristics, spatial distribution and processes of formation. Dokuchaev and his team were commissioned to carry out various geological–geographical surveys and this led him to propose a classification of natural soils (Cruickshank, 1972). Thus such terms as podzol, sierozem, solonchak, and chernozem were introduced. In addition he proposed a conceptual framework whereby soils were interrelated with such characteristics as geology, geomorphology, hydrological conditions, climate, flora, fauna and man's activities.

The focus of this book is the application of soil information to land use planning. The various techniques which are used to evaluate the suitability of soil for specific land uses will be examined. It needs to be stressed that this will be approached from a *spatial* rather than a *site* context. This means that the resolution of the analysis will stop before the site level. In other words the concern is with assessing *areas* in terms of the soil problems posed to particular land uses. Investigation of soils and land use problems at the site level tend to be carried out by such specialists as a soil chemist, or a geotechnical engineer. Of course soil maps can only be produced by collecting information from sites, but then this information has to be spatially generalised, with the degree of generalisation depending upon such factors as the intensity of sampling, the complexity of the area and the scale of mapping. The role of soil survey or some form of base environmental inventory is thus critical in any land use planning programme. We shall examine the procedures used in a soil survey in Chapter 2, but it is instructive to outline the foundation of national surveys during the twentieth century.

Credit must be given to the Americans for executing the first modern scientific soil surveys. The US Soil Survey was founded in 1898 by Milton Whitney, but prominence is usually given to C. F. Marbut who became director in 1913. Marbut was a distinguished pedologist and made important contributions to soil classification. His basic division of soils into pedalfers and pedocals is still found to be useful (Young, 1976). In Canada the first proper soil surveys were carried out in 1921 beginning in Saskatchewan and Alberta; in Australia a start was made in 1927. In Britain it is surprising, given the agricultural changes of the eighteenth and nineteenth centuries and the rise of agricultural science, that a national soil survey was not formed until comparatively late. Some important pioneering work was done in the 1920s and 1930s, but the Soil Survey for England and Wales was not founded until 1939 (ultimately based at Rothamsted Experimental Station, Harpenden) and the Soil Survey for Scotland in 1946 (based at the Macaulay Institute, Aberdeen). It is only during the last thirty years that many soil maps have become available in Britain. In Scotland, for example, one-third of the country is covered by published 1 : 63 360 soil maps; maps and surveys in preparation bring the proportion up to about one-half of the country (Grant, pers. comm. 1978). It should be stressed that the emphasis in Scotland has always been on mapping the soils in dominantly arable areas and the published maps cover about 90 per cent of the arable land. In England and Wales soil maps are available at a scale of 1 : 63 360 for about one-tenth of the area, but a policy change in 1966 has led to the abandonment of the 1 : 63 360 scale in favour of the 1 : 25 000 scale; maps at this latter scale cover 2 per cent of the country. Another example is New Zealand with detailed soil maps at a scale of 1 : 15 840 or 1 : 31 680 covering approximately 5 per cent of the country whilst maps at the district level (scales 1 : 63 360 and 1 : 126 720) cover about 50 per cent (Leamy, 1974a). Soil maps at a scale of 1 : 253 440 cover the whole of New Zealand. At the global scale only about a fifth of the world's soils have been surveyed, but such a statistic masks tremendous variation (Dudal, 1978). If the arid regions and permafrost areas are excluded, 10.8 per cent of Africa has been mapped to compare, for example, with 80.2 per cent for Europe, 46.1 per cent for North and Central America, 15.0 per cent for South America and 28.2 per cent for the world (Dudal, 1978). These figures indicate that there is still a tremendous lack of basic soil survey data for many areas of the world.

In addition to the post-war trend of the rise in number of published soil surveys, other patterns can be discerned. The mapping of soils is only possible if use is made of a soil classification system. Many systems are now in use and are summarised in Bridges (1977), but mention must be made of the American system (Soil Survey Staff, 1975) which is becoming international in use as well as the legend which accompanies the *FAO–Unesco soil map of the world* (FAO, 1974a). The underlying dictates of newer classification systems are the desire to reduce subjective interpretation in assigning soils to specific types, to improve the basic store of data about individual soils and to ease comparison of soils from different areas. A consequence of new classification methods has been the introduction of many new terms which pose major problems to the users of soil maps. This difficulty has troubled many soil surveys since they are obviously keen that their maps should be used. One solution has been the production of interpretative maps – for example, in addition to a soil survey map being published, a map of land suitability or capability is also produced. This map shows the variation in grade of land with reference to one or more land uses. This topic will be given much greater consideration in later chapters.

The funding of most national soil surveys is by the relevant ministry of agriculture. Naturally, the work of soil surveys has been primarily orientated to agricultural purposes. However, the trend since the early 1960s has been the gradual recognition that soil survey data are applicable to many non-agricultural land uses, for example to forestry, recreation, wildlife, routes for roads, pipelines, and regional and urban planning. Some soil surveys have strongly developed towards such increasing application of soil data. For example, the Netherlands Soil Survey includes a large department of applied soil survey. This broader approach is epitomised by the recent change in name of the Soil Research Institute in Ottawa, Canada, to the Land Resource Research Institute. One result of the increase in demand for soil data is the development of computer-based soil information systems, a topic to be discussed in Chapter 3. By such techniques soil data relevant to any land use problem can be quickly produced either in tabular or cartographic form.

This brief outline of the development of national soil surveys and the trends in new applications of survey data is sufficient to indicate the increasing importance which is being given to soils in aiding land use planning. Developments within pedology are encouraging the increasing use of soil information in planning, but the other side of the coin is that soil surveys are being increasingly approached by agencies or authorities to give advice on specific problems. Indeed a serious problem facing many soil research institutes is the extent to which soil surveyors' time can be devoted to such individual problems rather than carrying on with routine soil survey work. However, the requests for advice are not restricted to the local level – soil information is increasingly being sought at the local, regional, national and international scale. Although soil survey information is being used increasingly for non-agricultural land uses, without doubt the prime function of such surveys will always be towards agriculture. One force behind regional land use planning policies is the desire to maintain areas of particular agricultural value. Soil data are integral to the execution of such policies, a theme which we shall develop in the next section.

1.2 SOILS, AGRICULTURAL LAND AND PLANNING

Knowledge of soils is clearly integral to improving the management and output from existing agricultural areas as well as developing new localities. The planning of new arable areas, for example, requires information about the nutrient status of the soil so that appropriate types and quantities of fertilizers can be proposed. Also critical is the soil moisture regime in the rooting zone; many soils suffer from too much or too little moisture at critical periods during the farming year. Ultimate agricultural success will also depend on whether the soil is conducive to several crops being grown which can be fused into a profitable farming system. As already indicated, it is best to examine the incorporation of soil information into planning by considering various scales.

The global scale

Thomas Malthus in 1798 first drew attention to the tendency of people to increase in numbers at a geometric rate in contrast to the arithmetic rate of increase in food production. His pessimistic predictions were not realised because of technological, economic and sociological changes as well as by the opening up of new agricultural areas in North America and Australia, and the gradual introduction of birth control. His views have come to the fore again in recent decades resulting from a renewed concern with population trends and food supply, an issue which will intensify as we approach the twenty-first century. It is far beyond the scope of this book to enter into an analysis of this complex issue, but it is relevant to stress that any global land resource estimate can only be made if comprehensive soil information is available along with the specific soil requirements of different crops. Until very recently, soil maps covering the world based on soil surveys have been lacking and this explains in part why the estimates of the potential arable area of the world have been so variable. Grigg (1970) quotes studies dating from 1937 to 1958 which compare as percentages the global potential arable area with the arable area in use; the values range from 13 per cent to 375 per cent. In a more recent investigation of potentially arable soils of the world, Kellogg and Orvedal (1969) conclude that almost one-half of the soils in the world which have good physical and biological potential are already in use and they visualise soil surveys playing an important role in increasing productivity from such areas. In addition, according to their analysis, the areas of arable cultivation could be increased from *c.* 1.4 billion hectares to *c.* 3.2 billion hectares and this additional 1.8 billion hectares would not require additional irrigation beyond the existing wells and streams. Over one-half of this additional area lies in the tropics. This prediction by Kellogg and Orvedal is based on examination of major soil types and their distributions. Revelle (1976) in another analysis of global potentially arable land concludes that 3.2 billion hectares of land could be cropped without irrigation whilst this could be increased to 4.2 billion if irrigation systems were used. The most optimistic value for total arable area is 7.0 billion hectares (Pawley, 1971). As already stated, the marked variations in these estimates are in part due to a poor global soil and climatic data base as well as to differences in assumptions about management level, agricultural investment, economics of particular farming systems and the financial ability to buy fertilizers.

An important advance in terms of global land evaluation is under way by FAO (Dudal, 1978). The aim is to provide '. . . a more precise assessment of the production potential of the world's land resources, and so provide the physical data base necessary for planning future agricultural development . . .' (Dudal, 1978, p. 315). The work is based on the identification and delimitation of major agro-ecological zones. The background methodology to the evaluation procedure will be described in Chapter 3 where the FAO (1976) *Framework for Land Evaluation* is described. For the moment, it is important to realise that this global agro-ecological analysis is only possible through the publication in 1978 of the *FAO—Unesco Soil Map of the World*, published in nineteen sheets at a scale of 1 : 5 000 000. This project began in 1961 and necessitated much international collaboration and discussion of a legend and correlation of soils between countries. The maps were all published between 1974 and 1978 and are based on existing soil survey work throughout the world. These maps, in combination with a climatic assessment, will provide the basis for recognising agro-ecological types. Another example of the use of the 1 : 5 000 000 FAO–Unesco soil maps is given by Riquier (1975): he describes how the South America sheet has been digitised and additional information on climate, physiography, geology, vegetation, land use and land management is also stored for each soil unit. Such a data bank can then be used for a wide variety of land use problems.

This research by FAO should ultimately produce a comprehensive analysis of global land resources, and the preliminary results suggest that vast tracts of land are still available for cultivation (Dudal, 1978). However, it should always be borne in mind that the main hope for boosting world agricultural production must come from marked increases in yields from existing areas. Dudal also stresses that land evaluation exercises should be directed at the requirements of individual crops. An underlying difficulty to all global land resource appraisals is that countries vary in their socio-economic conditions and thus there will always be a marked difference between what could be achieved on scientific and technological evidence and what are realistic objectives within individual countries. Any predictions about food supply potential also can be outdated quickly by economic, technological or agricultural changes.

The national scale

Since there is no global government, land use planning backed by legislation at that scale is impossible. The world Food and Agriculture Organisation (FAO) acts as an important data-collecting centre and provides continuous reviews of the world food situation; FAO is also very much involved with agricultural development projects in various parts of the world. But it is at the national scale that a land use planning policy supported by legislation is first possible.

In Britain there is a long tradition of some form of control over land use. The first planning Act was passed in 1909, though its prime concern was with public health and housing. Further Acts followed in 1931 and 1932, but it was not until 1947 that comprehensive Acts were passed. These Town and Country Planning Acts (one for England and Wales and one for Scotland) imposed a statutory planning structure so that most forms of development had to receive planning permission from local authorities. Integral to these Acts was the zoning of land used for agriculture, and forestry. Various amendments were made to these Acts which were consolidated into the Town and Country Planning Act for England and Wales in 1971 followed by an Amendment Act in 1972. A separate Act for Scotland was passed in 1972. According to the 1947 Acts, authorities had to produce development plans which contained proposals on the use of land over a twenty-year period. Land was zoned for specific uses, for example green belts, and areas for urban, industrial, recreational and agricultural development and other community uses. The more recent 1971 and 1972 Acts provide a more positive approach to planning with the introduction of structure plans. These deal with strategic issues and policies for the development and the use of land. In addition detailed proposals for specific localities are presented in local plans. The procedure for such structure plans to become planning policy for specific areas is laid down fully within the Acts; before adoption, the plans must be available for public inspection and a method of objecting to any proposals is given in the Acts. In England and Wales the Ministry of Agriculture, Fisheries and Food, and in Scotland the Department of Agriculture and Fisheries, are consulted about such structure plans so that every attempt is made to conserve the best land for agriculture. As will be discussed, this policy seems to have worked reasonably well for England and Wales, but not in Scotland. Day-to-day planning is achieved by development control. This is when individual development proposals, for example extensions to private houses or the construction of new factories, are examined by the planning authorities. A variety of factors have to be taken into account including the policy statements in the strategic plan before planning permission can be granted. Planning authorities in England and Wales are obliged under the statute to consult the Ministry of Agriculture, Fisheries and Food when planning applications affect agriculture on areas greater than 5 ha. No such statutory requirement applies in Scotland, though the Secretary of State has issued a directive that planning authorities should consult the Department of Agriculture and Fisheries when areas greater than

5 ha and of grades A+ and A are being considered for non-agricultural development. The report by the Centre for Agricultural Strategy (1976) identifies several unsatisfactory aspects of British planning procedures in relation to agriculture and forestry. According to their view 'there is insufficient consideration of the future consequences of land use changes in the context of national policies for agriculture, forestry and urban activities' (p. 18). They identify the problems of making the correct planning decisions at the local level in terms of national priorities. Another unsatisfactory feature of the planning process in Britain as noted in the report by the Centre for Agricultural Strategy (1976) is that the involvement in the planning process of those concerned with agriculture and forestry is inadequate. Indeed, the prime function of this report was to focus attention on the very high priority which should be given to food and timber production in Britain; in addition the report proposes '. . . that everything possible should be done both to prevent the unnecessary loss of land from agriculture and forestry and to stimulate the potential output per unit area from the land remaining in use for these purposes' (p. 16). Much of this concern results from the loss of land by urbanisation.

It has been estimated for the UK that if the population increases to 61 million by the year 2000, the demand for more urban land will mean between 163 000 and 468 000 ha being changed to this land use; the size range is because calculation has been done using different urban population densities and the areas are between 0.8 and 2.5 per cent of the agricultural area in 1974 (Centre for Agricultural Strategy, 1976). Although it seems as though this population projection may not be achieved and despite increasing attention being given to the redevelopment of inner city areas, a certain amount of urban expansion is bound to take place. The planning policy is to limit such development to poorer quality land wherever possible. For England and Wales this policy seems to have been moderately successful according to the work of Best (1973) who has shown that there has been no disproportionate loss of good-quality agricultural land though Best (1976) also argues that there should be a stronger policy designed to conserve better land for agriculture. The situation in Scotland seems rather different. As can be seen in Table 1.1, from 1971 until 1977 there has been a disproportionately high loss to agriculture of the better categories of land. Only 2.8 per cent of the total area of Scotland is in grade A+ and A whilst from 1971/72 to 1976/77 between 17.5 and 29.0 per cent of the land transferred from agriculture was in these grades. Of course these figures must be interpreted with caution since in a strict sense they are not comparable, but it is clear that if such trends continue there will be a continuing loss of better agricultural land. Only for 1976/77 is there evidence of the poorest land (grade D) being more extensively used, but this figure for grade D results solely from one large industrial development.

In countries like Canada and the USA there is growing concern at the national level about the loss of good agricultural land to urbanisation. In the US until the early 1970s, there was the widespread belief that there was no need for concern about agricultural output. Continual increases in output were possible by the application of more fertilizers, new crop varieties and more efficient machinery. This view, expressed by Clawson (1972), has been challenged as a result of the marked increases in fuel and fertilizer costs in more recent years. In Canada, only about 15 per cent of the country has some potential for agriculture and less than 0.5per cent of this area can be considered to have prime soils in prime temperate climates (Nowland, 1978). This land is located in the Lakes Peninsula and the St Lawrence Lowlands. In Canada about 20 000 ha of land are being lost to urbanisation each year and the point that Nowland stresses is that most of this loss is taking place in the very limited areas of good land, a situation rather similar