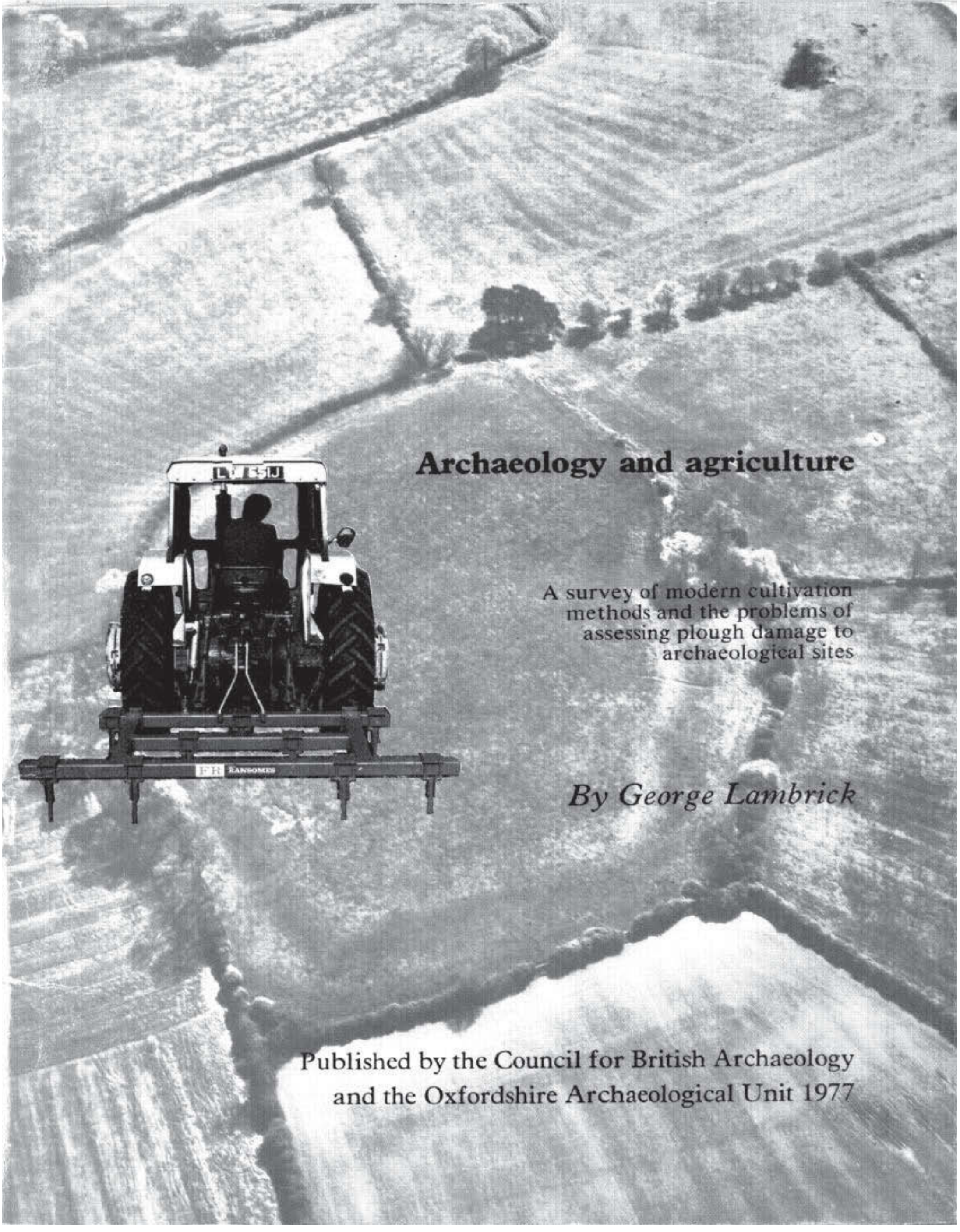
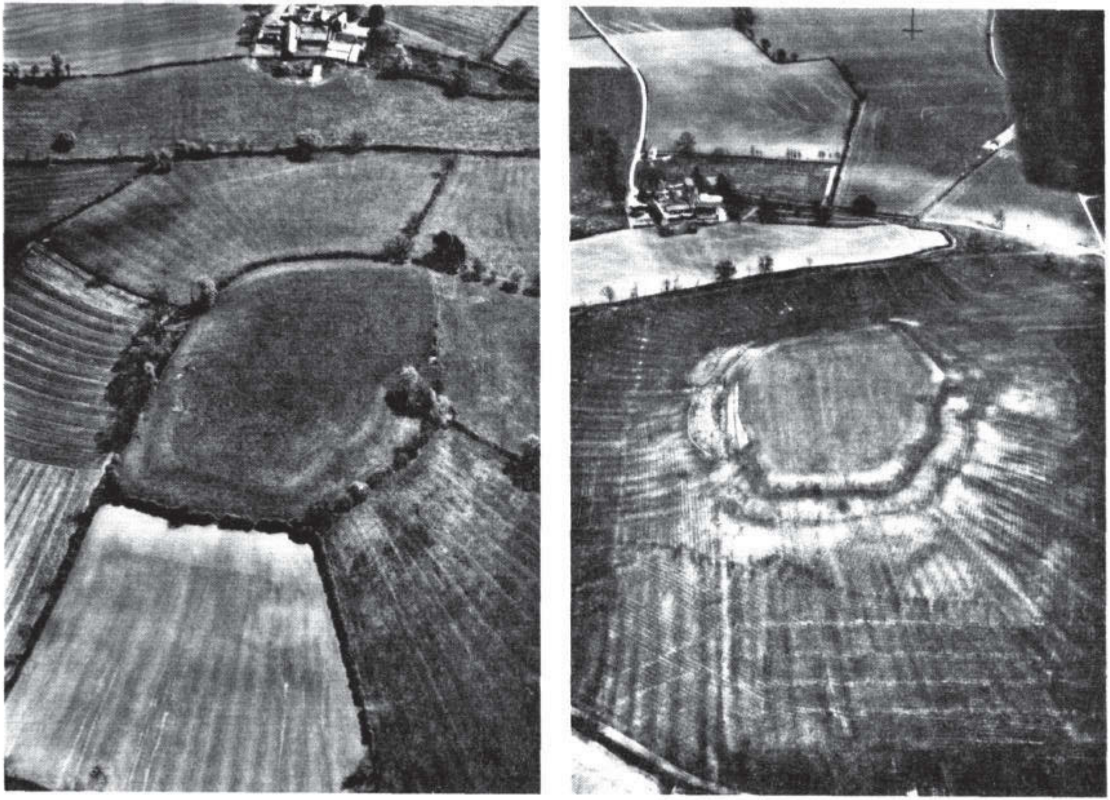


Archaeology and agriculture

A survey of modern cultivation methods and the problems of assessing plough damage to archaeological sites

By George Lambrick

Published by the Council for British Archaeology and the Oxfordshire Archaeological Unit 1977



Frontispiece Madmarston Camp, Oxon. Before (1961) and after (1968) a change in cultivation practice
(Cambridge University Collection; copyright reserved)

Oxfordshire Archaeological Unit Survey Number 4

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Contents

Introduction

Much interest has recently been aroused in the problem of ploughing as a destructive agent on archaeological sites. This renewed concern with the question has led to the undertaking of various pilot surveys of plough damage, mostly sponsored by the DoE in an attempt to define more clearly the extent of the problem and to reconsider the criteria for undertaking excavations on the grounds of plough damage. This booklet is a by-product of a feasibility study for a South Midlands Plough Survey which was carried out by the Oxfordshire Archaeological Unit in January and February 1975. This differed from most other pilot surveys in concentrating on an assessment of the available information and on possible methods of conducting surveys, rather than on actual field work. One result was that a great deal of information was accumulated on the technical side of cultivation methods and this forms the basis for the booklet.

The basic assumption on which the booklet rests is that, since different pieces of cultivation equipment arc designed to produce different effects on the soil, they will *ipso facto* produce different effects on archaeological sites. The intention is not to analyse these effects in detail, which would be an elaborate operation and should form a basic part of a proper survey, but rather to demonstrate that such an analysis may be fruitful, and, in a practical way, to assist the assessment of sites by fieldworkers in general, not merely those working specifically on the effects of cultivation. To say simply whether or not a site is cultivated is insufficiently accurate to make a detailed assessment of its condition. Enquiries as to the present and also the past and prospective methods of cultivation need also to be made. Many other factors such as soil type, slope, type of site, etc. are important and must be considered carefully, but the basic information of what has been done, when, is probably the most critical factor. The booklet is designed to give the fieldworker, professional or amateur, some basic information to help him in such enquiries.

It is not, nor is it intended to be, a comprehensive compendium of information: the subject is too vast for that to be possible or even desirable. Many who read it may already be familiar with all it contains, but those who are not should on no account believe that they know all that there is to know once they have read it; such an attitude would be a most undesirable result. If the booklet leads to a keener awareness of the problems of working the land and a better understanding of the reasons why different methods are used, and, on the basis of these, helps to promote a more accurate assessment of the condition of sites, it will largely have achieved its purpose.

As the economic pressures on farming increase (as they have very dramatically over the last few years), so it becomes increasingly important to ensure that archaeological policy in relation to farming is soundly based. At the moment archaeologists rely heavily on the goodwill of farmers, as their policy can often result in some financial loss to the farmer. This has to some extent been alleviated by the Acknowledgement Payments Scheme, but this was never intended to be full compensation and still falls short of it, although the size of payments has recently been doubled. It is likely that archaeology will still have to rely much on the goodwill of the farmer to protect sites, or will increasingly lose sites, if compensation or excavation cannot be afforded when declarations of intended damage are made. It is hoped that this booklet may to some extent help to improve this situation in two ways.

First, it may indirectly help to enhance co-operation. If it promotes a more accurate assessment of sites, to achieve more soundly based archaeological policy, farmers may be more convinced of the need for such policies and more willing to accept them. Perhaps more importantly, if it enables archaeologists to take a more knowledgeable interest and show greater understanding of at least one aspect of modern farming, farmers may be more willing to consider the interests of archaeology. This point is made very clearly by C C Taylor: 'It is necessary to be as much a diplomat as an archaeologist if fieldwork is to be carried out successfully and one must be prepared to meet landowners and farmers at their level of interests, not yours' (Taylor 1974, 22).

Secondly, the booklet briefly outlines a practical suggestion, made in more detail to the DoE, of a way to complement and perhaps further improve the effectiveness of the Acknowledgement Payments Scheme by the use of direct drilling. This should seriously be considered as a way of safeguarding more securely *both* the farmer's and the archaeologist's interests in sites.

Though essentially a factual pamphlet designed simply to provide information on modern cultivation techniques and equipment, the booklet also includes a more subjective section of archaeological comment, primarily intended to consider methods of defining the threat and dealing with it. No attempt has been made to assess the threat directly. A separate section briefly summarizes current trends in cultivation techniques. Discussion of the various methods begins with conventional mouldboard ploughing and works downwards and upwards (in terms of depth) from there, dealing with the action, the variations, the use and the problems and advantages of the techniques in each case. It is hoped that the annotated illustrations will serve to explain the terminology of each implement. The techniques are also illustrated in action. The booklet deals essentially only with primary cultivation techniques where differences seem most likely to affect archaeological sites in different ways.

Acknowledgements

The information in this booklet has almost entirely been gathered through personal conversation with agriculturalists, who were without exception extremely patient and helpful. Without their help and the benefit of their experience the study would have been very difficult. References to the sources of this information are omitted from the text since they would be almost continuous. Reference has been made to some published sources, and a bibliography is to be found in Appendix IT, but a very great debt of gratitude is expressed here to the following:

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Thanks are also due to the Department of the Environment for a substantial grant towards the cost of producing this booklet.

The views expressed in this booklet are those of the author.

The CBA and agriculture

The present booklet forms the first of an occasional series of such publications, on aspects of agriculture and archaeology, to be issued by the Council for British Archaeology. The second, the Proceedings of the Seminar on Plough Damage, will, it is hoped, appear during 1977.

The purpose of cultivation

Both cultivation and non-cultivation techniques are designed to fulfil the same basic requirements in preparing the land to take a crop. All are intended to maximize productivity, crop growth, and yield. The main aims of cultivation and non-cultivation methods may be summarized as the following:

(i) economic and efficient preparation of the soil;
(ii) weed control;
(iii) fertilization;
(iv) preparation of a seedbed which will encourage maximum germination, growth, and yield;
(v) care of soil structure and drainage.

These are used as the criteria against which the advantages and problems of each technique are judged. None of the methods is able to deal entirely satisfactorily with all these objectives. As a result of this and of purely technological and economic considerations, various techniques have been developed. Each tends to emphasize particular factors, and so they tend to vary considerably in their treatment of the soil. What is used when will be dictated by these considerations, but will depend also on other factors such as

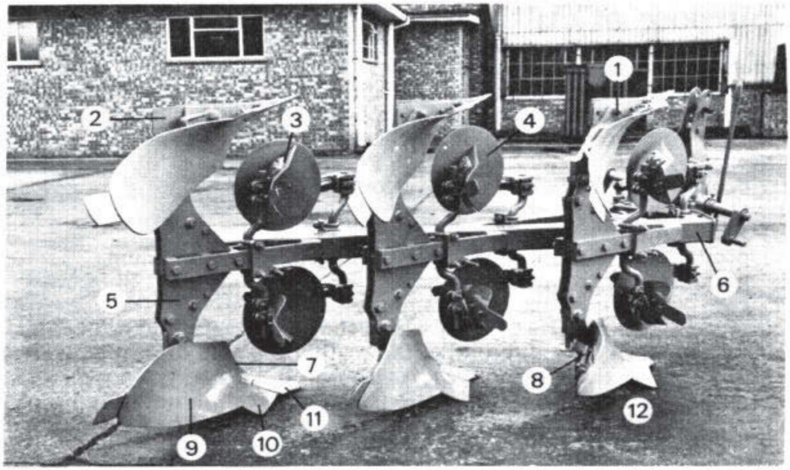
(i) soil type;
(ii) drainage considerations;
(iii) type of crop;
(iv) economics, including availability of capital and the availability and quality of labour;
(v) past experience and past yields etc;
(vi) weather.

Mouldboard ploughs

This is the traditional or conventional technique of ploughing. It is what is usually meant by 'ploughing' and is also the most commonly used method; although it is the best known technique, however, there are many refinements and variations which may substantially alter the effect of the plough on the soil, and which are less well known outside farming circles. This type of ploughing remains one of the most versatile methods and has by no means been superseded by more recent developments.

Action

The mouldboard plough is designed to loosen and turn over the soil, burying vegetation and 'trash' from the top, and exposing fresh soil from beneath. The soil is moved forwards slightly and sideways by the width of the furrow.



1. Frog 2. Landside 3. Skim 4. Disc coulter 5. Leg 6. Beam or frame 7. Shin 8. Mouldboard stay 9. Mouldboard 10. Share 11. Point 12. Body

Fig 1 3-furrow mounted reversible mouldboard plough (copyright Ransomes Ltd)

Variations

Almost all parts are replaceable and are available in a variety of forms to make up bodies for particular conditions.

Bodies also are adjustable, thus allowing very fine overall adjustments. The main types of body are *general purpose, semi-digger,* and *digger*. These vary the depth and width of furrows cut, and the inversion and draft (i.e. 'drag') characteristics, allowing most mouldboard ploughs to be used equally effectively on light, medium, and heavy soils in a wide variety of conditions. Depths vary from 3-4in to 12-14in, and the width of furrow from 8 to 16in.

The basic form of the plough is also variable: *Multiple furrow ploughs* are the standard form of mouldboard ploughs with two to six or seven bodies, used according to depth of work, soil conditions, and tractor power. *Stubble* or *shallow ploughs* have up to ten bodies for fast work at shallow depths and can be used in minimal cultivation systems (Anon. 1974b; Lucas 1974). *Reversible ploughs* are available with two to four bodies, mounted or semi-mounted. Two sets of bodies, one right-the other left-hand, are mounted one upside down above the other. The beam is flipped over so that all the furrows are turned in the same direction.

Fig 2 4-furrow semi-mounted reversible mouldboard plough working (copyright Ransomes Ltd)

Normally these ploughs are almost double the weight and double the cost of the equivalent non-reversible plough. *On-land ploughs* are another relatively new development, with the front end of the plough beam offset from the main linkage, allowing the tractor to drive on the unploughed land rather than partly in the previous furrow. These are mostly available with four to six bodies.

Depth and direction of work

Depth

Normally the heavier the land, the deeper ploughing will be. 'Deep ploughing' as a technical term is deep mouldboard ploughing, *not* pan-busting, subsoiling, or chisel ploughing, which are separate techniques. Deep ploughing at more than about 9in loosens up and aerates the soil, improving its structure and drainage through the breaking down of clods by weathering and the promotion of surface drainage, making the soil more workable and therefore more suitable for subsequent cultivation. The more the soil tends towards cloddiness and poor drainage, the more this needs to be done. On very light soils, fairly deep ploughing may be used to turn in vegetation to increase the depth of reasonably humic soil and thereby improve its capacity of retaining moisture. Normally, however, ploughing is kept to 4 or 6in on light soils, as this is not regarded as necessary. On medium soils depth varies considerably, though often it is kept at about 8in. Although common, deep ploughing is by no means the universal treatment of heavy land, and proper drainage, possibly in part by subsoiling, combined with lighter cultivation or shallow ploughing can be a better solution. The use of more powerful tractors and plough bodies turning wider, deeper furrows tend to encourage deeper ploughing. The old practice of ploughing deeply to deepen or improve the top-soil by ploughing subsoil into it, however, is now less common, and on the whole most farmers now try to avoid ploughing up relatively infertile subsoil.

Direction

There are three basic methods of ploughing a field.

Ploughing in lands is based on the medieval ridge-and-furrow method of ploughing in strips or 'lands', developed from the characteristic of the mouldboard plough of turning furrows only one way. Medieval ridges were made by always turning two groups of furrows towards each other; now the pattern of ploughing is the same, but the fields are kept flat by ploughing in much wider lands and by ploughing them in the opposite direction at each ploughing, so that the sideways and forward movement of the soil is reversed. The headlands across the ends of the lands tend always to be ploughed inwards from the edge of the field.

One-way ploughing, using a reversible plough, makes it possible to turn all the furrows in one direction moving all the soil one way. This may be reversed subsequently, but on slopes the furrows are sometimes always turned up the hill to counteract erosion. This is relatively rare and on steep slopes can be dangerous, but is thought by some to be effective on chalk and other hills with light soils.

Circular, envelope ploughing, or *ploughing on the square* is another technique which cuts out the unproductive time spent travelling between lands. The field is ploughed round and round, always turning the soil in one direction. Again the direction should be reversed at the next ploughing.

Advantages and problems

Economics and management

In general, the mouldboard plough is highly adaptable and very versatile. It can be used effectively on all types of soil and can be adapted to suit almost any particular conditions. At the same time it suffers from disadvantages in terms of economic efficiency. It tends to require more skilled labour than other techniques, and such labour is becoming scarce. It also requires a high input of time and energy because of its high power requirement and relatively slow workrate. Furthermore, it may mean much time being spent on subsequent cultivations, especially on heavy land. Recent developments have to some extent alleviated these problems. Eight- or ten-furrow stubble ploughs have a much higher workrate and can minimize the need for subsequent work in good conditions. Used thus as a minimum cultivation technique, mouldboard ploughing can be very much more economical without losing its main advantages. On the whole, however, this is rare compared to other minimum cultivation techniques. Reversible ploughs and ploughing on the square, by cutting out unproductive travelling time, can also speed up workrates, but neither of these techniques overcomes the basic slowness of the method.

Weed control

The mouldboard plough is probably the most efficient mechanical method of controlling weeds in general, and although it is not good at controlling some troublesome weeds, such as couch grass, it is relatively good for others (e.g. wild oats).

Fertilization

Fertilization is helped by the burial of old vegetation, which accelerates its decomposition. The well mixed soil produced may be an advantage, but many believe that this type of fertilization is not necessarily important and argue that the vegetation should be left to rot at the top of the ploughsoil to create a layer of humic soil on the surface where it occurs naturally and is most needed. Shallow working stubble ploughs overcome this objection to some extent.

The preparation of seedbeds

This can be greatly assisted by the effective burial of trash and the creation of a fresh clean soil surface. This is one of the most important advantages of the technique. Where the soil is well structured, light, and free of trash, seedbed preparation can be very easy and require very few subsequent passes. Conversely, in heavy land cloddiness not broken down by the plough can be a problem, but on such land deep mouldboard ploughing is often the best preparation of the soil, since effective weathering of the soil is greatly assisted by the setting up of the soil slice. For many crops it can be argued that normal ploughing at 6-9in is unnecessarily deep; direct drilling shows that soil disturbance may not be necessary at all, at least on well structured soils. Some root crops, such as potatoes, however, do need a deep seedbed which is usually thought to be prepared best by the plough.

Soil structure and drainage

These are clearly important and are increasingly becoming a major concern. In some ways the mouldboard plough can improve soil structure, especially on poorly structured soils. Deep, heavy clays are improved by being loosened up and turned to allow weathering. The addition of humus by the burial of trash can also help, especially on soils which are very light, where moisture-retentiveness is improved. Mouldboard ploughing can also be very damaging to structure, however, and this is one of the reasons for changes to other forms of cultivation. Many agriculturalists, especially direct drillers, argue that all forms of ploughing destroy the natural profile of the soil by inverting the top 8in or so. Even if the soil needs breaking up to improve its structure, it may be best to do this by subsoiling followed by a minimum cultivation technique to minimize disturbance of the natural soil profile.

The problem which is most serious and almost universally recognized is that of 'panning' (Anon. (MAFF/ADAS) 1970b; Anon, (MAFF) 1972; Baxter 1971). This can cause very serious problems of drainage and soil structure, leading to quite obvious deficiencies in crop growth. The problem occurs when a hard impermeable layer is created at the bottom of the plough soil. The effect of this is to limit root growth, prevent good subsoil drainage, and, in dry weather, to prevent moisture rising from below. Panning can also lead to chemical changes which tend to restrict root growth further. It can occur naturally, but this is not common and is seldom serious. The man-made pan, usually created by mouldboard ploughing on clayey soils, especially in wet conditions, can be extremely serious. The plough itself tends to smear the soil as it slides through the ground, and with most ploughs this is followed by the tractor running in the furrow, creating more smear by wheel slip as well as serious compaction. The impermeable and hard pan thus created tends to build up naturally as well as being aggravated by repeated ploughing to the same depth.

Various developments in mouldboard ploughs have tried to alleviate the problem. Bodies have been designed to reduce smear, bar points are used to break up previous pans, large multiple-furrow ploughs reduce the number of passes by the tractor, and most significantly on-land ploughs obviate the necessity of the tractor working in the furrow. The type of tractor also makes a difference: large modern tractors have increased the problem of compaction. Four-wheel drive versions can help to reduce the problem of smear by wheel-spinning, unless both wheels spin in the furrow. The mechanical working efficiency of most tractors is highest at about 15% wheel slip, which is almost invisible to the eye but nevertheless tends to smear the soil. Crawler tractors can reduce compaction problems by as much as two-thirds, and smear is also avoided. If ploughing is only carried out under the correct conditions, the problem of pan creation may thus be avoided, but waiting for the land to be dry enough can cause very serious problems of delay at a time of year when there is a bottleneck of work to be done, as occurred in the autumn and winter of 1974-75. If care is not taken, panning can be a recurring problem requiring regular pan-busting operations. Although the use of bar points or occasional very deep ploughing in good conditions can remove pans, the problem is more commonly dealt with using tined implements, the *bête noir* of cultivation techniques in the eyes of many archaeologists.

Subsoilers and panbusters

These are relatively new implements and for most archaeologists seem the most alarming. Their use should not be confused with deep ploughing or with chisel ploughing, which, though capable of breaking up pans, are essentially different techniques. Subsoiling and pan-busting are above all concerned with drainage and soil structure, not cultivation. The terms ‘subsoiler’ and ‘panbuster’ refer to the same implement, since in practice the two operations are normally combined as one. They are used very widely, and though other techniques and refinements may lessen the need for them in the future, this does not appear to be the case yet. Most agriculturalists would say that they are not used nearly enough.

Action

The subsoiler is not designed to turn the soil or to move it bodily, but to shake it up, including the subsoil and any pans, loosening it and creating fissures.

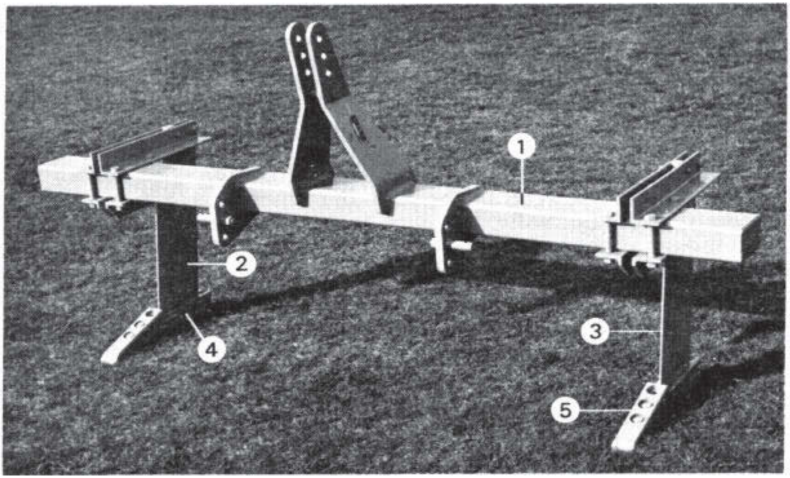
Variations

Only slight variations occur. Subsoilers penetrate 15-36in or more; many can be adapted for mole-draining by replacing the ‘shoe’ with a 'mole'; slanting and vibrating legs have been tried (Goodman 1974b) and the former are now commercially available. A bar or frame allows two, or (rarely) three, blades to be used, normally set about 4ft apart.

Depth and direction of work

Depth

Depth can vary almost as much as for mouldboard ploughing and is equally dependent on soil conditions and the effect required. Again, the heavier the soil the deeper the work is likely to be, since the heavy clay lands are the most likely to be affected by serious drainage and pan problems. Light and well structured soils normally require no subsoiling or panbusting at all. In poorly structured sands, compaction pans can occur, but can usually be broken up with a chisel plough rather than the deeper penetrating subsoiler. This deeper penetration is to ensure that the subsoil is disturbed to assist drainage and that a reasonable shattering effect is obtained laterally to break up pans, despite the wide spacing of the blades. Most subsoiling is now done at about 20in deep, but can vary from 15 to 30 or even 36in in extreme cases. Depth may be dictated by the position of existing land drains, usually 18-36in down: drains cannot be expected to work unless the soil above them is relatively porous, and subsoiling may need to go to within a few inches of the tops of drains, penetrating any permeable fill above them. In general subsoiling now tends to be used less deeply than it was at first, especially on the better types of heavy soil.



1. Beam 2. Leg or standard 3. Shin 4. Subsoiling shoe 5. Chisel blade

Fig 3 Twin-leg subsoiler (copyright Ransomes Ltd)

Direction

Direction of work should be across the line of any land-drains. Where no under-drainage system exists the direction matters little. The subsoiler is used at regular intervals of 3-6ft, depending on soil condition and depth of work. The intention is that the soil will crack upwards in a V-shape from the bottom of the blade, so the intervals between blades and/or passes should be such that the fissures created will meet at the top. Repeated subsoilings are normally done at right-angles to each other.

Advantages and problems

Economics and management

The subsoiler has disadvantages in being a tool with a very specific purpose and a fairly slow workrate, which may cause problems, since it is best used in the busy period after harvest and may therefore delay other jobs. Nevertheless, it is not an especially expensive piece of equipment, nor as expensive to use as, for instance, the mouldboard plough. Despite the considerable depth to which it works, it involves relatively little actual soil movement, and the wide spacing of the blades compensates for the added depth. The disadvantage of its being a separate piece of equipment not involved in actual cultivation is offset in most farmers' eyes by the fact that one subsoiling may improve yield for a number of years (Table II). In

Fig 4 Twin-leg subsoiler working (copyright Ransomes Ltd)

this respect its cost should not necessarily be compared with that of yearly cultivation. A further difficulty may be that deep subsoiling not only takes longer and costs more, but also requires a powerful tractor, preferably a crawler. The small farmer seldom has the capacity for doing the job, so that agricultural contractors are very commonly employed for subsoiling, although this adds fairly considerably to the cost.

Soil structure and drainage

These can be improved so much that in many cases subsoiling has come to be regarded as an essential regular operation. Nevertheless, problems can occur if the operation is badly timed. It should be done when the ground is as dry as possible to achieve the correct shattering effect; in wet conditions the subsoiler may act only as a square 'mole'. If successful, however, the effects will last for a few years, so that it is normally done only once every three to five years, or sometimes longer. The subsoiler also has an advantage in combining panbusting with its subsoil drainage effects, whereas only the former can be done with the deeper use of ordinary cultivation equipment (Anon. (MAFF/ADAS) 1970a; Anon. (MAFF) 1972; Baxter 1971; Swain 1972).

Mole ploughs

The mole plough is very similar to the subsoiler and, as already indicated, may use the same tool with a different 'shoe'. Nevertheless, the operation is different and serves to illustrate how even a very small change in equipment can entirely alter its use and its effect.

Action

The mole plough makes a small cylindrical tunnel through the subsoil and a slit through the ground above it.

Variations

These are similar to the subsoiler, but seldom include the use of more than one blade at a time.

Depth and direction of work

Depth

The mole plough has the same capacities as the subsoiler, but will normally be used at the deeper levels, around 24-36in, just above under-drainage systems.

Direction

The mole will work down slopes at spacings of 10-20ft (wider than subsoiling since no fissuring effect is intended).

Advantages and problems

Economics and management

Moling is a well established technique dating from the late 18th century. Though similar to the more recent technique of subsoiling, it is even more limited in versatility, doing only one job efficiently. It is cheaper than subsoiling because of the wider spacing of the passes,

Soil structure and drainage

Like the subsoiler, the only major concern of the mole plough is soil structure and drainage, but it is often more difficult to achieve lasting results. On heavy land the mole has the benefit of actually channelling the water away, but it does little to improve the structure of the soil to assist this. This is because of the wide spacing of the passes and the soil conditions at the time of the work. Unless the soil has a high-clay content and is fairly damp, the sides of the channel will easily crumble, leading to blockages. In these conditions the fissuring effect achieved by subsoiling does not occur to any great extent. Whether mole ploughing or subsoiling is used depends much on where the drainage problem lies; moling is now most commonly done as an essential part of new drainage schemes. Lasting success is more difficult to achieve and less predictable than with subsoiling because of the difficulty of creating good channels unless the soil conditions are exactly right (Swain 1972).

Chisel ploughs and rigid-tine cultivators

Rigid-tine cultivators are well established pieces of farm equipment, but it is only in the last ten years or so that they have become popular as 'chisel ploughs', being designed specifically as primary cultivation implements capable of replacing the mouldboard plough. Their enormous versatility and other considerable advantages have made them extremely popular and very widely used.

Action

The tines break up and loosen the soil, often lifting it and shattering clods, but disturbing it rather than turning it over.

Variations

The frame for the tines will also take subsoiling blades and often spring tines, enabling it to be used for most jobs. The tines are made in vertical and angled forms, some designs combining the advantages of both, having low draft and yet good shattering characteristics to break down the soil. The number of tines used can be varied according to the size of frame (6-18ft in width), the depth of working, soil conditions, and the power of the tractor. Depth of working is also highly variable, the maximum usually being about 15in. Different points for the tines are designed for particular jobs, from broad chisel ploughing blades to narrow pointed blades for aerating and thinning grassland.

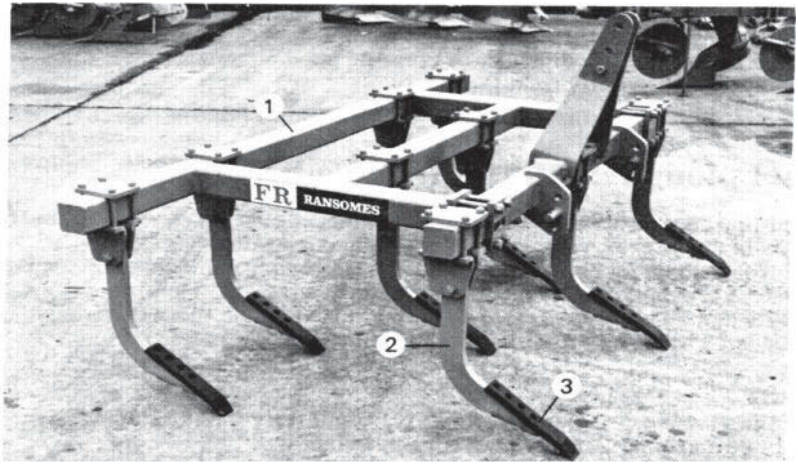
Depth and direction of work

Depth

This will vary according to soil conditions and the job being done. Panbusting can be done at depths of up to 15in; chisel ploughing is normally slightly shallower than mouldboard ploughing in comparable conditions, but this is by no means universal; it can be done at depths of 10 or 12in. As a reduced cultivation method it may penetrate only 4-5in. Stubble breaking and grass thinning also require only shallow depths.

Direction

The direction of work is largely unimportant, but normally for deeper cultivations several passes should be made, working down through the soil from the top with each pass at right-angles or askew to the others.



1. Frame 2. Rigid tine 3. Chisel blade

Fig 5 9-tine chisel plough (rigid-tine cultivator) (copyright Ransomes Ltd)

Fig 6 Chisel plough working (copyright Ransomes Ltd)

Normally the chisel plough works up and down slopes, especially where the gradient is steep, though on shallow slopes work along the contours can save on power requirements.

Advantages and problems

Economics and management

The chisel plough or rigid-tine cultivator has considerable economic advantages over the conventional plough. It can work in as many soils and conditions and is capable of doing more jobs, from panbusting to secondary cultivation. Less skilled labour is required and the work can be cheaper, unless large extra quantities of chemical weed-killers or fertilizers are required. The workrate is considerably faster, since the speed of work is greater and the width of ground covered by the machine is much larger. This point is important, for where cultivation is kept to a minimum the increasing pressure of post-harvest work can be reduced, thus increasing the productive capacity of the land. Even chisel ploughing followed by secondary cultivation can be quicker than mouldboard ploughing and its subsequent cultivations.

Weed control

This is variable: for couch grass the method is good, for wild oats it tends to be poor, while other weeds are dealt with no better than other systems. Other pests and diseases may be encouraged by not burying the trash effectively.

Fertilization

Fertilization can be assisted as the vegetation is left in the top of the soil to form a humic layer there, while a certain amount still reaches the lower layers. The breaking down of trash to humus may be helped by its being chopped up to some extent, but not by much of it being left unburied on the surface.

Preparation of seedbeds

This operation can be extremely easy, especially where tines are used for minimum cultivation at shallow depths requiring only a few rapid passes. Nevertheless, on heavy land the method may require at least as many and often more passes to prepare a seedbed than does mouldboard ploughing, especially as the technique is not as good at promoting the natural breaking down of the soil by weathering. In wet clay soil the technique may not work at all, merely creating grooves in the earth without breaking it up much. The extra passes, however, will normally be rapid and not very expensive. Other problems can arise from the failure of the method to bury trash. This can easily clog subsequent cultivations as well as the seed drill, and also tends to encourage disease and pests. To some extent this can be avoided by thorough straw disposal and by the correct setting of the tool itself, but the method never leaves as clean a surface as mouldboard ploughing, and for many farmers this is one of the most serious objections to the technique. (Hanley, Ridgeman, Allen 1972.)

Soil structure and drainage

Problems of structure and drainage can be alleviated by this technique. The soil profile is left intact to a greater extent by not deliberately inverting the soil, and pans can often be broken up without needing the subsoiler. Furthermore, although the extra number of passes may tend to encourage compaction, pans are quite easily avoided, since the points of the tines hardly smear at all, while the tractor stays in front of the cultivator on the undisturbed ground. A chisel plough hauled by a crawler tractor will almost entirely eliminate smear and compaction from the cultivation process. The subsoil problem will generally not be affected, however, and regular subsoiling may still be necessary.

Spring-tine cultivators

Although in the past these have been regarded exclusively as secondary cultivation implements, they are also now very occasionally used as primary means of cultivation and are sometimes specifically designed to be able to cope with primary cultivation.

Action

Basically similar to rigid tines, but the vibration produced by the spring tines tends to break the soil down to a finer tilth.

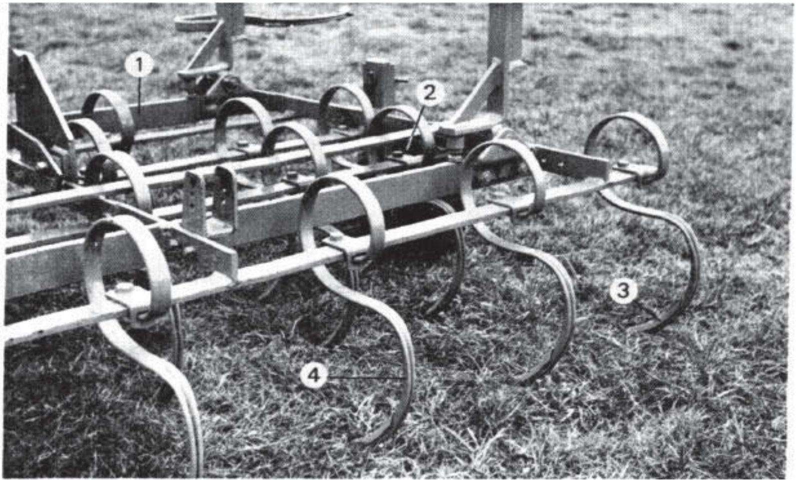
Variations

The two basic types of tine are the *S spring* and the *leaf spring*. The former may come in various designs based on the S shape including, for instance, those with a 'pigtail' coil at the top. They may also come in various sizes, one unusually being designed to work to a maximum of 12in instead of the more normal 6-7in (Anon. 1974c). Leaf springs are much tougher tines, the number of leaves varying between two and three. Occasionally coil cushioning springs are added for extra protection in rocky conditions. As with the rigid tines, a wide variety of points is available and the size of frame and number of tines vary: for leaf tines they are almost identical, while S tines are normally on lighter frames carrying up to 70 tines.

Depth and direction of work

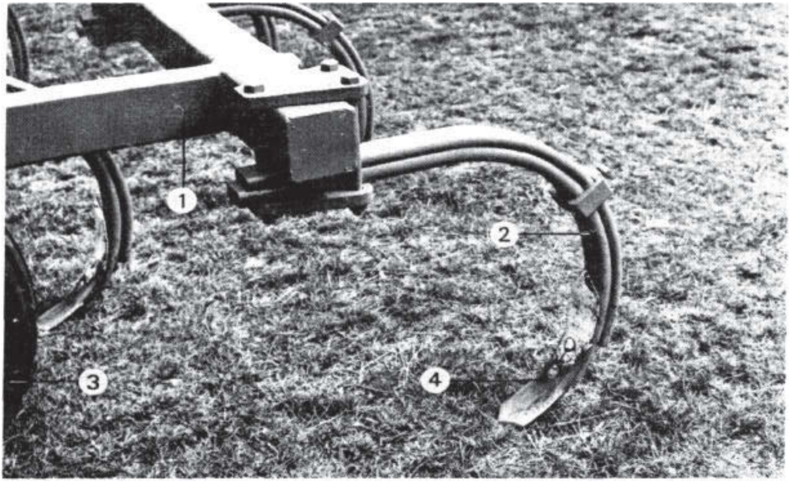
Depth

Leaf tines are used normally as an alternative to rigid tines or chisel ploughs. For S tines the 12in maximum quoted is exceptional; well under



1. Frame 2. Depth wheel 3. Reversible blade 4. Spring tine

Fig 7 S-spring tine cultivator (detail) (copyright Ransomes Ltd)



1. Frame 2. Double leaf-spring tine 3. Depth wheel 4. Reversible blade

Fig 8 Leaf-spring tine cultivator (detail) (copyright Ransomes Ltd)

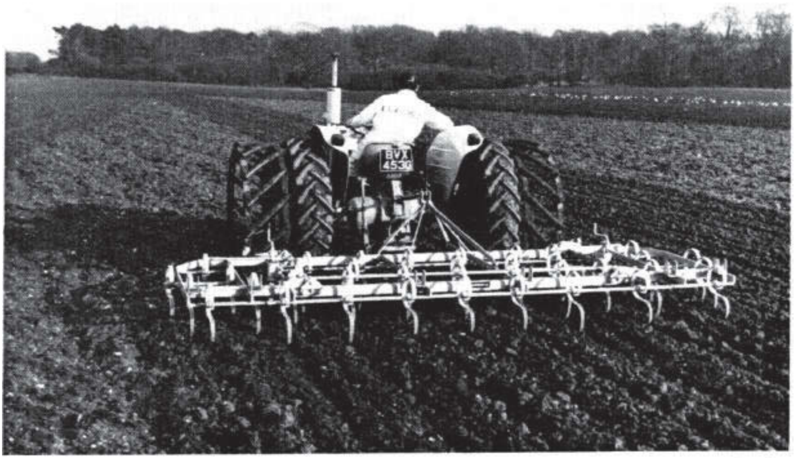


Fig 9 S-spring tine cultivator working (copyright Ransomes Ltd)

6in is more normal, since only secondary or minimum cultivations are intended. The 12in tine could only be used to such a depth to prepare a seedbed after deep ploughing.

Direction

This is dictated by the same conditions as rigid-tine cultivators.

Advantages and problems

Most of what has been said with regard to the rigid-tine equipment applies to any tined implement and need not be repeated, but there are some differences.

Preparation of seedbeds

S tines in particular give the advantage of achieving a generally finer tilth. In good conditions it is theoretically possible to work from stubble cleaning to a seedbed ready for drilling with the same tines, which is seldom the case with most rigid-tine cultivators. The leaf tine acts more like the rigid tines, and can seldom prepare the ground for immediate drilling.

Soil structure and drainage

Both are improved by the leaf tines which can tackle the heavy cultivation and panbusting jobs which the rigid tines do and can have advantages on stony ground, being less liable to damage. The S tine cannot tackle the heavy cultivation or panbusting jobs, and for primary cultivation is rare, being used only as a minimum cultivation implement.

Heavy discs

The disc harrow is another rarely used minimum cultivation technique, being less versatile than most other methods.

Action

The action of the disc harrow is that of cutting and crushing the soil, moving it slightly sideways one way and the other.

Variations

The discs vary in size and may also have either 'plain' or 'scalloped' edges, the latter being a more penetrating type, the former producing a finer tilth. The frames vary from 6 to 12ft in width, with a variable number of discs mounted in either A formation (one set of discs following another at opposite angles to the direction of work) or in tandem (two sets of discs following each other at angles forming an X pattern).

Depth and direction of work

Depth

Disc harrows are normally secondary cultivation implements and are by their nature shallow-working, but increasingly heavy versions have enabled depths of up to 4-Sin to be achieved, though for primary cultivations more than one pass is necessary to achieve this depth of seedbed.

Direction

The passes will normally alternate in direction, as with the tined implements.

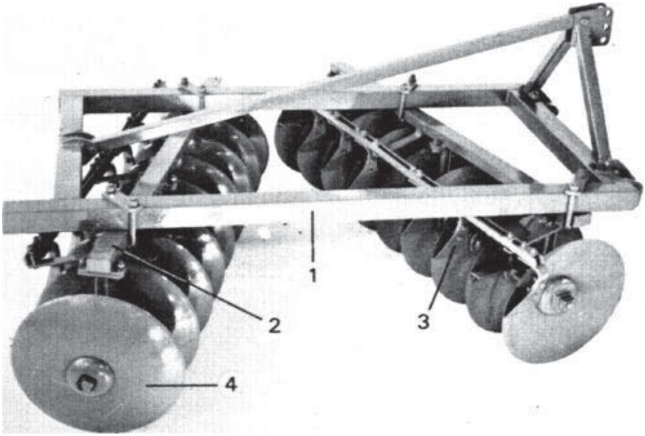
Advantages and problems

Economics and Management

As with all minimal cultivation methods, disc harrowing can save much time, energy, and expense compared to traditional cultivations; as a minimum cultivation method, however, it is not much better than others in most cases, tending to be more expensive and somewhat slower. It is also less versatile, being good in some conditions but harmful in others.

Weed control

This is not especially helped; couch grass, for instance, may be encouraged by being chopped but not brought to the surface to wither.



1. Frame 2. Adjustable mounting beam 3. Skim 4. Plain edged discs

Fig 10 A-frame disc harrow (copyright Ransomes Ltd)

Fig 11 A-frame disc harrow working (copyright Ransomes Ltd)

Fertilization

Discing does not help fertilization more than tined cultivation, except that trash tends to be chopped up to a greater extent.

Preparation of seedbeds

This can be good, on dry friable soils, but in wet conditions and on heavy soils cloddiness and compaction can easily occur.

Soil structure and drainage

These are not greatly affected. On light soils some compaction can help to keep the soil firm and well structured, while on heavier soils it can be damaging.

Powered rotary cultivators

These are relatively new machines and, though they are not yet widely popular, they are becoming more common and research is being carried out to improve their versatility.

Action

Rotary cultivators are powered by a shaft from the tractor, and thus break the soil by the independent movement of rotary blades more than by the forward movement of the machine. The effect on the soil is to chop it up and throw it about.

Variations

Rotary cultivators are available with vertical or horizontal rotors, varying in width from 5 to 8ft or more. Depth of work is adjustable and the speed of the rotor can be changed by gears. Normally there are alternative blades to suit different conditions. Versions with seeding systems attached are available, and this combination is being studied further by NIAE and may enhance the efficiency of rotary cultivation. (Occasionally these are misleadingly called direct drills.)

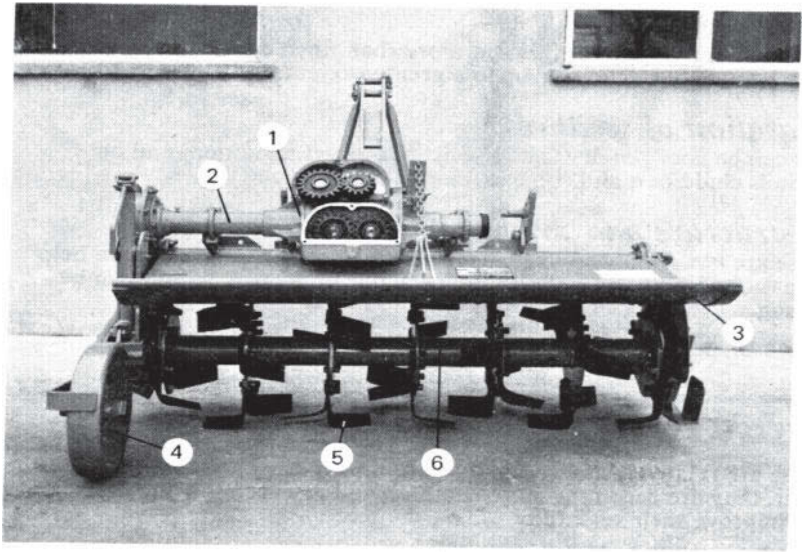
Depth and direction of work

Depth

Most rotary cultivators can work up to 6-8in, but normally they are used for shallower cultivations.

Direction

Essentially unimportant.



1. Gearbox 2. Drive shaft 3. Shield 4. Depth control wheel 5. Blade
6. Rotor shaft

Fig 12 Powered rotary cultivator (copyright Howard Rotavators Ltd)

Advantages and problems

Economics and management

In general rotary cultivators are expensive to run. They use a fairly considerable amount of power (though it is used more efficiently than by other techniques) and are noticeably slower than most unpowered techniques.

Fertilization

The chopping and burying of trash may enhance fertilization.

Weed control

Not significantly increased.

Preparation of seedbeds

This technique can enhance seedbed preparation by producing a fine tilth from cloddy soils fairly quickly, though large unbroken clods may

Fig 13 Powered rotary cultivator working (copyright Howard Rotavators Ltd)

remain buried beneath finer soil, giving a misleading appearance to the seedbed. One advantage of the machine is that in good conditions it can prepare the soil for drilling in only one pass, and if seeding equipment is attached can do the whole job in one operation.

Soil structure and drainage

These are not always helped and on dry soils the method can have a harmful pulverizing effect. Like tined implements, rotary cultivators have the advantage of reducing smear both by the tractor and the implement.

Direct drills

Direct drilling is a fairly new technique which was developed in the 1950s and began to make its mark in the mid-1960s. Even now it is not widely used. Although it is not strictly a cultivation method at all it is included in the booklet for the potential significance of that fact alone. Direct drilling is sometimes used meaning drilling after minimal cultivation, but it is used here in the sense of drilling without any prior cultivation.

Action

Two basic types of direct drill exist. The disc version opens a groove about 1-2in deep and about Sin or 0.5in wide in the soil surface and the seed and fertilizer are injected into the slot. The tined type creates greater disturbance, producing what may amount almost to a seedbed 2-3in deep into which the seed is injected through tubes on the back of the tines.

Variations

More robust versions of conventional seed drills (the most popular type), tined implements with a seed hopper and injection system attached, and rotary cultivators with seeding equipment attached are all used for direct drilling (Koronka 1973). Most direct drills can be adapted to some extent to suit conditions. The purpose-built direct drills and rotary cultivator-drills can sow almost any seed directly and can be adjusted to inject the right amount of fertilizer at the same time. Other types are less adaptable and one, for example, is marketed particularly as a kale drill (though it can be used for other seeds). The most popular triple-disc drill can be fitted with tines, but unlike many of the tine drills it is available in only one size. Most direct drills can also normally be used effectively for sowing after ordinary or minimal cultivations (though this may be limited in certain conditions; e.g. the triple-disc type of drill tends to clog in wet soil).

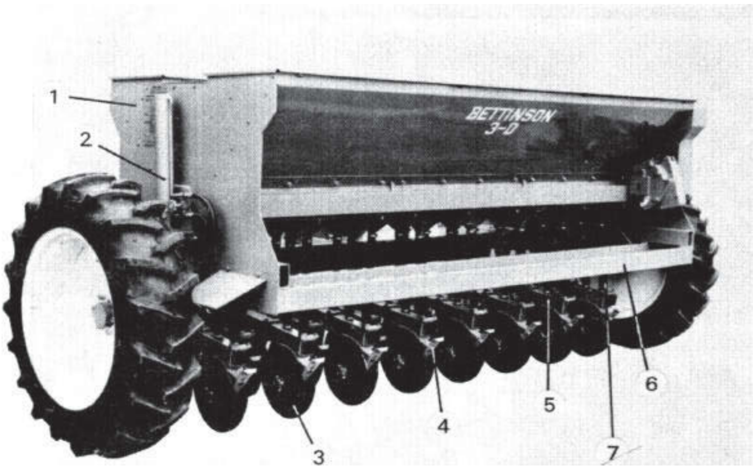
Depth and direction of work

Depth

Depth will vary according to type of seed: peas, beans, and maize are sown at 2-3in, but most cereals will be sown at 1-1½in, while grass, kale and clover will be sown at only ½in. The rotary cultivator-drills carry out minimum cultivation to 4-6in in advance of the drilling, and may therefore not be regarded as a direct drilling technique in the strict sense.

Direction

The direction of work is unimportant.



1. Seed and fertilizer hopper 2. Hydraulic lifting mechanism 3. Rear discs 3. Disc adjustment plate 5. Pressure beam 6. Frame 7. Flexible seed tube

Fig 14 Triple-disc direct drill (copyright P B Bettinson Ltd)

Problems and advantages

The problems and advantages of direct drilling are considerable. One of the prerequisites of direct drilling is that it must be done correctly without taking short cuts. Although this is obviously important in all forms of culivation, it is especially so for the non-cultivation techniques.

Economics and management

Direct drills are expensive pieces of equipment, costing up to £2000 or more. It is a fairly expensive technique, since it is essential that very thorough spraying is done with Paraquat (a fairly expensive contact weedkiller whose discovery in the 1950s allowed the successful development of the technique). Although it can be cheaper it does not necessarily represent much of a saving in itself; but to set against this substantial savings can be achieved in fuel, as well as tyres and cultivation equipment which, in rocky and flinty conditions, can suffer considerable wear with other techniques. The difference in yield per acre between techniques is marginal, though occasionally it may be less reliable with direct drilling (Table VI).

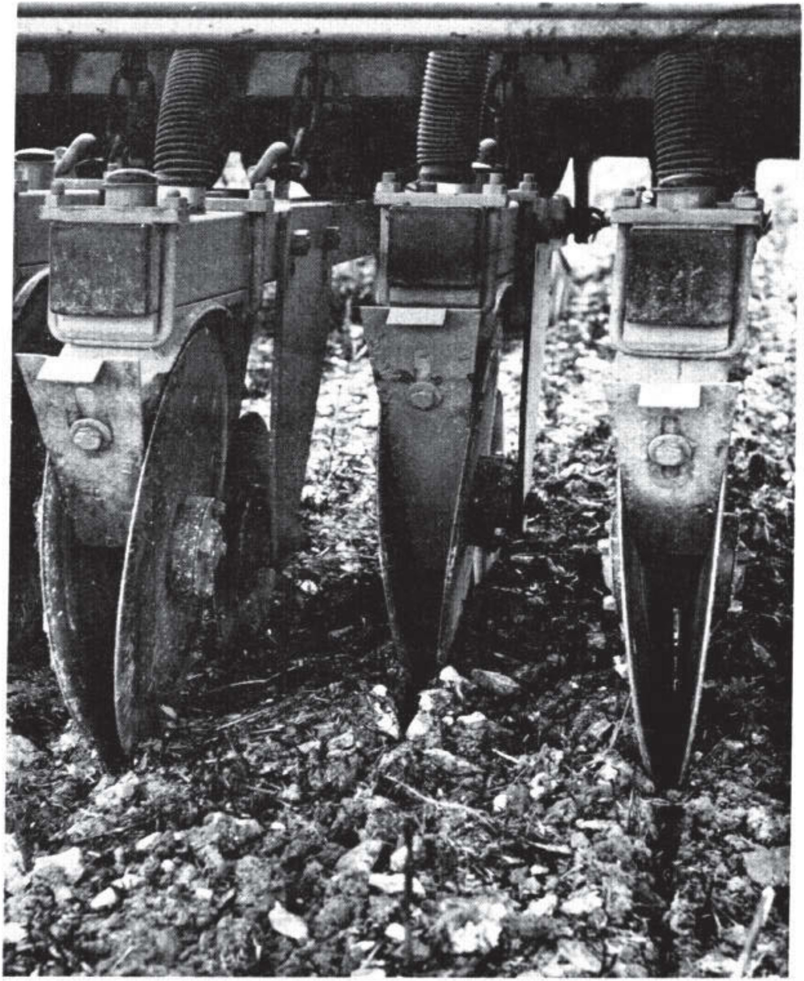


Fig 15 Detail of direct drill working (copyright ICI Ltd)

The really big economic advantage is the economy of labour and time achieved. This is even more applicable to direct drilling than the minimum cultivation techniques, and important advantages can result. Although costs may only be slightly lower, productivity is much higher: about five times the acreage of crop can be established by direct drilling as compared to ploughing, and this may be more if it can be finished before bad conditions restrict ploughing. The timing of sowing can be important and the speed of direct drilling allows the farmer to get as much as possible sown at the optimum time. This, in itself, can increase yields per acre over the same crops sown at less suitable times. Furthermore, yield varies with the type of crop and, if by using direct drilling a farmer can increase his acreage of winter wheat rather than being forced by bad weather to wait till he has to sow spring barley, he not only makes more profit on the wheat but also gets a greater yield (Tables III-VI).

Weed control

Using paraquat this can be excellent, together with the absence of cultivation, provided that spraying is done thoroughly in terms both of quantity and coverage. Wild oats can be controlled well, but couch grass can be a problem, and if well established may be disastrous for direct-drilled crops. Fields already infested with couch grass are normally quite unsuitable for direct drilling. It is hoped, however, that a new chemical will overcome this (Anon. 1975b). Other pests such as slugs have been noticed as a problem, but can be dealt with by slug pellets drilled with the seed. Diseases can be encouraged and pests harboured by any remaining trash.

Fertilization

This is encouraged by leaving stubble and dead vegetation to rot in the ground without being disturbed, the resulting humus remaining at the top. Nevertheless, full rates of chemical fertilizer are always advised.

Preparation of seedbeds

In its usual sense this is unnecessary, but nevertheless a great deal of care must be taken to prepare the ground properly. All straw must be removed by burning or baling, of which burning is usually recommended, being more thorough. Drilling normally is delayed for a few days after spraying, but in stubble can follow almost immediately. Compacted areas may need to be loosened up by shallow cultivation. After drilling, rolling or light harrowing may be necessary to cover the seeds. Apart from this broad type of preparation, the different types of drill do have different qualities in producing a seedbed. Though the penetration qualities of the triple-disc drills are good, heavy land tends to be drilled with the tined versions, since these afford greater disturbance of the soil, allowing better aeration and surface drainage with the seed benefiting from improved soil covering and looser soil beneath it for the penetration of young roots.

The triple-disc version is nevertheless widely used on heavy land as well as lighter soils. On friable soils this version is often considered more suitable, since the soil's natural friability provides some covering for the seed and not too compacted a soil for good root development. Even so harrowing is normally regarded as necessary.

Soil structure and drainage

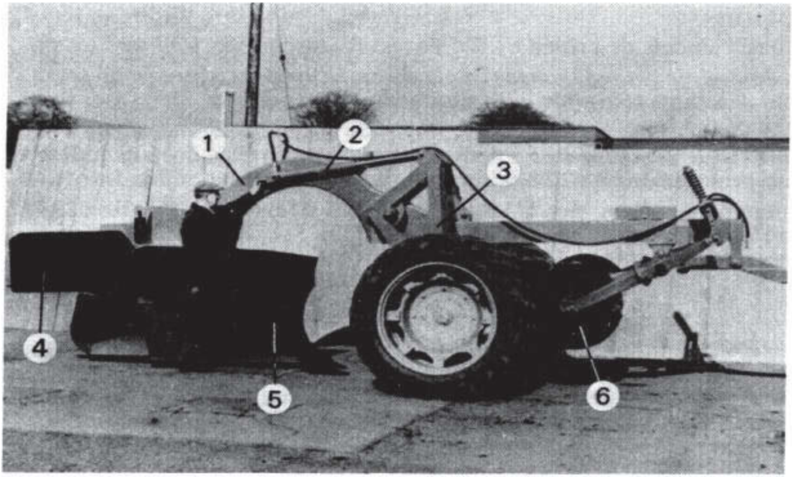
Although the better direct drills are capable of dealing with most soils, they tend to be most successful in friable soil. Elsewhere compaction can be a problem and if drilling is done in wet conditions smearing of the seed groove can restrict growth. So far almost all direct drilling is replaced by a year of cultivation every three or fouryears to loosen and aerate the soil, but experiments have shown that this may not be necessary, and that soil structure may start to improve after three or four years without disturbance, as the humus builds up in the top layer; worm populations increase after a few years of direct drilling, both indicating and assisting improved soil structure. On very light soils direct drilling can greatly assist in improving the top layers of soil, and it can be used to control wind erosion. On slopes, water erosion can also be checked to some extent by leaving the soil undisturbed (Gard and McKibben 1973). On badly structured heavy soils compaction and lack of drainage can become serious problems, and regular cultivations and subsoiling are often thought necessary, though the decrease in the repeated passage of heavy machinery can sometimes alleviate such problems. The question of structure and drainage is important and the wisdom of total lack of soil disturbance for much over five years, even on good soils, remains debateable (Cane11 and Finney 1973; Stranak 1968).

Forestry ploughs

Specialized forestry ploughs have been developed over the last twenty years or so to deal with the difficult conditions and special requirements of forestry in the highland zone. Apart from these, normal cultivation equipment is also often used, especially on small private plantations and in ordinary soil conditions. There is insufficient space here to deal with the special equipment in great detail, but *Forest Record No* 73 (Taylor 1970), from which this information is taken, discusses these ploughs and the techniques of forestry ploughing much more fully.

Action

There are three types of forestry plough; for drainage, turfing, and cultivation. All are based on the mouldboard plough, but are very much larger and produce very substantial furrows leaving the spoil on one side or, in some cases, on both sides. Tines may be coupled with the mould-board to produce a subsoiling effect as well.



1. Arched beam 2. Hydraulic lifting mechanism 3. Plough carriage with twin wheels
4. Heavy trailing mouldboard 5. Mouldboard 6. Twin spring-loaded discs

Fig 16 Forestry deep draining plough (Crown copyright)

Fig 17 Deep draining plough working (Crown copyright)

Variations

The basic models described by the Forest Record are as follows:

Deep draining mouldboard (single throw): Produces furrow up to 36in deep and 46in wide with spoil thrown on one side 18in from the edge of the furrow.

Tine single mouldboard: Produces furrow up to 24in deep including tine penetration and 20in wide with spoil on one edge of the furrow.

Tine double-throw mouldboard: Produces a furrow up to 12in deep and 34in wide with tine penetration to 24in. Spoil disposal on each edge.

Turfing single mouldboard: Produces a furrow up to 20in deep and 27in wide with spoil on one side 12in from edge.

Turfing double-throw mouldboard (shallow): Produces a furrow up to 12in deep and 34in wide with spoil near each edge.

Turfing double-throw mouldboard (deep): Produces a furrow up to 28in deep and 27in wide with spoil disposal on either side back from the edges of the furrow.

Depth and direction of work

Depth

Depth will vary according to the model used (see above).

Direction

Forestry ploughs work at about 5ft intervals working up and down slopes to produce well spaced spoil ridges for planting with the furrows acting as permanent, semi-permanent, or temporary local drains according to their size.

Advantages and problems

Economics and management

The very considerable power requirement and the slow work rate, which are characteristic of these heavy draft ploughs, are accepted as inevitable for large-scale forestry work on peat and other poorly drained land. Normal equipment usually cannot cope with such conditions. Where normal equipment can be used effectively it is far more economical. To some extent this is mitigated in that forestry ploughs achieve simultaneous seedbed preparation and drainage and are used at relatively wide spaces.

Weed control and fertilization

Not very significantly helped in most cases.

Preparation of seedbeds and soil structure and drainage

These are effectively achieved in the one operation of creating the spoil ridges and furrows. Simultaneous tining further improves drainage and soil structure on heavy soils.

Trends in modem cultivation techniques

Farming is essentially a matter of individual problems, any of which may change from year to year, making generalizations of limited value, or of none if applied to individual cases. This section has therefore been kept short and is intended largely to put the foregoing accounts of the cultivation techniques in perspective and to consider some of the general assumptions made by archaeologists and others about recent trends.

Perhaps the most generally expressed assumption is that there is a trend towards 'deep ploughing'. Often it is the only assumption ever voiced and it is in danger of becoming accepted as the most important trend in modern cultivation. This has already to some extent been dealt with in the section on mouldboard ploughing, where it was suggested that while much deep ploughing is being done it is probably not now increasing very much, or at least, not as much as it was five or ten years ago. Subsoiling and panbusting, on the other hand, are becoming more common as the value of subsoiling is more widely accepted and as the problem of pans becomes more clearly recognized, both helped by MAFF encouragement (Anon. (MAFF/ADAS) 1970a; Anon. (MAFF) 1972) and grants. Deep ploughing, subsoiling, and panbusting must not be confused: they are quite different operations and, being intended to have different effects on the soil, may produce very different results on archaeological remains.

The assumption that deep ploughing is rapidly increasing is thus misleading and, moreover, if expressed as the only major trend, may be doubly misleading in ignoring tendencies towards shallower cultivation.

The conversion to tined implements, for example, seems to be a well established continuing trend (Culpin 1974). Chisel ploughs and rigid-tine and leaf-spring-tine cultivators are commonly used simply to replace the mouldboard plough because of their more economical performance but, though work may continue at the same depth, it frequently does become shallower. Connected with this conversion is the tendency towards reduced or minimum cultivations, which are essentially a means of economizing on the numbers of passes over a field to prepare it for sowing.

In most cases the easiest way to ensure that this is possible is to reduce the depth of initial cultivation and to use a tool which will break down the soil to a reasonably fine condition from the start. Usually it is the rigid-tine cultivators that are used in these systems. The adoption of other minimum cultivation equipment, the stubble ploughs, S tines, discs, and rotary cultivators, which certainly make cultivations much shallower, is less common. In general the adoption of minimum cultivation systems has increased fairly rapidly but on a small scale. Although it is connected with the trend towards the use of tined implements, it is by no means an automatic corollary of such conversions: the tined implements are sufficiently economical in themselves to make direct substitution at the expense of the mouldboard plough a worthwhile operation. The Government has encouraged the adoption of minimum cultivation systems, though not with grants (Anon. (MAFF/ADAS) 1973) and, more important, economic pressures are likely to promote such systems (Anon. 1974a).

This is true also of direct drilling (Elliott 1973; Young 1973). So far, although the increase in its use has been rapid, it remains a technique used only by a small minority and one which is still regarded by many as essentially experimental. Again the greatest boost to it will be from economic pressures. Many such pressures are at work. Labour costs are rising and labour is becoming scarce; fuel and maintenance costs are rising as are machinery prices and those of chemical weedkillers and fertilizers. At the same time profits are seldom keeping up with these increases. This is not new and the introduction of continuous cropping, larger tractors, and larger ploughs, and then the faster chisel ploughs, have all been developments aimed at increasing output to overcome the effects of diminishing profit margins. Minimum cultivation and direct drilling are really the next developments in this direction and may yet become as popular as the earlier ones.

Another common assumption, and a more justified one, is that more grassland is being ploughed up. This should be put in perspective to some extent, for much grassland has already been ploughed up, especially during the last war and afterwards. This is particularly true of the chalk downlands, and though the trend continues it is now much slower (partly because so much is already ploughed). The tendency now seems to be more towards cultivating the heavy claylands, often for the first time since the Middle Ages (Morrison and Idle 1972). This is encouraged by the large drainage grants of between 25% and 55%, which include grants for subsoiling and moling as well as pipe drainage (Anon. (MAFF) 1974), while at the same time simple ploughing grants are no longer made. The profitable capacity of farming can thus be increased simply by putting more land under the more profitable crops. A connected trend is that towards grassland improvement: increasingly grass is regarded as a crop similar to other fodder crops like kale, and this often leads to the cultivation and reseeding of old grassland with long-term ley grass. Recent problems with fodder could lead to more use of carefully cultivated grass (Moore 1974).

It must be emphasized that all these trends remain minority ones: the great majority of farmers still use the traditional methods of mouldboard ploughing and crop rotation on the same fields, and do so not out of conservatism or habit so much so because the older techniques when used properly still give the most reliable results, often quite economically. The economic considerations which dictate the adoption of other techniques are most influential when it is felt that the quality of cultivation and the reliability of yield will not be impaired. Since many farmers remain sceptical of the quality of the new techniques, their spread will remain slow until economic pressures become a more important consideration, which has probably not yet happened.

It is difficult to substantiate these trends in figures and in any case it may not be important to define them closely since they can change or be reversed quite quickly. In addition, one cannot draw any very useful conclusions from them in practical terms. In farming so much depends on individual policy and circumstances that it is extremely dangerous to work from the general to the particular. Just because there is a trend to shallower cultivation it does not necessarily follow that the threat to archaeology is diminished, although that may be so. Similarly, though it may seem likely that the ploughing up of grassland is a serious threat, it is not demonstrable exactly how serious it is until many individual cases have been studied.

Archaeology and cultivation: problems of assessment

Introduction

Too little is known as yet about the effects of cultivation on sites to make any definitive statements: much more detailed information is needed and careful consideration will have to be given to its collection. The foregoing account of cultivation techniques deals with only one of the several variables which must be assessed. This section is intended to draw attention to some of the others, to possible ways of assessing the threat, and to some of the problems of doing so. No actual assessment has been attempted, as that could only be done by a proper survey, nor has any formal comparison been made between the different cultivation methods as potential threats, since this should be fairly obvious from the technical information coupled with field observation.

Although it is obvious to archaeologists, it is not widely appreciated outside archaeological circles that ploughing is often a serious threat to sites. It is commonly believed that sites are buried by 3ft or more of soil even in the countryside, whereas in fact the depth of a site below ground *surface is normally defined by the deepest level of ploughing.* Unploughed sites usually survive to within about 3 *inches* of the modern ground surface, with the stones of buried walls often visible through the grass. On ploughed sites, however, the later stratigraphy, sometimes all of it, will normally have been lost, the remaining levels surviving up to the lowest level of ploughing. It is most important that this is appreciated by farmers, since many sites are damaged or obliterated quite unintentionally through their not realizing how very easy it is to destroy archaeological remains. Centuries of history can be destroyed for ever by one pass of the plough. It is also important for archaeologists, not only because the ploughsoil often contains important archaeological evidence of occupation later than the surviving structure below, but also because it draws attention to the need, in assessing plough damage, to establish the lowest level to which cultivation has ever penetrated, rather than merely observing the surface appearance of a field.

The recognition of ploughing as a threat is not new: various antiquarians, including Stukeley, observed sites being damaged from the early 18th century onwards (Lambrick 1975), and until recently modern observations, if more frequent, have seldom been any more scientific than Stukeley's Reports of excavations on plough-threatened sites rarely discuss ploughing or even, in some cases, demonstrate the existence of the threat. Much work is now being done on the problem, but it is still not very well co-ordinated, although efforts are now being made to establish a coherent policy. Perhaps this booklet may be one contribution to such a policy.

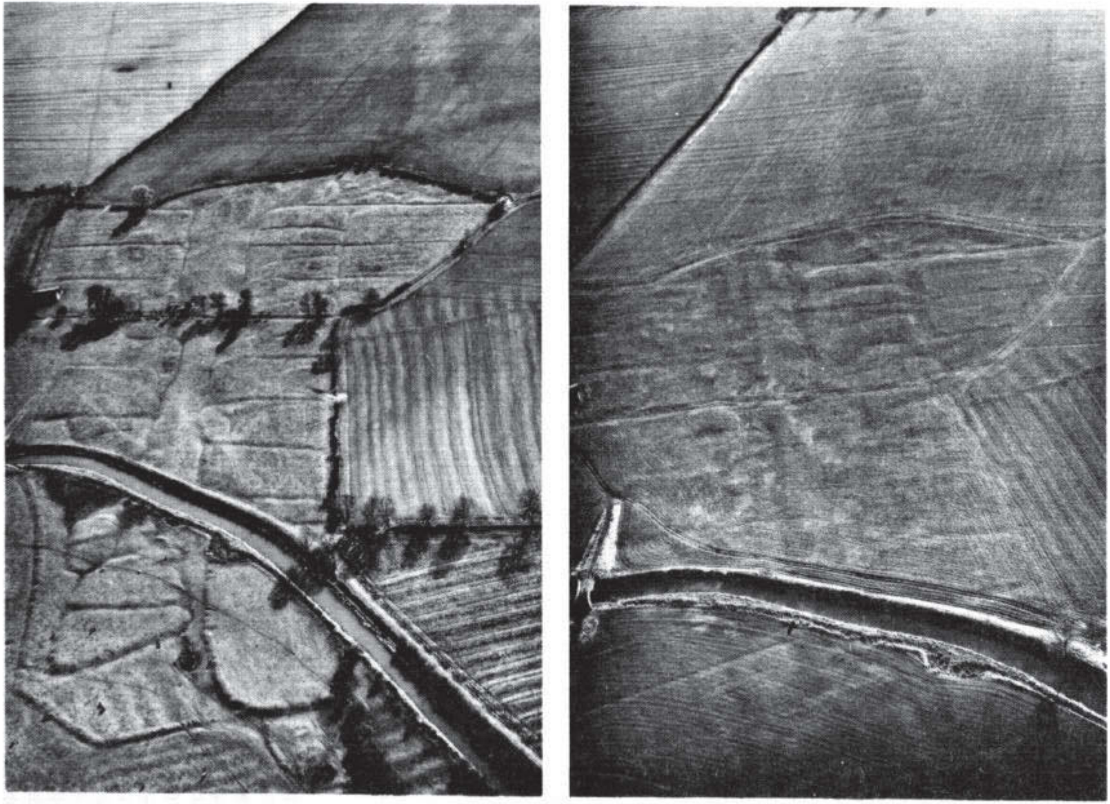


Fig 18 Downton deserted medieval village, Northants. Before (1963) and after (1965) ploughing of the site (Cambridge University Collection; copyright reserved)

Variables

The great problem with the assessment of ploughing threats is that of definition: there is no way, as with other types of threat, that one can look up where plough threats will occur or what damage will be done. There is only a complicated interaction of variables, each of which needs to be assessed in every case. At our present state of limited knowledge it is impossible to make generalizations about the threat; but even after careful study it may be found that the variables are such that it will remain dangerous to try to define threats in particular cases from broad generalizations. The most important variables are as follows:

Soil type and bedrock
Topography, especially slope
Type and usage of cultivation equipment
Depth of cultivation
Type and condition of archaeological remains
Previous cultivations

These are the minimum which should be considered if realistic assessments of sites are to be made, since each may be decisive. The potential variation of these is almost limitless (only the third factor is considered by this booklet for example), but the threat may nevertheless be divided into three broad categories:

The cultivation of previously unploughed sites
The deeper cultivation of existing arable
The effective deepening of cultivation caused by erosion, encouraged by ploughing to a constant relative depth.

Problems of definition

The cultivation of previously unploughed sites

This is probably the most serious type of threat in that unploughed sites are normally the best preserved and the closest to the surface. In most circumstances any cultivation on these sites will cause serious damage (perhaps the only really valid generalization at present). Even so, there may be problems of definition. Most unploughed sites are recognized by surviving earthworks, but such earthworks can survive, mutilated but recognizable even after a few years' cultivation. Thus it is important to be sure whether ploughing has not already taken place and the site reverted to grass.

The disturbance caused by the plough may not be the only damaging factor: once the grass cover is broken natural agencies of erosion will be encouraged considerably, and may be difficult to assess. Even more difficult to assess will be the rate of destruction. Earthworks tend to be planed flat by any form of cultivation, but the rate of this process is unknown, and in addition there are likely to be contrasting areas of denudation and deposition on bumps and in hollows. On stony sites the archaeological features may occasionally resist the plough at first, so that the real damage is not done until a second or third ploughing. This is in no way predictable and such a process would have to be assessed after progressive destructive cultivations. It should not be forgotten that a previously unploughed site may simply become partly mutilated like so many other ploughed ones rather than being totally destroyed at the first ploughing.

The deeper cultivation of existing arable

This presents a similar threat, except that much will normally already have been lost. The type of machine used may be an important variable in that, for example, subsoiling and deeper mouldboard ploughing will produce very different effects on the soil. The chief difficulty, however, is that of defining where deeper cultivation has occurred and how much extra damage has been caused. What the farmer intended may not always correspond exactly with what has actually happened in the ground. It may also be difficult to establish whether earlier cultivations, such as ridge and furrow or steam ploughing, have not already penetrated more deeply. On the other hand it is dangerous to assume, for instance, that ridge and furrow will already have destroyed a site, since the ridges may have afforded some protection. There may be considerable difficulty in finding satisfactory evidence on the ground to measure the degree of new disturbance, and again the rate of destruction is difficult to assess: one pass with a plough could be totally destructive, while subsoiling might vary considerably in its effect depending on localized soil conditions and the way the implement is used, as well as the type of site concerned.

The effective deepening of cultivation by erosion

This is probably the slowest type of destruction, but possibly the most widespread. Only long-term measurement can be used to measure its rate accurately, and it is in this area of fairly slow destruction that changes in the variables are likely to be most significant. Although erosion is clearly most serious on light soils on slopes, it will occur to some extent on all soils, and even on flat land where wind erosion may be serious. Earthworks as well as sites on generally sloping land can be affected. Erosion can, on the other hand, afford considerable protection to sites at the bottom of slopes where run-off collects. The bottom of slopes are often in practice the bottom of fields on slopes, and where field boundaries are changed, significant changes in erosion patterns may occur. Sites on slopes may thus vary considerably in their condition between the top and the bottom of the slope and either side of field boundaries.

Almost all ploughed sites, especially those on slopes, may suffer from this type of damage and one of the most difficult problems is that of deciding when the threat is serious enough to warrant positive action, and how much can be done to safeguard such sites.

In general it is essential to distinguish between damage that has already been done and damage which is currently happening. The former is usually quite easy to establish, the latter can be extremely difficult, and it is all too easy to quote evidence of past damage as indicating current damage without checking that the same conditions prevail among the variables.

Methodology and policy

Information on cultivation practices is not readily available in any detailed form, and to make any assessment of plough damage the archaeologist must accumulate most of the evidence himself. The evidence is varied both in its forms and usefulness, and the following consideration is intended partly to look at the limitations of some of the various forms.

Surface evidence

Although this is the most easy to acquire, it may have received undue attention in being used to indicate plough-damage. To try to measure soil movement by studying the movement of objects in the soil, for example, may result in no more than an analysis of the movement of those objects; the gradual dispersal of rubble scatters and soil marks so often observed from the air may prove nothing about the continuing condition of the site beneath the top-soil, and changes in the rate of dispersal could sometimes reflect only a non-destructive change in cultivation technique. It has not yet been *proved* that fresh breaks in pottery always indicate deeper disturbance rather than, for example, a change in cultivation methods, such as from tine harrowing to disc harrowing. Even if this type of evidence does usually indicate deeper disturbance (as is likely), it in no way measures how far damage has increased. The opinion, still sometimes voiced, that the mere continual appearance of pottery on the surface of ploughed fields indicates damage is plainly ridiculous: unless all the pottery is removed from the ploughsoil it will continue to be brought up by ploughing even at a shallower depth.

On the whole, studies of the contents of the ploughsoil provide information only about that layer, the archaeology which has already been lost, not about the survival of the undisturbed archaeology below. Finds from ploughsoil may provide valuable archaeological evidence of the continuation of occupation for which all structural evidence has been ploughed away, but in ploughing terms it is normally evidence only for past damage not current damage, unless much fresh material appears.

Other surface evidence is also limited in usefulness. It is often possible to measure the depths of the outermost furrow at the edge of a field, for instance, but this may not indicate the general depth of ploughing in the middle of the field or any change in the depth, and can in any case be done only with mouldboard ploughing. The appearance of freshly turned up subsoil on the ploughed surface can be a good indication of increased depth, but it is only clearly visible on suitable soils after mouldboard ploughing, and even so must be inspected carefully: a vast expanse of churned-up subsoil may be visible but, because it is the inverted bottom of the furrow which is seen, close examination is required to tell whether it is 0.5cm or 10cm thick, indicating the real increase in depth. It is also possible to tell from the cultivated surface of a field what implement has been used, but this is of little use unless the depth also can be ascertained, and the surface indications of subsoiling, for instance, are virtually undetectable as soon as the field has been cultivated.

On unploughed sites surface indications are more reliable in that it is easy enough to tell when grassland has been ploughed up. It may also be possible to tell whether grassland has been ploughed before, since mouldboard ploughing in lands usually leaves small distinct ridges and furrows spaced 15-25m apart. The botanical composition of the grass itself may also assist in determining whether a site has ever been disturbed.

In the case of erosion, surface observation is the only practicable means of assessing the problem, and this can be particularly effective with ploughed earthworks, but even so accurate assessment can only be made by detailed measurement from fixed datum points over a number of years. While relatively simple to carry out in practical terms, the interpretation and application of results may be complex when all the variables are taken into account. Further information about erosion may be obtained by other means, and, for example, experiments monitoring the movement of dyed soil are already under way.

A specialized form of surface observation is aerial reconnaissance, but here again there are problems and limitations. The condition of sites can be observed quite effectively from the air, especially changes such as the ploughing-up of earthwork sites (Fig. 18). The dispersal of rubble scatters or soil-marks are also often detectable, but it is not always clear that these indicate increased damage to the underlying sites rather than merely a gradual mixing of the soil above already destroyed features. Crop-marks are also observed to change, but again this cannot always be shown to be the result of damage to the underlying features, though gradual destruction of features on slopes can be apparent from the progressive disappearance of soil- or crop-marks from the top of the slope. Mostly aerial reconnaissance is useful to show past damage and it may also improve greatly the overall view of surface observations, but normally it cannot demonstrate conclusively continuing damage any better than work on the ground, and observations should be checked in the field. Used together, the two techniques can add much to each other.

It is important that the limitations of surface evidence should be recognized: even if it shows that damage is taking place, it can seldom show how serious the threat is. This sort of evidence is useful, however, in providing broad indications of damage and confirmation of other evidence, and, if only as the simplest method of obtaining evidence, it is likely to remain important in assessing damage.

Excavations and experiments

Both may be used to obtain more detailed information. Each has important advantages: excavations can deal with a wide range of real archaeological conditions, and can measure the depth of cultivation in specific cases; experiments can monitor more effectively the variations of soil, slope, and cultivation method, and can set up artificial conditions to assist the measurement of the effect of cultivation on buried features, objects, and erosion patterns. The main difficulty with such experiments is likely to be the artificiality and lack of variety of the 'archaeological' features which can convincingly be created. Given the artificiality of such experiments, it may be doubted how far general conclusions can reasonably apply directly to actual archaeological cases. This criticism is not confined to experimental results, however, and it is in any case too early to make any judgement on the usefulness of general conclusions.

The excavation of plough-threatened sites also has its limitations, especially in having less control on the variables. On the whole, excavations are likely to be most successful in investigating the effects of specific operations, such as the first ploughing of earthworks or subsoiling. Excavations may be carried out in various ways, such as before and after (or only after) specific operations, comparing ploughed and unploughed parts of the same site, or comparing current conditions with those observed in earlier excavations. It is also arguable that such excavations should stop at the bottom of the ploughsoil: thereafter, if the threat is shown to exist, the excavation could be justifiable only in normal rescue terms.

One method combining the advantages of experiments and excavations would be deliberately to plough and then excavate genuine features of no archaeological interest. There might however be many practical difficulties, not the least of which would be the question of whether features of 'no archaeological interest' exist.

Other sources of information

These include a minimal amount of documentary evidence for the past cultivation of a very few sites, but also the most important source of all, the farmers themselves. It is obviously the farmers who know most about the details of the cultivation of their fields, and it is hopeless to try to assess fully the threat to sites without obtaining as much information as possible from them. Even where the threat is absolutely obvious on the ground, information about proposed future cultivation policy is important. Co-operation and understanding between farmers and archaeologists are essential prerequisites for the successful assessment of plough damage, because only farmers can tell the archaeologist at all accurately what equipment has been used, when, where, and to what depth.

Clearly there is a conflict of interests and difficulties may arise, but unless the gap is bridged wherever possible there is little hope of establishing a more effective and realistic policy for the protection of rural sites. Discussions with farmers will not produce all the answers, but in most cases they will produce many which could not be obtained by other means. In the end constant cross-checking of *all* the evidence will enable the most accurate assessment to be made.

Policy

It is outside the scope of this booklet to suggest any detailed overall policy either towards ploughing threats themselves or their assessment, and only a number of general comments are included.

A recent advance in policy for the protection of rural sites was the Government's doubling of the scale of acknowledgement payments (Table VII). This has already led to an increase in the number of payments made, but of course it still applies only to unploughed sites, and is still limited in flexibility by not being scaled according to land classification. The scheme can be used to allow limited use of direct drilling, but such cases are very rare. A more extensive formal scheme should be considered to encourage the use of direct drilling where sites cannot be taken out of cultivation altogether, and recently an outline scheme has been suggested by the Oxfordshire Archaeological Unit. In such a scheme grants to compensate for any extra cost and/or loss of yield resulting from direct drilling would be available, thus fully compensating the farmers for any financial loss. The cost of such grants would probably at present be less per acre than the new acknowledgement payment rates. There are many complications, and in particular no subsoiling, levelling, or intermittent cultivations, commonly associated with direct drilling, would be allowed. Its application to unploughed sites could only be a last resort, but there seems little reason, given sufficient control, why it should not be applied to arable sites, Whether such a scheme would be acceptable either to farmers or archaeologists remains to be seen, but it is at least worth serious consideration. A further improvement to formal policy would be to establish closer contact between County archaeologists and the appropriate officers of the Agricultural Development Advisory Service. Drainage and subsoiling grants could thus be monitored for all archaeological sites in an attempt to control this form of threat, enabling the appropriate action to be taken before damage occurs.

Future policy is likely to include further surveys to assess plough threats, possibly on a more detailed level, as well as continued excavations on plough-threatened sites. In both cases it is to be hoped that the methodology and criteria used are described, and preferably that they should be agreed upon beforehand. Such work should not, if possible, be confined to earthwork sites, since this would ignore whole classes of site and major types of threat encountered only on arable land. As soon as arable sites are taken into consideration the work becomes more difficult and more time-consuming, but, if a reasonable overall assessment of the threat is to be made, all types of site must be included.

Already much work specifically concerned with cultivation on sites is well under way, but the work can easily be extended to encompass new sources of information if archaeologists in general, both excavators and field walkers, will record more details about cultivation practices and their effects on sites. The limitations of all the various sources of information must be considered and reconsidered as work progresses, but all should be used to their maximum potential if any real attempt is to be made to cope with the problem of plough damage to sites.

Appendix I: Tables

The following tables are intended to clarify and define to some extent the generalizations made in the foregoing discussion. This is by no means altogether satisfactory, since up-to-date figures seldom exist and are no more than very broad generalizations where they do. The tables are most useful in giving a rough comparison between the various techniques, but it should be realized that there are other considerations than these which may dictate a farmer's policy and that these only give average figures which may be highly inaccurate in particular circumstances. *All the agricultural costs quoted are 1973 figures and are included for comparative* purposes only; more recent costings are not readily available and would in any case rapidly become outdated.

TABLE I: Comparison of cost and workrates of different cultivation implements
(Source: *Power Farming Nov.* 1973)

1	Mouldboard plough, 3-furrow, 12in wide working 6in deep with 60hp tractor.		
	Heavy soil	0.75 acre/hr	£2.55/acre
	Medium soil	1.00 acre/hr	£1.91/acre
	Light soil	1.50 acre/hr	£1.27/acre
2	Mouldboard plough, 6-furrow, 12in wide working 6in deep with 105hp tractor.		
	Heavy soil	1.50 acre/hr	£2.34/acre
	Medium soil	2.25 acre/hr	£1.55/acre
	Light soil	3.25 acre/hr	£1.10/acre
3	Reversible plough, 3-furrow, 12in wide working 6in deep with 75hp tractor.		
	Heavy soil	1.00 acre/hr	£2.48/acre
	Medium soil	1.50 acre/hr	£1.65/acre
	Light soil	1.75 acre/hr	£1.38/acre
4	Subsoiler, twin-leg, working 18in deep with 60hp tractor.		
	Heavy soil	1.00 acre/hr	£2.05/acre
	Medium soil	1.75 acre/hr	£1.17/acre
	Light soil	2.50 acre/hr	£0.82/acre
5	Chisel plough, 7 tines, 8ft wide working 8in deep with 75hp tractor.		
	Heavy soil	2.00 acre/hr	£1.01/acre
	Medium soil	3.00 acre/hr	£0.68/acre
	Light soil	4.00 acre/hr	£0.51/acre
6	Spring-tine cultivator, 35 tines, 11ft wide working 4in deep with 60hp tractor.		
	Heavy soil	4.50 acre/hr	£0.48/acre
	Medium soil	5.00 acre/hr	£0.43/acre
	Light soil	5.50 acrefhr	£0.39/acre
7	Disc harrow, 8.5ft wide working 4in deep with 60hp tractor.		
	Heavy soil	3.00 acre/hr	£0.73/acre
	Medium soil	4.00 acre/hr	£0.55/acre
	Light soil	5.00 acre/hr	£0.44/acre
8	Rotary harrow, horizontal rotor, 5ft wide working 5in deep with 60hp tractor.		
	Heavy soil	1.00 acre/hr	£2.61/acre
	Medium soil	1.50 acre/hr	£1.74/acre
	Light soil	2.00 acre/hr	£1.30/acre

TABLE II: Increased yield achieved by subsoiling panned soil
(Source: ADAS *Berkshire Bulletin* no. 85, Sept 1971)

	Av. increased, cwt/acre		
Cereals on heavy soil	2.3	4.1	4.2
Cereals on light soil	1.8	1.9	1.1
Grassland			

(grain yield at 15% moisture content; grassland yield expressed as dry matter).

TABLE III: Comparison of approx. cost/acre of different cultivation systems
(Source: ADAS *Profitable Farm Enterprises Non-ploughing for Cereals* 1973)

ploughing		*cultivation*		*drilling*	
ploughing	£1.59	2x heavy cultivation	£1.69	spray	£2.82
2x discs	£1.95	spray.	£1.88	spraying	£0.38
spring tines	£0.21	spraying	£0.38	harrowing	£0.21
totals	£3.75	spring tines	£0.21		
			£4.16		£3.41

TABLE IV: Comparison of acreages established by different cultivation systems
(Source: ADAS *Profitable Farm Enterprises Non-ploughing for Cereals 1973)*

	plouging	*Reducea cultivation*	*Direct drilling*
Man hrs/acre	2.1	1.5	0.4
Acres established in 40hr week	19.0	26.5	100.0

TABLE V: Comparison of workrates and power requirements of different cultivation implements
(Source: ADAS *Profitable Farm Enterprises Non-ploughing for Cereals 1973)*

	Plough	*Chise plough*	*Direct Drill*
Hp hrs/acre	25	14	8
Acres/hr (75hp tractor)	1.5	2.8	5.0

TABLE VI: Comparison of yields of winter wheat and spring barley achieved by direct drilling as against ploughing
(Source: ADAS *Profitable Farm Enterprises Non-Ploughing for Cereals 1973)*

	No.of Experiments	*No. of cases where yield was 20% lower*	*20% higher*	*within 20%*
Winter wheat	36	12	2	22
Spring barley	42	20	4	18

TABLE VII: Acknowledgement Payments Scheme rates of payment
(Source: DoE, Ancient Monuments Secretariat)

SCALE 1 (to 1st April 1977)

First acre	£20 per acre
Next four acres	£4 per acre
Next five acres	
Remaining acres	£2 per acre

For monuments over 1 acre in aggregate consisting of a number of pockets of land there are two options:

1. A scale payment assessed according to the aggregate

or 2. £5 for each individual scheduled pocket subject to a maximum of £100 under this option.

SCALE 2 (after 1st April 1977)

0 -0.5 ha	£25
0.5-1.0 ..	£40
1.0-1.5 ..	£50
1.5-2.0 ..	£60
2.0-2.5 ..	£68
2.5-3.0 ..	£75
3.0-4.0 ..	£80
Remaining hectare(s) or part hectare	£5

For monuments over 0.5 ha in aggregate consisting of a number of pockets of land there are two options:

1. A scale payment assessed according to the aggregate area.

or 2. £5 for each individual scheduled pocket subject to a maximum of £100 under this option.

Appendix II: Bibliography

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