

# The Management of Archaeological Sites in Arable Landscapes BD1701, CSG15

## Final Project Report



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Research and Development

# Final Project Report

(Not to be used for LINK projects)

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## Executive summary (maximum 2 sides A4)

The *Management of Archaeological Sites in Arable Landscapes* project has been undertaken for the Department of Environment Food and Rural Affairs (DEFRA) by Oxford Archaeology in conjunction with the Council for British Archaeology, Oxford University and Reading Agricultural Consultants. The objective has been to establish the basis for developing a management strategy for preserving archaeological sites on arable land that will focus on where damage is most serious and will provide sustainable remediation of the problem. To be sustainable solutions must be both effective in substantially reducing the medium to long term threat of damage (within a clear perspective of where damage is most likely to occur), while also maintaining agricultural viability and minimising extra cost to the exchequer or loss of revenue to the farmer.

### As an environmental issue for arable landscapes, agricultural damage to archaeological sites has a number of key characteristics:

- Archaeology is the *only* source for 80% of human history since the introduction of farming, and is also vital for more recent periods;
- Rural areas represent the most extensive and varied source of this evidence, and much of the countryside is in arable production;
- Very high densities of archaeological sites occur in many areas of intensive arable which have always favoured human settlement;
- Archaeological sites are entirely non-regenerating: a Bronze Age barrow cannot be recreated;
- Much of the resource is in the middle of intensively cultivated fields: remediation has to be where the resource is;
- Most of the resource is buried - albeit often at shallow depths - which makes reliable assessment of damage intrinsically difficult;
- A major proportion of sites remain to be discovered, perhaps as much as five to ten times more than is known at present.

Plough damage to archaeological remains is as old as farming itself, and it has been acknowledged as a problem for conservation since at least the early 17th century. Several regional studies and individual cases are reviewed that have indicated the scale and nature of the problem in the last 30 years. The English Heritage Monuments at Risk Survey, published in 1998, showed that agriculture has been responsible for 10% of all cases of destruction, and 30% of all piecemeal cumulative damage to ancient monuments in the last 50 years. 65% of monuments in arable areas are at

medium or high risk of damage. According to figures from MARS data provided by English Heritage for rural monuments only, 32% of all rural archaeological sites and 21% of rural sites protected as Scheduled Ancient Monuments were still under arable cultivation in 1995. A study of English Wetlands indicates that 9020 monuments have been damaged by drainage and 2180 monuments have been damaged by conversion of pasture to arable.

Numerous cases are used to illustrate the range and character of damage to archaeological sites in arable landscapes which include:

- The cultivation of previously unploughed sites or parts of sites;
- Lateral encroachment of arable onto archaeological sites;
- The gradual planing flat of upstanding earthworks surviving within arable;
- The deeper cultivation or regular subsoiling of flattened sites in existing arable;
- The effective deepening of cultivation caused by erosion, peat shrinkage and compaction while ploughing to a constant depth;
- Disturbance, breakage and chemical deterioration of portable antiquities;
- Physical damage and desiccation of organically preserved sites and objects caused by drainage;
- Physical damage caused by ancillary works such as farm tracks, barns, irrigation lagoons etc;
- Damage to uncultivated sites within arable areas caused by burrowing animals and visitor wear; such ancillary damage is often the result of the isolation of these features and subsequent neglect.

While it is often easy to demonstrate that damage has occurred, it is usually more difficult to show how active or rapid the attrition may be. Often there is a threshold effect where critical evidence could be destroyed at a stroke by only slightly deeper cultivation. Although many individual sites have been carefully examined in the past, it is plainly not feasible to carry out archaeological evaluation of every threatened site.

To help develop a framework for clearer prioritisation, a reasonably robust and simple method of assessing the risk of damage occurring to particular sites, together with a broader assessment of where geographically the threat is likely to be most serious, have been developed. Both are geared to the key factors that affect whether or not damage is likely to occur, which include both characteristics that are intrinsic to the site, and aspects of how the land is managed. These include:

- The nature of the archaeological remains and quality of their survival;
- Depth of current ploughsoil and extent/ thickness of previous ploughsoils, colluvium and alluvium over archaeology;
- Soil characteristics (erodability, drainage requirements, susceptibility to compaction etc);
- Issues of slope influencing the likelihood of erosion;
- Cropping patterns and rotation;
- Cultivation methods and depths and timing;
- Background issues relating to farm structure and economics, neglect and isolation of features.

At the site-specific level, two approaches to assessing the risk of damage on the ground have been devised and field-tested, one based on a scoring method, the other a decision-tree approach, both of which appear to predict the risk of damage reasonably well. The extent and scale of the risk at a national level has been mapped on a 1km square basis using digitally available data from which documented soil characteristics (depth, erodability and drainage) have been combined with cropping patterns. The patterns of higher and lower risk correlate well with documented damage.

There are broadly two means of reducing the rate of cultivation damage. Reversion to grassland is archaeologically the most secure solution and offers numerous well-established potential benefits in terms of habitat regeneration, soil conservation and promotion of farmland bird populations. Direct drilling and various forms of minimum cultivation offer alternative approaches that potentially allow archaeological sites to remain in arable production without deep soil disturbance. Although there are some geographical and practical limitations to their use or effectiveness, an encouraging finding is that the areas where there is the greatest risk of damage to the archaeology are also those where direct drilling is technically most viable. Shallow cultivation systems are less geographically restricted, but offer less long-term value, especially on earthworks and moderate to steep slopes. No-till and minimum cultivation systems also offer other environmental benefits, including better soil management, lower energy consumption, and reduced use of agro-chemicals, as well as potential for improving arable biodiversity. Simple verification of adherence to restrictions on subsoiling and depth of cultivation are reviewed and are likely to be more problematical than reversion.

For some areas, neither reversion nor minimum cultivation offers a simple, practicable and cost-effective solution to the problem of plough damage. In the East Anglian Fens deep cultivation for high value root crops combined with drainage threatens exceptionally well preserved archaeology that is steadily emerging from beneath the shrinking peat – this problem is particularly challenging in terms of the farm economics of the area and the unsuitability of minimum cultivation methods for root crops. This looks likely to become one of the key test areas for resolving the conflict between high value farming and high value archaeology.

Nine aspects needing further research are identified, which would assist development of policy and practical implementation of improved remediation, but progress towards better remediation of the problem does not need to be delayed to await the results of such research.



## Scientific report (maximum 20 sides A4)

### INTRODUCTION: PROJECT OBJECTIVES AND APPROACH

The Management of Archaeological Sites in Arable Landscapes Project has been undertaken for the Department for Environment Food and Rural Affairs (DEFRA) by Oxford Archaeology (OA) in collaboration with the Council for British Archaeology (CBA), the Institute of Environmental Change at Oxford University and Reading Agricultural Consultants. The study took place during a period of substantial change for farming, especially in the wake of the foot and mouth crisis of 2001.

The objective of this study has been to review the evidence for different kinds of damage and establish the basis for developing a management strategy for preserving archaeological sites in arable landscapes that focuses on where damage is most likely to be serious and which provides sustainable remediation of the problem. To be sustainable, solutions must be both effective and monitorable/verifiable in substantially reducing the medium to long term threat of damage (within a clear perspective of where damage is most likely to occur), while also maintaining agricultural viability and minimising extra cost to the exchequer or loss of revenue to the farmer.

The project was divided into stages, several of which involved production of interim working papers.

*Stage 1:* bibliographic review and questionnaire-based gathering of existing evidence; *Stage 2:* review of the issues that affect how plough damage occurs; *Stage 3:* creation of site specific and national models of risk of plough damage; *Stage 4:* evaluating and testing the models; *Stage 5:* developing best practice for conserving archaeological sites in arable; *Stage 6:* report preparation; *Stage 7:* preparation for guidance for farmers.

These interim working papers have been revised to form supporting documentation supplied to DEFRA on CD ROM and have been added to the DEFRA website as Appendices A-L: **Appendix A:** Initial brief and summary of Final Approach, Methodology and Outputs; **Appendix B:** Details of Regional Plough Damage Studies; **Appendix C:** Legislation and Policy for Archaeological Conservation; **Appendix Di** Introduction to Arable Issues; **Appendix Dii:** The Relationship between Agronomic Factors and Archaeological Survival and the Advantages of Minimal Cultivation and Direct Drilling Techniques; **Appendix Ei:** Introduction to Erosion Issues; **Appendix Eii:** The Relationship between Erosion and Archaeological Survival on Arable Land; **Appendix F:** Case Studies of Archaeological Damage from Arable Activities; **Appendix G:** Site-Specific Assessment and Monitoring; **Appendix H:** National Model of Plough Damage and Statistics; **Appendix J:** Work Commissioned as part of this Study and Stand-alone Documents of Unpublished Work (Halkon 2001, White and Cotton, 2001, French, 2001, Honnor and Lane, 2002, Abrams and Macaulay, 2001, Roberts and Martine 2001, Rollright Trust 2002, Cromwell, 2002, McAvoy 2002) **Appendix K:** Consultations; **Appendix L:** Bibliography

### BACKGROUND

Agricultural damage to archaeological sites has a number of key characteristics as an environmental issue for arable landscapes:

- Archaeology is the *only* source of information for 80% of human history since the introduction of farming, and is a vital source for more recent periods since records began;
- Rural areas represent the most extensive and varied source of this evidence, and much of the countryside is in arable production;
- Very high densities of archaeological sites occur in many areas of intensive arable which have always favoured human settlement;
- Archaeological sites are entirely non-regenerating: a Bronze Age barrow cannot be recreated;
- Much of the resource is in the middle of intensively cultivated fields. It is not possible to choose where to apply remediation measures as it is for example in choosing to use field margins for habitat recreation: remediation has to be where the resource is;
- Most of the resource is buried - albeit often at shallow depths - which makes reliable assessment of damage intrinsically difficult and certainly not immediately obvious to the farmer without guidance;
- A major proportion of sites remain to be discovered, perhaps as much as five to ten times more than is known at present (Darvill and Fulton 1998, 14).

Cultivation damage to physical remains of previous human activity is as old as ploughing itself (Bowen 1980; Richards 1978, 61; Manby 1980), and the fact that archaeological remains can progressively be damaged, or destroyed altogether by ploughing has been acknowledged by antiquaries and archaeologists since at least the early 17th century. From 1870 concern raised by cases like the destruction of prehistoric earthworks like Dyke Hills, Dorchester-on-Thames, Oxfordshire, contributed to the passing of the first Ancient Monuments Act in 1882. The Council for British Archaeology has been highlighting the problem over the last 25 years and more (eg Lambrick 1977; CBA 1988; 1993; 1996). In 1980, the then Chief Inspector of Ancient Monuments summed up the findings of a conference on *The Past under the Plough*, stating:

*"There can be few, if any archaeologists who are not aware that arable farming and forestry are the agencies of the greatest destruction of the material evidence for the understanding of our past..."* (Hinchliffe and Schadla-Hall 1980, 8).

Several regional surveys from the 1970s onwards quantified the problem of archaeological plough-damage (Drinkwater 1972; Gingell 1976; Schadla-Hall 1977; Drewett 1980; Saville 1980; Allden 1981; Lawson et al 1986; Barnatt 1989, Barnatt and Collis 1996; Dunkin 1996 (Appendix B)). But until the last few years there was slow progress in addressing the problem.

The 1972 Field Monuments Act had introduced flat rate acknowledgement payments to help farmers look after protected monuments, and the (current) 1979 Ancient Monuments and Archaeological Areas Act sought to strengthen protection and positive management. Archaeological conservation, together with landscape and wildlife, became a statutory concern for the then Ministry of Agriculture under Section 17 of the 1986 Agriculture Act (Appendix C).

The scale of the problem of archaeological conservation of archaeological sites in arable landscapes was reinforced by the results of English Heritage's Monuments at Risk Survey (Darvill and Fulton 1998). Of c 937,500 known sites and monuments in England the 5%

sample examined indicated that agriculture has been responsible for 10% of all cases of destruction, and 30% of all piecemeal cumulative damage to ancient monuments in the last 50 years. 65% of monuments in arable areas were at medium or high risk of damage. According to figures from MARS data provided by English Heritage for rural monuments only, 32% of all rural archaeological sites and 21% of rural sites protected as Scheduled Ancient Monuments were still under arable cultivation in 1995 (S Trow pers. comm. 2002).

#### **TYPES OF DAMAGE TO ARCHAEOLOGICAL SITES IN ARABLE LANDSCAPES (FOR DETAILS ON ALL THE TOPICS IN THIS SECTION SEE APPENDIX F)**

The range and character of damage to archaeological sites in arable landscapes are well-attested and varied. They include:

- The cultivation of previously unploughed sites or parts of sites;
- Lateral encroachment;
- The gradual planing flat of upstanding earthworks surviving within arable;
- The deeper cultivation or regular subsoiling of flattened sites in existing arable;
- The effective deepening of cultivation caused by water and wind erosion, and peat shrinkage, encouraged by ploughing to a constant relative depth;
- Disturbance, breakage and chemical deterioration of portable antiquities;
- Physical damage and desiccation of organically preserved sites and objects caused by drainage;
- Physical damage caused by ancillary works such as farm tracks, barns, irrigation lagoons etc;
- Damage to uncultivated sites within arable areas caused by burrowing animals and visitor wear; such ancillary damage is often the result of the isolation of these features and subsequent neglect.

#### **Cultivation of previously uncultivated archaeological sites**

The cultivation of previously uncultivated archaeological sites is probably the most serious type of threat within the context of the subject. Any ploughing is likely to cause damage to upstanding archaeological features, as well as underlying archaeological deposits. Unploughed sites are normally the best preserved and can survive very close to the ground surface. The depth of ploughed sites below the surface normally depends on the greatest depth to which the land has been cultivated in the past, unless the site has been protected from disturbance by overlying colluvial or alluvial deposits or peat growth. The preparation of land prior to ploughing can also be enormously damaging through bulldozing of earthworks, clearance and burial of boulders and intrusive drainage operations

For particular cases of the effects of the cultivation of previously uncultivated sites evidence has been gathered from Cook and Rowley 1985; O'Neil 1966; Smith 1990; Broughton 1998; Hinchcliffe 1980; Waddington, 2001; Richards 1985; Bellamy et al 1983: details in Appendix F.

#### **Lateral impingement on undisturbed archaeological deposits**

Sites that exist as islands within cultivated fields are vulnerable to gradual encroachment by ploughing, sometimes only a furrow at a time, destroying upstanding monuments bit by bit. Eventually this gradual encroachment, if not halted, can lead to the total loss of a monument. If the earthwork survives to a reasonable height this gradual chipping away can lead to the undercutting of the upstanding monument, causing mini-collapses every time the plough bites. Encroachment by ploughing is known to gradually alter the shape of upstanding monuments thereby making their interpretation and identification more difficult. Encroachment can also occur accidentally around such sites, as the upstanding monument is often a small part of the overall archaeological resource. For example, burial mounds often have associated but unseen ditches and burials, or there might be associated settlements, field systems or other ritual monuments in the near vicinity, which are unrecognisable at ground level.

For particular cases of the effects of lateral erosion evidence has been gathered from Lewis and Miles 1985, 116; Lambrick 1986; Rollright Trust unpub 2001; French 2001; Ashbee et al 1979; Woodward 1991; OAU 2000a; Gibson 1998; Evans and Simpson 1991; Saville, 1990: for details see Appendix F.

#### **Deeper ploughing of already cultivated sites**

Any form of disturbance which penetrates deeper than the existing ploughsoil can cause damage to underlying archaeology. Deep ploughing is often carried out to try to deepen the ploughsoil, by ploughing up and mixing in the subsoil, despite the fact that the usefulness of this process in agricultural terms is debatable. This kind of damage to archaeological deposits can be severe and widespread. Severe damage can also be caused by subsoiling and stone-cleaning and various forms of harvesting for potatoes and sugar beet (White and Cotton 2001). Switching to organic farming may also result in deeper cultivation – eg to control regrowth of weeds in the absence of the chemical herbicides which in non-organic farming can be combined with shallow or no-till cultivation systems. The grubbing up of energy crops (especially fast-grown coppice) prior to replanting or conversion back to arable is also likely to be highly destructive (see below). Deeper ploughing may also be associated with the introduction of new tractor power, technology, or cultivation equipment, though the latter may be as or more likely to result in shallower cultivation (Christian and Ball, 1994).

The occurrence and distribution of artefacts brought to the surface by ploughing is an important means by which sites are detected (Clarke and Schofield 1991), but this is the result of past disturbance of in situ archaeological deposits, and the archaeological value of disturbed artefacts is greatly diminished by the loss of depositional context. Scatters of material that are unabraded, and the appearance of earlier, previously undisturbed material from deeper deposits, can be clear indications of ongoing damage to in situ archaeology. While many sites are discovered by archaeologists carrying out 'field walking' surveys for surface artefacts, others are found through metal detecting. This is especially important for major arable areas in eastern England for the early medieval period since earthworks and soil- and cropmarks of sites of this period are rare, and metal artefacts are common and robust compared with contemporary pottery. In Norfolk metal detectorists found 24 new Anglo-Saxon cemeteries in 1998, 7 in 1999 and 6 in 2000; in Suffolk pre-1990 finds revealed c 36 sites, and a further 30 have been discovered since 1990 (H Geake pers. comm.). It is thought that these discoveries may indicate that upwards of 40 sites of this period are being plough-damaged in Norfolk, and c 60 in Suffolk (ibid.).

For particular cases of the effects of deeper cultivation evidence has been gathered from Brown 1999, 4; Essex CC nd; Corney 1984, 245; Miles, 1980; Macaulay 1995; Miles et al forthcoming; Barclay & Halpin 1999; Crummy & Smith 1979; Malim 1992; Malim & Hines 1998; Rickett 1995; Mercer, 1980, 23; Niblett undated; OAU 2000b: details in Appendix F.

### The effective deepening of cultivation over archaeological sites through cultivation to a constant depth

Over the last 50 years the overall area of land in arable cultivation has been falling, but in the last 10 years the loss of archaeological monuments has been climbing steadily, which is thought to result from the cumulatively destructive relationship between ploughing and soil erosion (Darvill and Fulton 1998, 8). This type of gradual erosion occurs in two main forms.

**First**, cultivation tends to plane minor undulations (like archaeological earthworks) flat, and numerous observations of cultivation of earthworks (especially barrows) indicate typical rates of erosion of 0.02 to 0.05m per year. Even with reduced cultivation, the only closely monitored site (the Rockbourne long barrow, Hampshire) suggests that erosion may continue at c 0.005-0.006m per year (Cromwell 2002). For particular studies on the flattening of earthworks evidence has been gathered from Drewett 1975; Drewett 1980; Lawson 1980; Lawson 1981; Crummy & Smith 1979; Allden 1981; Gibson 1998; Blockley et al 1990; S Harrison pers. comm.; Cromwell 2002 & pers. comm.: for details see Appendix F.

**Second**, even when a consistent cultivation depth is maintained, the plough will often automatically penetrate deeper into any archaeological deposits (and the sub-soil) where the soil surface is lowered in relation to surviving archaeological deposits through water or wind erosion, peat shrinkage, or soil compaction. This can lead to subsoil (and archaeological deposits) being continually disturbed to maintain topsoil/ploughsoil depth. Soil erosion is most common on cultivated bare soils and less common on established pasture. Research on erosion in general has emphasised the exacerbating effect of the type and timing of cultivation and different crops as well as factors of soil, slope and weather (Boardman 1992). While water erosion is most serious on light soils, especially on slopes, it can be significant on surprisingly shallow slopes, and wind erosion is a problem on flat land especially with light soils. The archaeological effects of erosion do not generally result from one particular arable episode but from repeated cycles of ploughing and associated erosion.

Differential erosion between the subsoil under an earthwork and in the surrounding area, especially in chalk areas, can result in the subsoil under the earthwork being higher than that away from it. This often gives the false impression of a surviving upstanding monument, whereas all that survives is in fact the upstanding subsoil, formerly protected by the earthwork. This differential erosion may be associated with natural solution as well as being accelerated by modern agricultural techniques (for discussion of this issue see Atkinson 1957; Proudfoot 1965; Groube and Bowden 1982).

This leads to problems in interpretation and management: if archaeological remains do survive, these rather unimpressive monuments can be very vulnerable to destruction. Only one episode of slightly deeper cultivation could destroy any surviving earthwork material or buried soil, and therefore destroy any archaeological evidence that there was once a feature at this point. This illustrates the problem in judging the 'threshold effect' where one further season of erosion can wipe out the remaining, and perhaps the most important evidence, of an archaeological site (Lambrick 1988). At the other extreme, sites may be protected by colluvial or alluvial deposits (Bell and Boardman 1992; Needham and Macklin 1992). On many sites differential survival can be observed depending on the topography of the site (see also dispersal of finds).

For particular cases of erosion of flattened archaeological sites and differential erosion and deposition effects evidence has been gathered from: Lambrick 1988; Malim 1992; Malim & Hines 1998; White forthcoming; Jackson, 2000, 193; Hinchliffe 1980; Crummy & Smith 1979; P Austin, pers. comm.; White and Cotton 2001; J Plouviez and C Pendleton pers. comm.; Waddington, 2001, 9; Humble, 1994, 177; Darvill & Timby 1985: see Appendix F for details.

### Compaction problems

Soil compaction gives rise to several agronomic problems and tends to result from poor soil management (eg working soil when it is too wet, using poorly adjusted or wrong equipment). Soil compaction, under any particular combination of soil conditions, is largely a function of ground pressure and number of machinery passes; the higher the pressure, the more dense the soil becomes, and the greater the depth to which compaction occurs. Rutting can occur, particularly along "tramlines" or in especially wet conditions. Problems may also be exacerbated by activities such as wetting the soil prior to potato harvesting (White and Cotton 2001). The worst conditions for causing compaction are a combination of wet soils and heavy machinery. The presence of general compaction pans can often be seen in soils, just below the drill layer and at plough depth. These are formed when the soil is cultivated or drilled when it is too wet, causing the soil to deform and compact. Surface pans contribute to water erosion.

The most effective method of controlling compaction is to use the lightest appropriate machines, to spread the weight of a load over a wider range of wheel combinations to reduce ground pressure, to avoid land work when the soil is wet, and to minimise machinery passes over the land. Although a controlled traffic approach can be adopted whereby the same wheel tracks are used for all cultivation and crop management operations (to minimise the extent of compaction), this can result in localised rutting. Where soil compaction is not avoided deep ploughing and subsoiling is needed to reflate the soil and remove any compaction pans.

Archaeological damage arises in three main ways. **Firstly**, direct archaeological damage arises from the crushing effects of heavy machinery (for soil preparation, cultivation and harvesting) which has mainly been observed in relation to cemeteries, where the effects on human burials and intact artefacts (eg skulls, burial urns, etc) make the damage especially evident. Observations suggests that this arises both from rutting and general compaction and panning effects.

**Secondly**, soil compaction leads indirectly to further – and probably much more extensive – archaeological damage through the remedial operations required to break-up soil pans. Deep ploughing is one approach to this problem and can be carried out at depths of up to 0.40-0.50m. Subsoiling is often carried out to break up soil pans built up below the base of the ploughsoil. Since deep ploughing inverts the whole soil body it is potentially especially damaging if significantly deeper than previous cultivations. The damage that any single subsoiling operation can do is less comprehensive and varies a great deal between sites, depending on the

types of archaeological deposits and the type of soil present. Subsoiling tines typically penetrate to 0.40-0.70m at c 1.5-2m intervals, but can be deeper below the ground surface. Repeated subsoiling, often at right angles to previous operations, is cumulatively likely to be especially damaging, as has been observed in some cases.

For particular cases on the effects of subsoiling of archaeological sites evidence has been gathered from: Harman et al 1978; Miles 1980; Burke, 2002; Waddington, 2001: details in Appendix F.

**Thirdly**, as noted above, soil compaction can result in a thinning/reduction in the depth of the plough soil, leading once again to the plough effectively biting deeper into the ground when used at a constant operating depth. R Evans (pers. comm.) notes that increased density of the soil can typically reduce the depth of ploughsoil from 250 to 192mm, which is sufficient to induce serious archaeological damage especially where important deposits are sensitive to threshold effects.

### Damage to artefacts

There have been several studies which shed some light on how arable farming affects the condition of artefacts in the soil. It is clear that new artefacts are brought to the surface by ploughing if the plough disturbs an archaeological horizon (see above, deeper cultivation) and these can become badly abraded, and in some cases totally destroyed after entering the ploughsoil. This damage to artefacts is caused by a combination of physical and chemical destruction. The issue is becoming increasingly significant as the substantial body of archaeological metalwork in ploughsoils becomes evident from the recently improved reporting of metal detecting finds (DCMS 1999, 2000, 2001, 2002). In addition to the effects triggered by disturbing objects physically, changes in soil chemistry and microbial activity (particularly in relation to soil moisture content) can lead to destruction or significant deterioration in the condition of objects and deposits that remain buried. This is especially serious with respect to waterlogged deposits, which can be very extensive and archaeologically exceptionally rich in wetland areas (see below).

Work that has been carried out on **physical** damage to artefacts in ploughsoils indicates that:

- Pottery becomes increasingly fragmented the longer it is left in the ploughsoil (Reynolds 1989);
- In the case of fragile pottery (eg low fired prehistoric and Saxon wares), a winter's exposure is enough to break down the fabric to the point where any movement would cause its destruction, therefore leaving no trace of the site within the ploughsoil (ibid.);
- Experiments have shown that after 5 seasons of ploughing 50% of pottery in the ploughsoil would reach the surface, and after 10 ploughings 75% would have surfaced and therefore become vulnerable to the actions of farm machinery and processes like freeze-thaw (ibid.);
- In a study of metal artefacts it was concluded that even in a relatively short period, 8 years, continuous cultivation can cause an increase in damage to artefacts from something like one quarter to one half (J May pers. comm.).

For particular studies on mechanical damage to surface finds evidence has been gathered from: Pendleton 1999, 63; Reynolds, 1989; Clark and Schofield 1991 Richards 1985; J May forthcoming and pers. comm.; Dobinson & Denison 1995, 52: for details see Appendix F.

Artefacts can also be affected by **chemical** attrition. Objects that have lain undisturbed in the soil for a long period of time tend to have reached a chemical equilibrium in association with the soil around them which allows their preservation. However, any change in the chemical make-up of the surrounding soil is likely to upset this balance and may cause the artefacts to decay. Bones and metal objects including coins are especially vulnerable. Once a crop has been established it will frequently be subjected to inputs of a variety of agro-chemicals (herbicides, nitrates, weedkillers, pesticides and fertilisers). There is some evidence that buried artefacts are suffering active destruction as a result of the effects of these chemicals. A series of studies in Europe have been set up to look at the problems of metal corrosion in soils, examining whether in fact this corrosion has increased recently and what specifically is causing it. Professor M Pollard (pers. comm.) notes that:

*"The corrosivity of soils is fundamentally related to soil electrical resistivity, which in turn depends on soil structure, water content and dissolved salt concentrations (Wranglen 1995). Soils of low resistivity are usually highly corrosive, except in anaerobic conditions (i.e., deep, waterlogged soils), where the corrosion rate is limited by oxygen availability."*

*"Recent work in Sweden (Nord et al. 1998; Mattsson et al. 1996) has investigated the deterioration of archaeological metal artefacts in soils, examining the impact of atmospheric pollution, and subsequently increased soil acidification, on metal corrosion. Similarly, Gerwin and Baumhauer (2000), Kars (1998) and Meeussen et al. (1997) have investigated declining groundwater tables and other soil parameters on metal corrosion and decay. The issue of intensification of agricultural practices has been raised as a possible cause for the observed trend in increased decay of freshly excavated archaeological metals (Kars 1998:139; Gerwin and Baumhauer 2000:64), but the impact of mineral fertilisers has never been addressed in a systematic manner."*

The issues and factors of corrosion processes in soils are complex and the studies are all in their early stages, but several basic points can be drawn out which can be related to agricultural processes. Four of the areas of concern voiced are:

- Cultivation bringing artefacts into contact with the atmosphere after centuries of burial, where they begin to dry out and shrink, react with the air or crumble as they lose the support of the surrounding soil and are subject to exposure to an oxidising environment (thought to be the most rapid cause of decay)
- The changes in the acidification of soils caused by the application of fertilisers, in particular those which alter chloride levels.
- Fluctuations of groundwater leading to similar changes in the chemical equilibrium in soils, having highly destructive effects on organic deposits and artefacts in wetland areas (see below)
- The results of atmospheric pollution leading to acid rain polluting soils which has led and will lead to the lowering of the acid buffering capacity of many European soils (Fjaestad et al 1997, 32).

Additional threats have been identified from the spreading of slurry on fields and the spraying of sulphuric acids on fields after harvest (Waddington 2001). Scharff & Huesmann (1997, 17) suggest that *"The acidification of soil that promotes soil corrosion is increased by acid rain and the development of acids due to the oxidisation of certain common fertilisers.... Intensive fertilisation of land with liquid*

*animal waste can produce high acid input that can be as high as acidic rainfall.*" Wagner et al (1997, 23) have observed that "draining of wetlands containing substantial quantities of reduced sulphur minerals can produce very rapid oxidation: sulphate flushed out as sulphuric acids can thus lead to extreme acidification of soils. The effects on artefact preservation can be dramatic because metal solubility is a stronger non-linear function of pH." Decomposition of crop residues within the plough zone can also affect the chemical make-up of the soil, in that it releases a series of acids which attack clay colloids. However, their interaction and effect on pottery have never been studied (Boismier 1997).

The mechanics of cultivation have also been identified as being responsible for changing soil structure and chemistry. Aeration of the soil caused by breaking up the soil can have effects on the soil's chemistry similar to drainage. In addition, where artefacts enter the ploughsoil from a sealed context below, they are exposed to higher oxygen levels, fluctuating temperatures, moisture (leading to freeze thaw action), and changing humidity (Wranglen 1995; Reynolds 1989; Malim and Hines 1998).

Surface scatters of artefacts are also affected by physical **movement and dispersal**. Often the only way to identify the presence of an archaeological site in a ploughed field is from the artefacts on the soil surface. Such scatters of objects not only indicate the presence of an archaeological site in the vicinity but also that the site is being, or has in the past been, damaged by the plough. Although sites are often located by artefact scatters, it is clear that continuous ploughing disperses these artefact scatters quite widely within relatively few years (Reynolds 1989; Allen 1991; Clark and Schofield, 1991; Forrest, 1995), making identification of the location of sites more difficult unless fresh finds are brought up by further damage (see issues of deeper cultivation above; Boismier 1997).

For particular studies on dispersal of surface finds evidence has been gathered from: Waddington, forthcoming 90-91; Allen 1991, 47; Clark & Schofield, 1991, 95-100; Forrest, 1995; F McAvoy, 2002; Reynolds 1989: for details see Appendix F.

#### **Land Drains, Mole Drains and Field Ditches**

Within arable landscapes, especially on claylands, one of main threats from agriculture is the necessity for inserting land drains of various types. Pipe drains are installed with or without trenches. A trencher cuts a trench 0.2-0.3m wide, the soil is removed, the pipes are laid and the trench is backfilled. The machinery used to lay trenchless pipes (mole drains) are simply tines which open up the soil to allow the pipe to be laid. The soil then falls back into place, leaving the pipe in a trench c 0.10-0.15m wide. Pipe drains are usually laid at depths of 0.75-1.25m and mole drains drawn at depths of 0.50-0.60m. The pipes are usually spaced at 30-40m on sandy soils and up to 5m apart on clays. Mole drains are usually spaced at 2-3m. Pipe drains are expected to last 40-60 years, whereas mole drains are usually renewed every 5-6 years (Spoor 1980).

Mole drains have a similar effect on archaeological sites to subsoiling. They disturb the soil and cause problems with mixing of soils through fissuring which can lead to problems in interpretation during excavation. Laying ceramic, plastic or tile pipe drains is a far more destructive process as they require the excavation of deep trenches. The resultant criss-crossing of a field by these drains effectively severs many archaeological layers and can destroy many stratigraphic relationships within a site.

Open ditches along field boundaries are characteristic of land requiring drainage (and have been since late prehistoric times). Archaeological sites may be detected through observing the sides and spoil of recently cleaned ditches (eg Fens Survey, Hall 1987). Open drains can result in significant localised lowering of the water table resulting in desiccation of archaeological deposits (and see below). For particular cases of land drainage effects evidence has been gathered from: Essex CC undated; Honnor and Lane 2002; Waddington 2001; Darvill 1986: for details see Appendix F.

#### **Hydrological effects of lowering of water tables through water extraction and drainage of wetland areas**

In 2000 English Heritage commissioned a desk-based assessment of Monuments at Risk in England's Wetlands (MAREW) to provide a general picture of the condition of England's wetland archaeological resource and the risks it faces (Van de Noort et al 2001).

*The significance of wetland monuments lies in a) the preservation of organic archaeological remains that are usually not found in free-draining soils, b) the presence of a sedimentary matrix that provides additional protection against physical destruction and c) the palaeoenvironmental material in the matrix or the context of the resource that allows for dating and environmental reconstruction.* (Van de Noort et al 2001, 3)

The preservation of these remains relies on maintaining a high water table which:

- ensures the preservation of a wide range of materials by the creation of an anaerobic environment which prevents the natural decay of organic material through the activities of biological agents
- reduces the likelihood of the chemical degradation of organic materials, determined by the acidity of the environment
- excludes burrowing and activities of animals living underground therefore preserving the original context and stratigraphy
- prevents erosion, desiccation and degradation of associated peat soils which both contain, and protect beneath them, a rich archaeological landscape.

Unlike wildlife habitats, waterlogged archaeological remains cannot be restored through rewetting; once they have dried out, the information present will disappear:

*it is now being realised that dryland sites, largely bereft of environmental evidence and with limited cultural material, offer only about 10 per cent of the information available in a waterlogged deposit.... all the (waterlogged) remains are threatened by agricultural techniques and a lowering water-table* (Hall, 1987, 1).

For all of England's wetlands it has been calculated that 72% are used for arable (an increase of 8% of total land-use since the 1930s) and 12% are used as pasture (a decrease of 15% since the 1930s). This expansion of arable has affected 165,000ha of pasture over the last 50 years (Van de Noort et al 2001, 12 & 16).

One of the main threats identified to wetland archaeological resources is drainage, especially where associated with arable landuse. The main wetland landscapes which are threatened by arable agriculture are the East Anglian Fens, the peatlands of the Northwest, the Humber wetlands, and the Somerset Levels. The English Heritage study concentrates on these areas. General changes in ground

water tables have been reviewed on the basis of hydrographs provided by the Environment Agency, indicating that in the alluviated lowlands of the North West and South West the groundwater table has been lowered by 2 to 3m over the last 50 years (mainly since 1970). French (2000, 5) has commented specifically in the Fens:

*Up until the mid-1980s, many of the internal drainage boards were deepening and widening drainage dykes throughout the region on a 5-7 year continuous cycle. In many cases, the setting of levels in the cuts, dykes and ditches was controlled by individual judgement and existing land-use, rather than according to any overall scheme. If drainage on this kind of scale continues, organic artifactual and environmental remains, whose continued preservation depends on the maintenance of anaerobic environments, will degrade and eventually disappear from the record*

**Effects of drainage on peat shrinkage** Virtually no lowland peatlands or alluviated lowlands remain completely free from the effects of drainage (Van de Noort et al 2001, 16) and resultant rates of peat wastage reflect a substantial threat to archaeological resources – not just through physical attrition as the effective depth is lowered, but also through the drying out of organic deposits that have been preserved often for millennia.

These wastage rates suggest that over many areas of the Fens, depending on the original depth of the peat itself, the potential for any peat deposits to survive into the near future is limited. In 1991 Professor John Coles commented, *'today much of the Fenland lies like one of its bog bodies, a desiccated corpse, a thin skin of peat stretched to breaking point over the skeleton in some places'* (Crowson et al 2000, 2). Brunning (2001) predicts that all known waterlogged sites of national importance in the Somerset Levels will be destroyed by the end of the century if current rates of peat wastage continue. The rate of shrinkage is faster in areas of arable land use in eastern England, where the rate of shrinkage is comparable to plough erosion of earthworks (see above).

Regardless of whether drainage is slowed in the Fens the fertility of much of the peat, i.e. the organic content, has already been irreparably destroyed through deflation and microbial decay, leaving only the mineral material. French (2000) notes that in many places, the underlying fen clay or marine derived clastic material is being ploughed up onto the surface, and in these places the peat resource has been destroyed. This was noted on many sites visited by French where effectively the upper peat is now rarely more than an inorganic mineral ploughsoil. He also notes that *'often, where it does just survive the farmers are actively encouraging its destruction by subsoiling to increase its mineral content'* (French 2000, 5). This erosion of the organic content of soils makes them generally much less stable and increases the process of erosion by wind and water.

For particular studies with evidence of rates of wetland shrinkage see: Van de Noort et al 2001, 16-17; Honnor and Lane 2002; Hutchinson 1980; French and Pryor 1993; Seale 1975; French 2000; Brunning 2001; Ellis, 1993, 109; Burton & Hodgson 1987.

**Effects of drainage on organic preservation:** Hydrographs from boreholes were studied as part of the Humber Wetlands survey. Variations in water levels over a period of time were looked at for two boreholes. At Cherry Tree Farm, Hatfield Chase, the lowest annual groundwater level in the 1960s was c 0.5m OD; during the 1970s it fell to -1.2m OD, and between 1979-1988 the lowest level fluctuated between -0.5 to -1.0m OD. Since 1988 it has fallen further to a record low in 1992 of -1.7m OD. The results of this survey showed that for sites with archaeological and palaeoenvironmental material, fragile organic material will only now survive under -1.7m OD, and that timber structures above -1.7m OD may survive for the moment but will deteriorate fast. From these results it was predicted that within this area, without remedial action in the near future, more than 2m of potentially rich archaeological stratigraphy will have been lost since the late 1960s through falling watertables (Ellis 1993, 109).

In a detailed study of the effect of agriculture and drainage undertaken in three parishes in Cambridgeshire (Honner & Lane 2002), it was observed here that water levels are now regarded by farmers and the Drainage Board as being at an optimal level in many areas of the Fens. However, from the point of view of the archaeologist these levels are too low. For example, in Moreton Fen where the water level is maintained at 1.20-1.50m below the ground surface, the water levels on archaeological sites in the area lie well below the archaeological remains (eg at the Morton saltern site). The Internal Drainage Board predicted that little change would take place in the water levels in the future, leading to a continuation of low levels and a necessity to reduce OD heights of water in the remaining peat areas in line with peat shrinkage.

For particular cases of degradation of deposits through dewatering evidence has been gathered from: French and Pryor 1993; Murphy 2000; Ellis, 1993, 109; J Rackam, pers. comm.; Taylor 1994; French and Taylor 1985; Barclay et al forthcoming; for details see Appendix F.

**Density of wetland sites** A further factor exacerbating the problems of archaeological conservation in arable wetland areas is that the density of archaeological sites is high. In the lowland peatlands MAREW estimates that the density of archaeological sites in the Fens, the North West wetlands and the Humber wetlands is 1 per km<sup>2</sup>; in the Somerset Levels 1 site per 2.2km<sup>2</sup>. From this the estimated archaeological resource in the lowland peatlands is 4,200 monuments, of which a significant proportion is likely to include wet-preserved remains. An additional number of unknown sites will be deeply buried, and this is estimated at an additional number of c 2,940 monuments. On this basis the number of known sites is 7,400 monuments, of which possibly up to a third include wet-preserved remains. It is possible that the number of deeply buried sites may double the number of sites (Van de Noort et al, 2001).

In terms of rates of destruction, MAREW estimated that in the last 50 years:

- 10,450 wetland monuments have suffered damage, desiccation and partial destruction;
- 9020 monuments have been damaged by drainage;
- 2950 wetland monuments have suffered wholesale destruction (mainly sites in lowland peatlands) through peat wastage;
- 2180 monuments have been damaged by conversion of pasture to arable.

Van de Noort (2001, 3) comments *'the greatest impact on the wetland archaeological resource is from drainage of land for agriculture and the subsequent drying out of the archaeological remains and peat wastage from agricultural land'*. Current designations are regarded as insufficient to safeguard the waterlogged components of wetland monuments (Brunning 2001). This issue has very serious implications, not only for the archaeological resource but also for the agronomic, economic and social fabric of arable wetlands,

especially as the peat soils as well as the archaeology are a depleting, non-renewable resource.

### Effects of field boundaries

Traditional field boundaries are of agricultural, ecological, historic, landscape and amenity importance and contribute significantly to local distinctiveness. They represent a very important component of the historic landscape and contain much of the story of its development. The loss of traditional boundaries over the last 50 years has been well documented (CPRE 1999; DoE 1990; CBA 1998, 5; Winter et al 1998; DEFRA 2001b). Some have been reconstructed but this can not restore their historical and archaeological significance, though it can help to recreate their visual contribution to the landscape and some nature conservation interest. The removal of hedges and field boundaries to allow easier access for large machinery and to increase arable acreage for production, not only detracts from the diversity of the countryside, but can also cause the destruction of archaeological sites once protected by these hedges. Often boundaries utilised, or were sited on, earlier features such as earlier ditches or upstanding monuments, i.e. barrows, therefore effectively sidelining these features from cultivation. Hedges and walls can also provide a barrier to the downslope movement of soil where they run across slopes, leading to sites on the upslope side of a boundary being far better preserved than on the downslope side, which will have suffered greater adverse effects from cultivation.

For particular cases illustrating the effects of field boundaries and their removal evidence has been gathered from: Woodward, 1991; Leech 1976; Hinchliffe, 1980; Miles 1980; Phillips 1989, 188: see Appendix F for details.

### Ancillary ground disturbance and other impacts associated with arable landuse

Many ancillary ground disturbances associated with farming do not require planning consent and whilst they do not cause as much widespread damage as ploughing they can be very archaeologically destructive on a localised scale. They can also affect the setting of archaeological sites and monuments. Such ancillary disturbance includes: water abstraction ponds for irrigation, the digging of slurry lagoons, topsoil movement, both from and onto a field, continued turf stripping, boulder clearance, farm and road building and other activities permitted by the 1988 General Development Order.

For particular cases of ancillary operations information has been gathered from: OAU 1995; Darvill 1986; J Newman and C Pendleton, pers. comm.: for details see Appendix F.

### Animal burrowing and visitors

While not directly part of the arable farming regime, burrowing animals, particularly rabbits and sometimes badgers are a common threat to sites in predominantly arable landscapes, especially where sites are isolated and neglected because of the arable regime, eg where a site has been fenced off from its arable context, and grassed over with no further management input. Infestations of burrowing animals can be very severe, destroying much of the integrity of monuments if allowed to develop unchecked. Historic Scotland (1999) has produced a Technical Guidance note on '*Burrowing Animals and Archaeology*', which includes information on the damage caused by rabbits, rats, moles, badgers, foxes and puffins. It highlights the three main results of this damage: disfigurement, destabilisation and irretrievable loss of information. Visitor erosion is primarily a problem for well known and very accessible sites.

For surveys of the effect of burrowing animals information has been gathered from: OAU 2000a; Burnham 1996; Historic Scotland 1999: see Appendix F for details.

## FACTORS INFLUENCING THE OCCURRENCE OF CULTIVATION DAMAGE TO ARCHAEOLOGICAL SITES IN ARABLE LANDSCAPES (FOR DETAILS ON ALL THE TOPICS IN THIS SECTION SEE APPENDIX F)

### Type and condition of archaeological remains

Archaeological remains in arable landscapes display a wide variety of kinds of survival, reflecting both their original form and subsequent modification by human or natural agencies (Appendix F). This affects both their vulnerability to further damage and their archaeological potential as a source of evidence. Sites often exhibit more than one form of survival.

- Some early prehistoric activity areas – and occasionally later sites like battlefields – are only (or principally) evident from artefact scatters left on the then ground surface and subsequently incorporated into (and dispersed in) the plough soil.
- On more complex sites, a build up of stratified layers can survive (eg successive floors, yard surfaces, occupation debris etc). Once these layers come within ploughing depth they will be successively eroded, and may be removed by one ploughing episode.
- The successive erosion of earthworks will occur when ploughed, as each year the plough repeatedly flattens them out or encroaches on their edges.
- Earthworks often protect buried ground surfaces of importance for evidence of earlier landuse and environmental characteristics, which will become increasingly vulnerable as the earthwork is destroyed.
- Where the remains of stone walls have survived below the ploughsoil, they may resist destruction initially, but continued cultivation can lead to sudden collapse (especially after the introduction of new and more powerful machinery)
- In wetland and alluvial areas and in topographical situations where perched water tables occur organic deposits and objects often survive, greatly enhancing the value of *in situ* deposits.
- Where a site has already been truncated by ploughing, features such as ditches, postholes, pits and wells cut into the subsoil may be all that survives, often detectable as cropmarks or soil marks on well-drained soils, and/or reflected in finds scatters. These can nevertheless be of considerable value (many sites of the this kind are amongst the largest scheduled monuments).

Even sites already truncated by cultivation can be very vulnerable to threshold effects where for example critical occupation levels, buried ground surfaces, human burials, or the last traces of shallow features are reached ie the archaeologically most critical features, which may easily be removed by one season's slightly deeper ploughing. Examples include plough scored Roman mosaics (eg Trow 2002, *British Archaeology* 2002) and almost flattened barrows (eg 0.15m high barrow excavated at Rollright, Oxon., where virtually nothing remained of the barrow mound except a thin layer of flat stones, but where the old ground surface contained cremations, an unusual scatter of Mesolithic bladelets and valuable palaeo-environmental evidence, all vulnerable to the threshold effect – Lambrick

1988). Successive seasons of damage can culminate in a single episode which will destroy crucial evidence of this type.

**Previous cultivation/land-use (especially whether previous historical cultivation has been deeper)**

Not all damage to archaeological monuments from cultivation is of recent date (Appendix F). It is clear that later prehistoric, Roman and medieval cultivation all damaged earlier deposits. Certain types of cultivation undertaken in the 19th and early 20th centuries extended deeper into the soil than even modern ploughing. Steam ploughing and the use of the Derby Digger could cause disturbance to depths of between 0.35-0.45m (Essex CC nd; Lambrick 1988). Protection can be offered to sites from the early formation of ploughing lynchets, from the ridges associated with medieval ridge and furrow, and from headlands; earlier, deeper, ploughsoil can protect surviving features from the effects of modern ploughing (Wood et al 1959; Miles 1980; Palmer 1996; Halkon 2001). The effects of ridge and furrow cultivation on differential survival have often been noted (eg Essex CC nd; Green 1977; G Hey pers. comm.; B Kerr pers. comm., noting comments from D.Neal)

**Vulnerability to erosion (climate, topography, soil /bedrock type) (see also Appendix E in addition to Appendix F)**

Any form of erosion which lowers the ploughsoil will effectively result in any archaeological deposits below becoming increasingly vulnerable to the effects of cultivation, as it in effect causes the deepening of cultivation. Physical factors affecting erosion include soil character (Greenland et al. 1975; Evans 1990), rainfall, wind, slope and topography, and cropping and farming practices.

The K value in the Universal Soil Loss Equation (USLE) describes a soil's erodibility. Soils with high proportions of fine sand and silt and low amounts of organic matter have high K values and are therefore erodible. Soils under continuous arable cultivation suffer a decline in organic matter content. The loss of rotations and mixed farming is held to blame for this change. Soils with low organic matter content are less structurally stable and therefore more prone to disaggregation. A figure frequently quoted is that of Greenland et al. (1975) who showed that soils with less than 2% organic carbon are structurally unstable.

Rainfall induces the detachment and movement of soil particles, and can generate soil crusts increasing the risk of runoff. The amount of runoff depends on the character of the rainfall (amount, intensity, duration) and the character of the soil surface and subsurface and the crop cover. When crop cover is below c 30%, it is insufficient to inhibit runoff and erosion. Thus, the months of highest risk of erosion are October and November when the fields are smooth and bare and rainfall is high. Results of three recent ADAS Surveys (Chambers and Garwood 2000, Chambers et al 1992 and Chambers et al 2000) conclude that some key factors have exacerbated rainfall erosion: winter cereals, slopes (often less than 7°), the presence of compacted wheelings and tramlines and the loss of historic field boundaries. Effective ways to reduce this risk include minimal tillage techniques, avoiding finely rolled seed beds, retaining field boundaries, minimising crusting/capping, early drilling and avoiding compaction and tramlines.

Examples of high erosion rates are frequently associated with long slopes, steep slopes and areas of high relief within the field. Ephemeral gullying is now recognised as a significant contributor to total erosion and therefore elements in the landscape that concentrate water flow assume importance. These have been referred to as 'linear elements' and include field boundaries, tracks and roads, wheelings, drill lines, furrows and topographic depressions. These interact with areas of cultivated, bare and crusted soils to generate runoff.

Erosion is affected by the ground cover provided by crops through the distance apart of rows, type of crop and rate of growth and time to achieve adequate ground cover and the arrangement of fields of similar crop/soil surface condition, which can be an important influence on flow of runoff over long distances (on the South Downs, there have been recent cases where 60% of particular catchments are under winter cereals and therefore at high risk to erosion by gullying in October-November). Fields sown with maize and sugar beet are particularly subject to erosion. Farming practices associated with each crop can also affect the risk of erosion through timing of drilling and ground preparation in relation to climatic events, presence or absence of wheelings or tramlines, compaction due to other activities such as harvesting, direction of drilling and production of fine tilths by power harrows (Frost and Speirs 1984). The location within the landscape of farm infrastructure (field boundaries, farm roads and tracks, gates) can also affect runoff and erosion.

The effect of slope on the survival of archaeological sites can be variable (see above). Archaeological sites located at the top of slopes are very vulnerable to erosion as the covering soil erodes downslope. This movement of soil downslope leads to colluvial deposition downslope which may protect and mask archaeological sites. The occurrence of erosion on shallow slopes depends much on type of soil, drainage, compaction, crop cover, field boundaries, time of sowing etc. At Icklingham Roman villa site (Suffolk) on sand and gravel soils, a c 1m thick deposit of plough wash has accumulated at the base of a slope of only 2° (C Pendleton 1999 and pers. comm.). In an extensive archaeological study of the area around the small Roman town of Ariconium, work from previous excavations and the results of an erosion report undertaken by ADAS were drawn together to assess the survival of the archaeological deposits in the light of the identified threat of soil erosion (Jackson 2000).

By comparison with water erosion, wind erosion is less of a problem except in certain susceptible areas. Archaeological sites where the detrimental affects of wind erosion have been recorded include cropmarks in the Milfield Basin (Northumberland), various sites on light soils in East Anglia, Shefford's Hill cemetery (Lincolnshire), the peat soils of the Fens and elsewhere (as moisture content is lessened following drainage), the light silty soils of eastern England and the sandy soils in the Vale of York. Aeolian deposition can also be useful in preserving sites, as at West Heslerton in the Vale of Pickering (Powersland 1988). The occurrence of wind erosion can be affected by many factors such as the removal of hedges, the destruction of the soil's stability, the type of soil, when the crop is drilled etc. The type of crop also affects the likelihood of wind erosion, being most serious with smooth seed beds associated with slow germinating crops (e.g. sugar beet, carrots, onions).

Evans (1990) has classified the soils of England and Wales in terms of their erosion risk. This takes into account all factors including current land use which has been used in developing the National map of risk to archaeological sites in arable landscapes (see below).

**Susceptibility to compaction and need for drainage (see also Appendix E in addition to Appendix F)**

As noted above in the sections covering types of archaeological damage, the likelihood of soil compaction occurring and the need for

drainage are both important factors influencing the risk of archaeological damage occurring. They are broadly inter-related in that sub-surface compaction in particular is often related to impeded drainage and working relatively poorly drained soils in wet conditions.

Soil type can influence the necessity for, and type of, drainage required and the need for subsoiling. Loamy and silt soils are prone to the formation of surface crusts or caps, but these will be removed by normal ploughing. Lighter, fine and sandy soils are prone to the formation of iron pans at their base, which have to be removed by deep ploughing or subsoiling. Clay soils are less affected by natural weathering, but they are very susceptible to machinery damage causing compaction, especially when wet. The higher the clay content, the poorer the drainage and the lower the organic content. These are all factors which contribute to the formation of subsurface compaction pans which are often then removed by deep ploughing or subsoiling (Spoor 1980).

In areas of lowland wetlands (eg the Fens of East Anglia, the Humber and Somerset Levels) strategic drainage on a major scale has been required to maintain the land's capacity for cultivation (in many areas such systems date back to the 17<sup>th</sup> century). On a smaller scale drainage is also fundamental to the cultivation of many lowland river floodplains.

#### **Cultivation systems (see Appendix D)**

A wide range of cultivation or tillage systems exist which either share or overcome the deficiencies of the plough and similar equipment in terms of archaeological impact. The basic range of equipment and systems is not much different from those described by Lambrick (1977; 1980), but numerous detailed improvements, and in particular developments of multiple function systems have been developed in the last 20 years. Briefly they can be grouped in modern terminology as:

- conventional tillage mouldboard ploughing followed by seedbed preparation and sowing
- minimum or shallow tillage, reducing depth of soil disturbance using a cultivator, disc harrow, rotavator etc.
- non-tillage or direct drilling into soil where crop residues have been removed and weeds suppressed by chemicals.
- conservation tillage in which crop and plant residues are retained, with the crop established by direct drilling or reduced tillage.

*Conventional tillage* using mouldboard ploughs utilises a wide range of equipment in terms of the width and depth of working (usually 200-250 mm). The soil is inverted and partially broken up, and other implements such as discs followed by tines and harrows are then used to produce a finer tilth. The act of ploughing controls weeds and buries surface residues, while the tilth produced aids soil/seed contact, root penetration and the release of nutrients.

*Reduced or minimum tillage* techniques are less invasive, cultivating the soil from the top down to produce a fine tilth at the surface and loosened soil below. This surface cultivation can be achieved by shallow ploughs working at 0.10-0.15m depth, and/or multiple passes of discs and tines. Davies (1988) provides a review of the implements used.

*Direct drilling* is the least invasive cultivation technique. In this system, seed is delivered into a slot, formed by either a disc or tine, in otherwise uncultivated land. The technique is highly reliant on herbicides (paraquat or glyphosate) for weed control. It can be used for grass, forage brassicas and combine-harvested crops (mainly cereals, oil seeds, peas and beans) but requires a well-structured soil and may result in weed or soil structure problems if used sequentially in less than ideal conditions. The science and practice of the technique is reviewed by Baker et al (1996). Cannell, Davies and Pigeon (1979) divided soil suitability for direct drilling into three classes, having regard to soil type, climate and experimental experience, which they mapped (Appendix H).

- Class 1 represents c 30% of soils in cereal areas, including well-structured and well-drained soils on chalk and limestone and well-drained loams where sowing of both autumn and spring sown cereal is possible with yields similar to conventional systems.
- Class 2 represents c 50% of soils in cereal areas, including calcareous clays, clayey, and loamy over clayey soils that have secondary drainage, which need good soil and crop management to achieve equal yields with direct drilled or conventionally grown winter cereals, and yields of spring sown crops are likely to be reduced.
- Class 3 represents soils unsuitable for direct drilling (sands with low organic matter, silts, wet clays and alluvial soils).

A comprehensive review of reduced cultivation and direct drilling in the UK context is found in Christian and Ball (1994). Minimal cultivation is particularly appropriate on heavy land where it avoids bringing up clods which are difficult to break down, but may encourage weeds and diseases. Direct drilling into the stubble of the previous crop is the quickest and cheapest establishment system but requires uncompacted and residue and weed-free conditions. Minimum cultivation methods suffered from the ban on burning crop residues in 1992, since more cultivations are required to deal with the resultant residues, while direct drilling requires suitable soils.

The adoption of a particular cultivation system depends on a range of factors including crop type, soil type, timing of crop and time available, rainfall and weather conditions, erosion risk, weed, pest and disease considerations, and availability of traction power and equipment. Traditionally in the UK great weight has been placed on the burial of crop residues in the interests of controlling weeds, pests and diseases, and facilitating the sowing of the next crop without blockage by excessive residues. Consequently, mouldboard ploughs and variants upon them have been much to the fore, and there are demonstrable agricultural benefits from using this system. However, there are a number of disadvantages associated with inverting the soil to a significant depth and subjecting it to multiple seedbed preparation operations. It is in response to these deficiencies that reduced and minimum tillage techniques have been developed (Townsend 1998; Davies 1988; Baker et al 1996; Christian and Ball 1994; Tebrugge and During 1999).

The economic, agronomic and environmental benefits of direct drilling and minimum cultivation systems are further outlined below, in the discussion of the merits of different remediation measures for damage to archaeological sites in arable landscapes.

The recent trend in tractor replacement towards larger and more powerful units (average tractor power has increased from 32kW or 43hp, to 53kW or 71hp) has primarily been to help reduce labour costs, but the increased speed of working has enabled many more farms to exploit the short autumn workability window to sow winter crops, and the increased power has enabled a wider range of equipment to be used over a greater range of physical conditions therefore expanding into areas where archaeology historically was considered safe (Cracknell 1995).

#### **Requirements of different crops (see Appendix D)**

The basis of the majority of arable crop production systems is an effective rotation. There are many crop combinations, but they all have the same objectives: to optimise profit potential, to maintain soil fertility, and to control weeds and soil-borne pests and diseases. The historic importance of rotations has declined with the rise in the use of manufactured fertilisers, although this is under pressure from rising costs and environmental constraints. In theory, all rotations should ensure that the land benefits from restorative crops and variations in cultivation and that weeds diseases and pests do not build up. In practice rotations are often 'stretched' with lower value crops sown later than is optimal, in order that a preceding higher value crop can be secured.

*Cereals* can be grown on a wide range of soil types, wheat being favoured by heavier soils and barley by lighter soils. Spring cereals are generally drilled in March and April usually following conventional ploughing and secondary cultivations. Winter cereals can be established by a wider range of methods, but are more prone to encouraging erosion than cereals sown in spring. Conventional ploughing buries cropping residues, gives good control of difficult weeds, relieves superficial compaction and gives a level surface, but its cost makes minimal cultivation and direct drilling systems preferable on economic grounds where they are viable.

*Maize* is normally grown on relatively deep, medium to heavy soils, requiring high moisture content. A particular issue for maize is its wide row spacing and relatively slow initial growth which make it especially susceptible to erosion problems.

*Oilseed rape* is susceptible to a range of cultivation approaches and will accept a wide range of soil conditions. A new development, increasing in popularity, is to broadcast the crop during the harvesting of the previous cereal. Rape seed is very small and requires a fine clod-free seedbed to ensure good soil/seed contact, firm to conserve moisture but free from compaction and well drained.

*Peas and beans* are normally cultivated by conventional methods. Field beans are traditionally associated with heavier soils not prone to drought, while peas prefer lighter, more freely draining soils and lower rainfall areas. Both crops are sensitive to waterlogging and compaction. Very light soils are unsuitable due to the risk of drought, although this may be counteracted to a degree by irrigation. A good seedbed is essential for successful pea establishment. Beans do not require a fine seed bed; indeed the easiest, effective method is ploughing in the seed to a depth of about 0.15m after broadcasting. Spring varieties are typically drilled in 0.15-0.35m rows at a depth of 0.06-0.08m.

*Root crops* require deep ploughing and a series of soil preparation, cultivation and harvesting techniques that are more archaeologically destructive than conventional ploughing (White and Cotton 2001) (Appendix F). This includes:

- Good deep seedbeds (in the case of potatoes constructed by a bed-former) following deep ploughing
- Subsoiling may be required to loosen the ground and improve drainage, reaching depths of c 0.5-0.9m
- De-stoning can be needed to improve growing conditions and allow successful harvesting. This tends to be destructive to archaeological stratigraphy and disturbs artefact distributions, sometimes entirely removing artefacts from the field

Further disturbance occurs at harvest with a flat share or inclined discs passing under the seedbed to lift the crop. Wetting of the soil prior to harvesting can occur to prevent damage to the crop, therefore increasing the dangers of compaction.

Work in Herefordshire by White and Cotton (2001) concludes that a site only needs to be farmed once for potatoes to result in archaeological features, especially shallow ones, being totally destroyed. The profitability of potato growing is increasingly leading to the investment in larger machinery to speed up preparation of the soil and harvesting, compounded by the fact that most of the work is carried out by contractors, with specialist, modern machinery. This can lead to deeper and further damage to the archaeological resource and increase the likelihood of rutting and compaction. Often unploughed/permanent grassland is used for new potato fields as the soil is relatively free of pests, leading to risk of disturbance of previously unploughed archaeological sites and increased soil erosion on slopes. Potato processors actively seek this type of land through advertisement. Enlargement of fields by hedge removal can also occur. Some areas have seen significant increases in potato cultivation eg 80% increase in Herefordshire since 1987; see also Appendix H for root crops in general.

For archaeological effects of potato cultivation, evidence has been gathered from H Geake, pers. comm.; C Pendleton, pers. comm.; Dr T Pestell, pers. comm. – and see: White and Cotton 2001; Waddington 2001; Garton 1989 and Halkon, 2001: for details see Appendix F.

*Sugar Beet* also involves particular problems. The land often requires subsoiling, and the crop is often harvested in wet weather (September to December) which can cause much damage to the soil structure associated with heavy machinery running over the wet ground - ie rutting, compaction etc, as well as directly disturbing the soil to lift the crop. Sugar beet cultivation can also contribute to soil erosion, especially on light soils, as a smooth seed bed is required and the crop is slow germinating, encouraging run-off and wind erosion resulting in the thinning of soils. The archaeological effects of sugar beet growing are broadly similar to potatoes, but erosion problems tend to be greater and in common with potatoes, there is also a risk of gradual thinning of the ploughsoil caused by the removal of soil from the fields during harvesting. Recent research on sugar beet by DEFRA has shown '*less [soil] is removed here than in other European countries, these losses are still substantial - 35,000 tonnes per year, all of which is repatriated back to agricultural land or used in other applications*' (DEFRA 2002b, 10).

*Energy Crops* are being promoted by DEFRA as part of the UK's contribution to reducing reliance on fossil fuels (Appendices F and D). The cultivation of biofuel crops on arable land and set-aside is supported through the EDRP Energy Crop Scheme which supports cultivation of Short Rotation Coppice and Miscanthus. Whilst there has been a study into the rooting habits of SRC (Crow 2001) and Miscanthus (Riche and Christian 2001a), their effect on below-ground archaeological remains has yet to be investigated. Although the majority of willow and poplar roots appear to be restricted to the topsoil, the potential damage of deeper penetrating roots when planted in areas where there may be archaeological deposits forming softer and more easily penetrated deposits, is not yet understood. In the case of Miscanthus, the majority of roots were found to grow in the top 0.60m of soil, the zone where most archaeological deposits would be located. Further root growth was also found penetrating to 1.80m, with no roots found below 2.00m (Riche and Christian 2001a). This is much deeper than ordinary arable crops, and roots extending to this depth could adversely affect archaeology below the topsoil.

Serious archaeological damage could arise from grubbing out of old short rotation coppice stools, and *Miscanthus* rhizomes rather than spraying with herbicide and discing. Replanting or reversion to normal cropping or grass may represent the most serious threat of these crops. There is also concern that these crops will be planted in wetland environments due to their copious need for water to ensure efficient growth. Riche and Christian (2001b) note that if *Miscanthus* and other winter harvested biomass crops are grown on a large scale it will be important to consider their water requirements, and any effects on ground water reserves. This could affect preservation of archaeological sites in wetland and peat areas, where ground water levels are dropping (Van de Noort et al 2001).

### Rotations (Appendix D)

Most of the preceding section has concentrated on the cultivation requirements of individual crops, and illustrates the complexity of the timing of the requirements and other characteristics (Appendix D). This complexity is compounded by the further important consideration, that these crops are normally grown in combinations or rotations. Although there are now few rotations which are firmly adhered to over decades, winter cereal growing is the basis of most arable systems and fits into a wide range of rotations (see below).

Not all the crops considered have the same cultivation requirements. Consequently, in multi-crop rotations it may not be possible to avoid the more invasive soil cultivation systems. Even where crops are amenable to reduced tillage systems, it is evident that these systems are predominantly associated with optimum soil conditions, and that outside the optimum more invasive operations may be necessary to address natural and man-induced constraints.

#### Typical rotations

Continuous wheat	Heavy land
Winter wheat > winter wheat > set aside > beans	
Winter wheat > winter barley > set aside > oilseed rape	
Winter wheat > potatoes/sugar beet > winter wheat > vegetables-	Silt
Winter wheat > peas/beans/oilseed rape	
Winter wheat > winter wheat > sugar beet > set aside > peas	
Winter wheat > winter barley > peas > winter barley > potatoes/sugar beet	Medium /light land

### Cost (Appendix D)

Cost is a further important factor that influences the use of different cultivation systems, but only within the context of the other considerations outlined above. Various sources indicate the following basic range, but many other considerations of indirect costs and savings, often quite specific to locality and farming structure will affect how individual farmers assess their costs:

Establishment Method	Cost per ha (£)
Traditional plough-based approach	79-96
Non-inversion - discing	70-93.5
Non-inversion - combination machines	64.5
Minimum/shallow tillage	26-72
Direct drilling	25-48.5

### Farm infrastructure and investment in cultivation systems (Appendix D)

The ability and willingness of farmers to make significant adjustments to their cultivation systems and rotations for environmental and/or archaeological purposes will vary in relation to overall size of enterprise and the significance of arable production to the enterprise, coupled with a series of wider factors that influence investment decisions. With respect to direct drilling and minimum cultivation systems adoption is hampered by factors such as:

- The established versatility of traditional conventional systems for all crop types, minimising risks as market conditions change
- Perception that minimum cultivation systems may readily succeed in trial conditions, but are much less certain on a day-to-day basis
- A suspicion of new “fads” promoted commercially or by academic research compared with “real” experience of neighbours
- Economic and farm infrastructure barriers to investing in new equipment, including sequencing and timing of equipment upgrades and the need to change tried and tested rotations
- Inhibitions arising from potential instability of market conditions over timescale of machinery investment and depreciation cycles
- Options for reducing financial and other risks of adopting new systems through machinery partnerships or contracting out

The fact that minimum cultivation and direct drilling systems were not more widely adopted in the 1980s and 1990s, despite the agronomic and economic benefits then demonstrated, reinforces the view that if the environmental benefits they offer are to be achieved, greater incentives for their adoption are still needed. This is likely to be especially problematic where soil conditions and traditional cropping regimes are not ideal for such systems (see below).

### THE DEVELOPMENT OF AN APPROACH TO ASSESSING RISK (FOR DETAILS SEE APPENDIX G)

In order to address the problems of conserving archaeological sites in arable landscapes a systematic method both for assessing whether and where damage is likely to be occurring, and for monitoring whether it continues— including whether remediation measures are successful in addressing the problem – is needed. This section looks first at the range and potential of existing assessment and monitoring methods and then reports the results of developing a new approach, at both a site-specific and strategic level.

#### Existing archaeological methods of assessing plough damage (Appendix G)

Tackling the issue of conserving archaeological remains in arable landscapes has been dogged in the past by the sheer scale of the

problem. A wide variety of archaeological techniques can be used to demonstrate damage. Non-intrusive methods include air photography, geophysics, surface collection survey, metal detecting, topographical survey, augering and simple visual inspection. For buried sites some of these can be very valuable and reliable indicators. Surface observations are ideally supported by direct observation of damage through more intrusive test pitting or trenching, though this is often not essential to making a reliable assessment. The use of topographical survey combined with augering or geophysics for predicting damage is relatively new, and has been very successfully trialled by Burke (2002) in Scotland where prediction of areas of high and medium risk in a field were shown by excavation to correlate reasonably well with excavated evidence of damage by ploughing and/or subsoiling. Similar detailed work by English Heritage at Owmbly in Lincolnshire produced less clear-cut results (McAvoy 2002).

In reviewing these methods it is clear that all have their merits, though some are more effective than others. In practice it appears that a combination of several of these methods is often the most effective way to judge plough damage. However, a crucial consideration for any wider application is cost, and almost any technique that involves much more than simple visual inspection does entail significant expense. While some sites do need detailed investigation (like the scheduled Roman city of Verulamium – OAU 2000b), it is not feasible to carry out elaborate (and potentially quite expensive) archaeological evaluations of every threatened site.

### Existing approaches to ongoing assessment and monitoring

There are numerous site-specific examples of repeated observations using a variety of methods to show whether new damage has occurred (Appendix F). However these methods do not represent a systematic approach to assessment and monitoring as a whole, and there are no generally agreed archaeological standards, sets of indicators or procedures for undertaking this type of monitoring (see Appendix G for review of methods). This is part of a more general lack of procedures for making electronically retrievable records of the condition of archaeological sites. Three reasonably cost effective methods offer most potential for more systematic monitoring.

First, methods of assessment by **visual observation** have been used in many contexts and are often used both for assessment and on-going monitoring of the condition of archaeological sites. Several of these were reviewed in relation to the specific issues of arable damage and the factors that influence its occurrence (Drewett, 1976, Dunkin 1996, Ellis 1993, OAU 2000a, Darvill and Fulton 1998 and Humble 2001). This is reported in more detail in the Appendices. None of the visual inspection methods reviewed (including those of other previous regional studies) fully addresses all the key factors that affect whether plough damage is occurring, with the exception of perhaps the Monuments at Risk Pilot (Humble 2001), though some include valuable elements. This includes a specific method of assessing risk of cultivation damage based partly on the decision tree approach outlined below, where it is discussed further.

Second, preliminary results of studies by Cadw and English Heritage suggest that **aerial survey and remote sensing** can be successful in monitoring erosion by livestock and visitors, but its full effectiveness in monitoring other forms of damage has not yet been systematically assessed (I George pers. comm.) Similar comments have been made by A Tinniswood (pers. comm.) in relation to Hertfordshire County Council's annual aerial survey programme. The possibility of assessing use of archaeologically damaging or benign cultivation techniques (eg subsoiling, direct drilling, minimum cultivation) is limited, and if feasible, is likely to be highly seasonal and directly dependent on timing of the work. There may be some potential in using airborne laser scanning (LIDAR) surveys to make accurate, replicable records of changes in micro-topography and absolute ground levels as a means of monitoring the condition of sites in or surrounded by cultivation over time.

A third possible technique for monitoring of sites is to use rapid **ground-based survey and monitoring of buried markers**. For earthworks this might be through rapid measured topographical survey of fixed transects tied in to a local TBM (a simplified version of the Rockbourne approach, (Cromwell, 2002)). This would also have some potential for non-earthwork sites. However, for both earthworks and buried sites a more reliable means of establishing whether new disturbance is occurring is to bury easily retrievable markers at the junction between the base of the ploughsoil and the archaeological horizon or at just below a pre-determined depth limit on cultivation. If these markers are brought to the surface then there is a strong likelihood that plough damage is occurring – or depth restrictions are not being adhered to. A variation of this method has been demonstrated through English Heritage's work at Owmbly using blue plastic discs (F McAvoy 2002) and the Cambridgeshire Farm Estates project where 3m lengths of geotextile were laid at the soil/ archaeology interface (Abrams 2001). M Anderton (pers. comm.) has suggested the use of metal transponders buried at relevant levels, as successfully developed by Gary Booth at Sheffield University for monitoring taphonomic processes in an estuarine environment. The use of metal detectors and global positioning equipment to detect lateral movement of buried metal objects would be a similar approach.

This brief review of existing methods of assessment and monitoring shows that there is no **cheap**, simple means of systematically **recording** and monitoring damage to archaeological sites in arable landscapes **that is both fully reliable and cost-effective for tackling the scale of the problem**. An approach based on risk assessment related to the factors that most strongly influence the occurrence of damage is the most realistic way of focussing on sites where damage is **most likely** to be a serious issue. Where the risk is identified, the use of more expensive assessment and monitoring methods may or may not be justified by the nature and scale of remediation measures adopted, or where they provide potential for integration with other monitoring requirements.

### Development of an approach to plough damage risk assessment

The MARS approach to risk assessment for archaeological sites was a fairly simple estimate of the scale and likelihood of damage occurring, and was applied to all kinds of rural and urban landuse. A more tailor-made approach is needed for addressing damage to archaeological sites in arable landscapes to provide a framework by which individual decisions can be based within a general strategy for addressing the problem. Such a framework needs to be geared to the key factors that affect whether or not damage is likely to occur, including both characteristics that are intrinsic to the land, and aspects of its management.

Intrinsic site factors include:

- The nature of the archaeological remains and quality of their survival
- Depth of current ploughsoil and extent/ thickness of any previous cultivation soils, colluvium and alluvium overlying archaeology
- Soil characteristics (erodibility, drainage requirements, susceptibility to compaction etc)

Issues of slope influencing the likelihood of erosion

Management factors include:

- Cropping patterns and rotation
- Cultivation methods and depths and timing
- Background issues relating to farm structure and economics

**Site-specific Risks**

The idea of developing a site-specific method for assessing whether sites are at risk of damage is intended to provide a reasonably straightforward framework for predicting, on a site-by-site basis, whether and where plough damage is likely to be a problem. Two methods have been developed and were field-tested together in a variety of ways and stages, on a wide range of sites, under a wide range of circumstances and by a wide range of people (see Appendix G). As a first stage an initial assessment was made by project staff against c 23 adequately documented archaeological excavations. This enabled the predictive value of the methods to be assessed by comparing what had been known before excavation and in the light of what was found. This suggested both methods were reasonably robust and detailed modifications were made to each. The second stage was to test the methods through external means, supported by a guidance booklet which explained the logic behind the two methods and how they should be used, together with questionnaires eliciting comments on the use of the methods and issues to be addressed. This stage included:

Further pre-and post-excavation desk-based testing by OA

- Comments and field testing on 82 monuments visited by archaeologists advising on management of rural archaeological sites
- 24 sets of pre- and post-excavation testing through ongoing or commissioned fieldwork

The main phase of testing was carried out during the height of the Foot and Mouth crisis which seriously curtailed access to farms and monuments by archaeologists, and so the response from some of the above was disappointing. However, the responses received proved very useful in developing the methods.

**Decision Tree Method (Figure 1)**

The first method is a decision-tree method based on working step-by-step through various intrinsic site factors which lead through to a variety of scales of risk, ranging from effectively no risk, or various degrees of moderate risk, to cases of serious risk. A decision on what management prescriptions might be needed to address the problem for the site would be based on what would be realistically practicable within the context of that particular farm business. It is possible that existing management practice is already in line with the degree of risk indicated so that no need for change would be indicated. The method is accompanied by guidance on how the decision choices should be made.

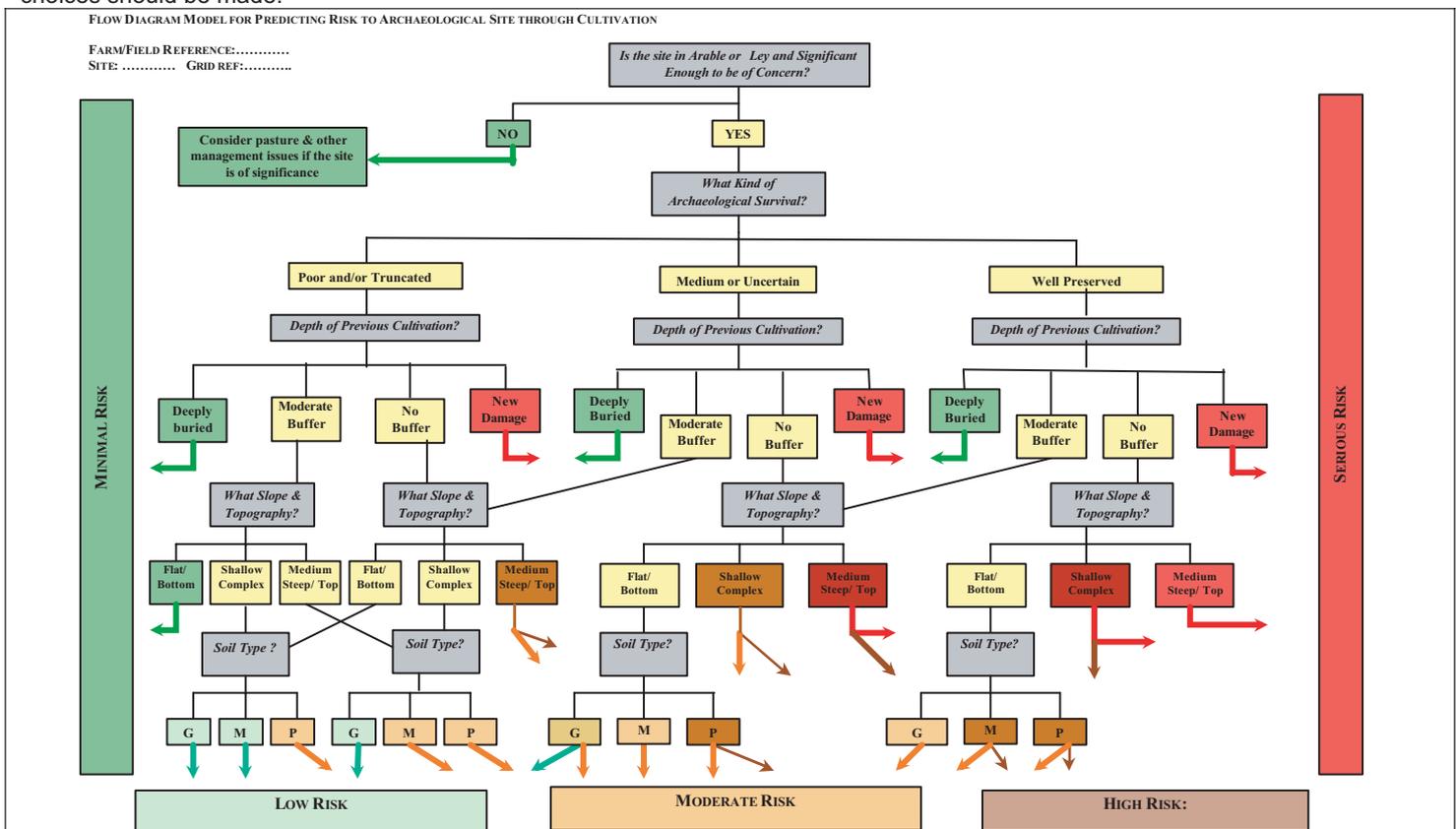


Figure 1: Flow diagram Method for Predicting Risk to Archaeological Sites Through Cultivation. © Oxford Archaeological Unit Ltd. 2002

Key: G = Good, M = Medium, P = Poor

**Scoring Method**

The second approach developed is a scoring method. The principles of how to judge the effects of each category are the same as for the decision tree method, but are rather more explicitly linked to the standard definition of 'Risk' as *the scale of hazard x the likelihood of occurrence*. On this basis the hazard is defined as damage to significant archaeology, and the likelihood of occurrence is determined by other, non-archaeological intrinsic site characteristics and management practices. This method has the advantage of more explicitly incorporating management factors and archaeological significance and survival. The pro forma for carrying out this method of assessment is as follows and it too is accompanied by guidance notes.

**Scoring Method**

Likelihood of Occurrence	Serious Score 4	High Score 3	Medium Score 2	Low Score 1	Minimum Score 0	Score*
<b>Site Intrinsic Factors</b>						
Buffer zones: previous cultivation depth/ extent in relation to archaeology	New cultivation or encroachment on sites or where planned in the future; evidence of new disturbance	Present cultivation likely to be at interface with archaeology	Shallow buffer (eg 0.10-0.20m); previous cultivation has left differential cut/ fill	Consistent moderate undisturbed buffer (eg 0.20-0.75m) of old colluvium or alluvium	Deeply buried (eg > 0.75m)	A B C
Soils		Light soils subject to erosion; heavy soils subject to deep cultivation, compaction, drainage	Medium soils with some difficulties	Medium, well drained, well structured soils with no difficulties		A B C
Micro-topography and Slopes		Upper slopes or top of slope; steep to moderate slopes	Mid slope; variable slope; Moderate to shallow slopes	Slope bottom; Flat ground		A B C
<b>Site Management Factors</b>						
Cultivation method and depth	New significantly deeper ploughing evident from fresh disturbance (finds/ subsoil) – or is planned in future	Regular deep ploughing, deep rotovating, stone cleaning etc (or proposed in the future)	Normal ploughing, chisel ploughing	Shallow minimum cultivation methods	Continuous direct drilling without any subsoiling	A B C
Cropping regime		Cropping includes sugar beet, potatoes, etc needing deep soils	Cropping includes cereals, non-root crops	Cropping includes long term grass ley (or set-aside) > 5yrs;		A B C
Compaction & Drainage	New regular subsoiling < 3yrs old	Regular or occasional subsoiling Wetland water table lowering (or proposed in future)	Rare subsoiling required; moling and drains	Subsoiling unlikely; drainage problems not significant [No risk scores 0, but not weighted]		A B C
Initial "probability of occurrence" score (in box to right)						
Intrinsic site factor weightings	<b>Any of above = Total score x 1.5</b>				<b>Any of above (where 0) = Total score x 0.5</b>	
<b>Probability of Occurrence score to be calculated in boxes a) and b) to right: Initial Score multiplied by any weighting derived from "Serious" and/or "Minimum" columns as applicable</b> (Do not weight scores at this stage if no 'serious' or 'minimum' risk issues arise)			<b>a) Score above to multiply by serious/ minimum weightings:</b> ..... X .....		<b>b) Result = Final Score (may be graded A,B, C*):</b> .....	

\*Scores to be given by quality of supporting evidence: A = Good evidence; B = Some evidence; C = Poor evidence, mainly assumption

Archaeological Hazard Scale	Serious Hazard Score 4	High Hazard Score 3	Medium Hazard Score 2	Low Hazard Score 1	Minimum Hazard Score 0	Score*
Archaeological survival and vulnerability	- Clear upstanding earthworks and structures - Low earthworks etc coupled with buried ground surface - 'Soft' horizontal stratigraphy, floor & occupation surfaces	- Low earthworks; - Shallow negative features with important contents (eg shallow graves)	- Incomplete and damaged upstanding archaeology or stratigraphy; - Shallow negative features; - Surface finds not reflected in underlying archaeology	- Site already substantially damaged; - Only deep negative features likely to survive.	- Site largely destroyed leaving very little potential	A B C
Archaeological significance	SAM/ national significance	Regional or county significance	County or regional significance	Clear local significance	No obvious significance	A B C
<b>Archaeological Hazard score</b>						
Weightings to apply to scale of Archaeological Hazard	For Archaeological Hazard score of 7-8 use weighting factor = 3; For score of 6 use weighting factor = 1.5; For score of 5 use weighting factor = 1.3; For score of 4 use weighting factor = 1; For score of 2-3 use weighting factor = 0.5.				Plus additional weighting of 0.5, if any of the above scores 0	Score:
<b>TOTAL WEIGHTED SCORE: Initial Score from Intrinsic Site and Management Factors</b>		<b>Probability of Occurrence score x Archaeological Hazard score:</b> ..... X .....		<b>Enter Final Score against confidence grade*</b> A ..... B ..... C .....		

\*Scores to be given by quality of supporting evidence: A = Good evidence; B = Some evidence; C = Poor evidence, mainly assumption

Using this system, final Scores over 15 may warrant specific management prescriptions, and over 20 will very likely do so. B and C scores under (or over) 15 may warrant further investigation to confirm or clarify any critical assumptions (especially if these affect the weighting used)

#### *Results of Testing*

Feedback from field tests indicated that both methods were readily usable (with refinements being suggested for each). In terms of whether they produced accurate assessments, there was a considerable degree of agreement that results of both methods accorded with expectations based on professional judgement. The value of the methods was mainly seen as providing threshold indicators of the possible or definite need for action, not prescriptive outcomes. They are also seen as having value in terms of an audit trail to back up the justification for decisions made.

The results of before-and-after excavation assessments reinforce the view that both methods accorded with expectations based on professional judgement, and gave some general reassurance of their predictive value. This emerged both from the initial desk-based assessment and subsequent field testing by a wider number of individuals. Where the results following excavation differed from pre-excavation predictions there were usually good explanations in terms of factors that could not have been foreseen in advance. On the whole these discrepancies were not substantial, but in some cases the risk was underestimated prior to excavation.

#### *Future application*

A number of valuable suggestions were made about the practical application of the methods. In particular it was felt that both methods had a potential role, with the decision tree method well suited to the rapid identification of when there is an issue to be addressed within a general consideration assessment of agri-environment management needs. Feedback from field tests on the decision tree method indicates that this is the simpler of the two approaches and reasonably reliable. With access to relevant information and some training, it could become usable by farmers and non-archaeological environmental advisors as well as by archaeologists. The scoring method is potentially more suitable for rather more specialist assessment (eg by archaeological advisers, field monuments wardens etc).

While this testing has demonstrated the viability of the approach, and has done much to explore specific issues, there were some limitations on the extent of the trials. The effects of the Foot and Mouth crisis restricted access for fieldwork and also resulted in exceptional workloads for DEFRA archaeologists and others who were best placed to trial the methods. Non-archaeological agricultural advisers have not been involved. Other limitations include the bias in the trials towards sites already known to be of some significance (the majority of cases tested therefore suggested the need for some remediation measures, but this is not a reliable indication of what would emerge from wider application). There remains some scope for drawing on other systems – especially the very similar approach being developed in parallel by English Heritage in their East Midlands Monuments at Risk Study (Humble 2001) – to finalise the approach.

### **National Map of Risk of Arable Damage to Archaeology (Figure 2 & Appendix H)**

The development of a national map of the risk of damage to archaeology arising from arable landuse has the potential to predict in broad terms where plough damage to archaeological sites is likely to be most prevalent in a way that was not attempted by the MARS work, which was based on a point survey of a 5% sample of England rather than complete coverage.

#### *Methodology and development*

Several of the main factors that determine the risk of archaeological damage in arable landscapes are reflected in characteristics of different 'soil associations' as summarised in the legend of the Soil Survey's 1:250,000 map of England and Wales, amplified for erosion issues by Evans (1990). Furthermore, very broad general farming landuse is reflected in cropping records provided by farmers' regular normal returns to DEFRA in claiming production support. The national risk map was therefore developed by scoring documented characteristics of different soil associations (in terms of depth, erodability and drainage) combined with cropping patterns, in order to derive a single combined weighted score that maps plough damage risk on a 1km square basis.

#### *Correlations with recorded damage*

The results of the national risk map were compared with regional datasets, plots of cropmarks and earthworks provided by the RCHME and monuments which MARS identified as being at Risk from agriculture. The MARS data set was not ideal for this purpose as it only assessed risk where the monument was visible above ground which led to the 21% of monuments in the sample which were flattened, not being assessed. However, this was the only data set available which covered the whole country, comprised a survey of a significant number of monuments and which specifically assessed the effects of arable.

Correlation of MARS recorded risk damage per km<sup>2</sup> with the risk factors used in compiling the map, indicates that the cropping factor is strongly correlated (26% correspond to cropping score 6 (high risk), 28% score 5, 17% score 4, 9% score 3, 9% score 2, 4% score 1 and 7% score 0 (no risk)). Since much of this relates to the basic density of cropping it is unsurprising. The factors using soil characteristics do not reveal as strong a pattern, and the way they interrelate with the risk of damage is much more complex. However, it was noticeable that removing these factors from the mapping significantly downgrades the overall picture for some areas where risks are known to be high, as in the Cotswolds or much of East Anglia.

The overall weighted scores of higher and lower risk of archaeological damage correlate reasonably well with the density of recorded damage based on the MARS survey (see Figure 5), with the minimal risk score (0) accounting for 2% of MARS sites per km<sup>2</sup>, then increasing with the risk scores (0-4.2 = 5%, 4.2-5.25 = 7%, 5.25-6.3 = 10%, 6.3-8 = 10%, 8-9 = 14%, 9-11.25 = 15%) to the second highest risk score (11.25 to 13.5) accounting for 19% of MARS sites per km<sup>2</sup>. The highest risk category of all (scores over 13.5) accounts for 14% of MARS sites per km<sup>2</sup>. This somewhat lower figure than the next category down is likely to be explained by the high proportion of the highest scoring area being fenland peats where the very high risk is clear, but was under-recorded by the MARS survey (Darvill and Fulton 1998, 227; Van de Noort 2001).

This indicates a general correspondence between the risk modelling and recorded damage, but suggests that not too much weight should be put upon the detailed grading of risk. In practical terms a perfect correlation of recorded damage against the mapped risk is not to be expected: whereas the risk model is based on the predominant conditions for each kilometre square, the archaeological sites represent point data (usually to within 100m). It is thus reasonable to expect both that undamaged sites may occur in pasture fields or woods in areas that are predominantly used for intensive arable (some such sites may be protected monuments), and likewise it is to be expected that cultivation damage occurs in arable parts of areas that are predominantly pasture.

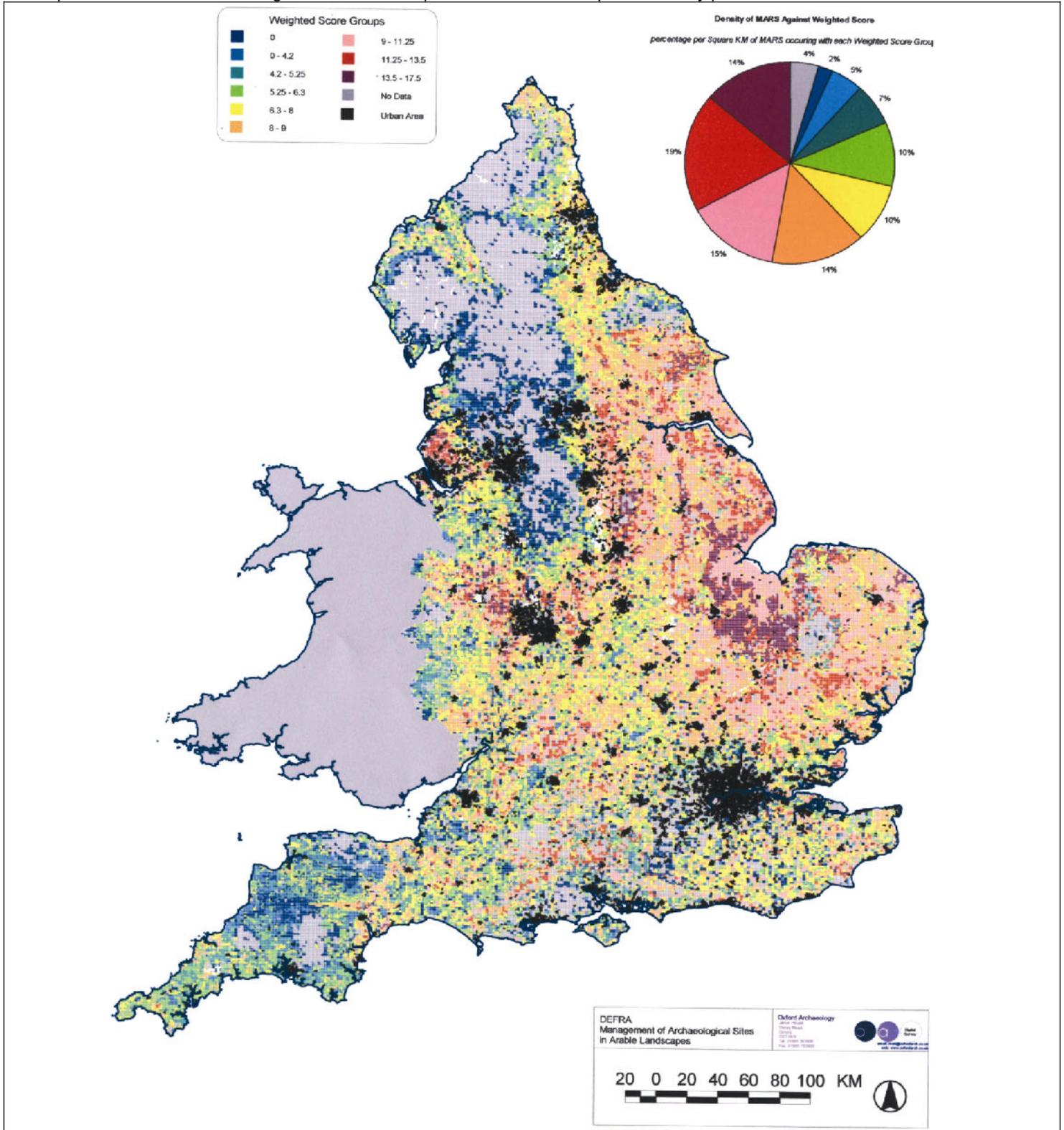


Figure 2 - Map of the risk of plough damage to archaeological sites.

Key soil characteristics for England and Wales (based on data giving the predominant soils per 1km square supplied by the National Soil Resources Institute of Cranfield) are combined with data giving coverage and types of crops for England only provided by the GIS Unit, DEFRA Leeds Office.

### *Geographical results*

By area, 7% of non-urban England is classified as areas of very high risk of damage to archaeological sites in arable landuse (scores over 11.25); 25% as high risk (scores 8-11.25); 26% as medium risk (scores 5.25-8); 18% as low risk (scores 0-5.25-8); and 32% as minimal risk (scores 0 and no score). The minimal risk category includes 'no score' data, the vast bulk of which represents non-arable areas, such as extensive tracts of the Uplands and smaller areas such as Salisbury Plain, the New Forest and the Breckland. It also includes small scattered areas within the other categories which are unclassified because of lack of data, not because they are not arable. This includes many parts of the Chalk in southern England.

The map clearly reflects areas of high risk in areas where plough damage has long been recognised as a problem (eg the Fens, Yorkshire Wolds, Cotswolds, various areas of chalk downs, Norfolk, Lincolnshire). The map also highlights other areas which, on the same basis of scoring are likely to be at high risk, but have not yet been clearly recognised as such in the archaeological literature (eg Staffordshire, South Lancashire, North Nottinghamshire, and a more general band from Birmingham sweeping northwards to Leeds). Several of these areas are evident from the MARS data, or from more individual studies. Other smaller areas that have been subject to archaeological study also emerge as relative hot spots compared with their surroundings (eg Herefordshire, the Exe Valley, and the Milfield Basin in Northumberland).

However, some care is needed in interpreting the map. Areas with high scores can also be where most damage has already occurred, so that survival may be relatively poor compared with lower scoring areas. This will depend on individual circumstances and the ways in which the weighting factors have operated (eg a high scoring area on the top of limestone or chalk ridges may have much more denuded archaeology than a high scoring area in peat fens).

### *Cropping changes*

Between 1950 and 1980 some 600,000ha of additional farmland were brought into cereal production. At the same time, there was a major change in the structure of the agricultural industry with the disappearance of 100,000 very small holdings (less than 20 ha) and a 50% increase in the number of large farms of over 100 ha. The strong correlation of recorded damage with the cropping factor makes it pertinent to examine recent trends in cropping patterns to identify any particular areas where significant changes have been taking place. This has been examined by using data supplied by the DEFRA GIS Unit, Leeds to plot areas where between 1990 and 1999 arable crops (excluding roots and temporary grass) have increased by more than 45ha or decreased by more than 39ha per km<sup>2</sup>, and where root crops have increased by more than 15ha or decreased by more than 12ha per km<sup>2</sup> (Appendix H).

These patterns indicate that several areas within the highest two risk categories are also characterised by increasing cultivation of roots. In the Fens this can be seen to correspond with a decline in cereals, but this is not the pattern everywhere. While there is a wide pattern of mixed gains and losses in cereals, the south west is notable as an area with much scattered increase in cereal growing which is not balanced by reductions. This is less obviously the pattern in other western and northern areas. The map clearly shows increases in root crops in Herefordshire and Shropshire, areas flagged up as being at high risk during consultations. The area in Shropshire is highlighted as high risk on the national mapping but the correlation in Herefordshire is less clear.

For the most part these patterns of cropping change reinforce the patterns of risk established for the main map, and if anything emphasise that risks may be higher elsewhere, eg see Herefordshire above. This has not been fully analysed, but may be a worthwhile avenue to be explored in more detailed studies of the problem.

### *The geographical coverage of existing agri-environment schemes in relation to the risk of damage to archaeological sites in arable areas*

The DEFRA annual report for 2000 indicates that 33.2% of all land was under arable, and 27.4% under improved grassland. Countryside Stewardship Agreements cover 192,067ha of land, and the 22 ESAs in England cover an area of over 1.1 million hectares, of which about 500,000ha are under agreement. Total set-aside in 2001 was 745,099ha. A total of 8% of English farmers and 6.5% of Welsh farmers were participating in one or more agri-environmental schemes in the mid 1990s (Winter et al 1998). Watkins (2000) found that entry to agri-environment schemes involving the historic environment is often dependent on a combination of economic and non-economic factors – which can be personal and unpredictable, however this study did not address the specific issue of how farmers' attitudes relate to archaeological sites in arable areas.

The main disadvantage of agri-environment schemes in relation to conservation of archaeological sites in arable areas is their limited and biased geographical coverage. ESA designations cover less than 7% of agricultural land, and the majority of these are not in areas of high risk for arable archaeology. Correlation with the national risk map shows exceptionally low ESA coverage of highest risk areas (3%) and exceptionally high ESA coverage of minimal risk (57%), others being high risk at 11%, medium risk at 17%, and low risk at 11%. These figures may be somewhat distorted by a relatively high incidence of 'no score' areas within some ESAs in otherwise high risk areas such as the chalk, but this does not alter the main pattern. Plotting the location of agreements within the ESAs suggests an even stronger trend away from areas of highest risk for arable archaeology (highest risk areas have 1.5% of agreements, high 9%, medium 22%, low 14%, minimal 54%) (see Appendix H).

Countryside Stewardship is not aimed at particular geographical areas, but is targeted at particular environmental landuse classes. These are very substantially non-arable land, other than the new arable stewardship prescriptions, which are largely aimed at ecological objectives, but as with ESAs there is provision for arable reversion which can be used for archaeological conservation. The distribution of agreements in relation to arable archaeological risk suggests much better correlation than with ESAs (highest 7%, high 24%, medium 30%, low 13%, minimal 16%).

### *Commentary*

The national map (Figure 2) is intended for use in general policy development and support for further research: it is likely to be most useful in helping to develop national, regional and county level strategies for addressing the issue, but is not suitable for making

specific judgements about particular places. It strongly reinforces a number of challenges for the conservation of archaeological remains in arable areas, perhaps most notably the Fens, where high risks to archaeology coincide with significant issues for sustainability of a depleting soil resource and high value cropping. More detailed review by archaeological advisers within DEFRA, local authorities and English Heritage would be valuable in adding more specific regional insights.

Some of the ways in which this GIS risk mapping can be integrated with other data sets are illustrated both above and below with respect to agri-environment schemes and the relationship between levels of archaeological risk and applicability of direct drilling. Numerous correlations with other kinds of archaeological data (eg site type and condition), historic landscape or natural character areas, and agricultural data (eg farm type and size) would be possible where suitable data sets exist (many Sites and Monuments Records are in digital form and many have GIS facilities).

#### POSSIBLE BEST PRACTICE OPTIONS

In practical terms there are broadly two means of stopping, or at least slowing down the problem of cultivation damage. The first is to revert land to grassland or other benign non-intrusive land use. The second is to adopt archaeologically benign methods of cultivation that are not damaging, or at least substantially postpone the point when damage will start to occur again. Either can be combined with other measures to address problems that arise from other threats to archaeology in arable landscapes, such as drainage and farm infrastructure requirements, burrowing animals and visitor wear.

#### Reversion

As Lane Fox said with reference to Dyke Hills (Cook and Rowley 1985), *the harmless sheep is no foe to history*. There can be little doubt that reversion to permanent, preferably sheep-grazed, grassland is the ideal solution to the insidious degradation of sites being damaged by cultivation (Berry and Brown 1994; 1995).

The environmental benefit of reversion in terms of habitat recreation and wildlife enhancement is already well established, and substantially built into existing agri-environment schemes. Benefits have been examined extensively through other DEFRA research projects, some of which indicate the increased biodiversity benefits of larger scale habitat creation (eg Asteraki 2000, on the benefit of wide rather than relatively narrow field margins). However, the potential role of integrating habitat creation with archaeological conservation to maximise such environmental benefits on an even larger scale has received relatively little attention, although many unploughed archaeological sites within arable areas can be important refuges of unimproved habitats (such as the unploughed henge monument at Knowlton, see Appendix F). Soil conservation benefits of reversion are also well recognised (eg Environment Agency 2001, 33).

However, some forms of reversion, including tree planting and some uses of set-aside land, are not automatically archaeologically beneficial, and some can be damaging. Moreover, reversion to grass is not always practicable or attractive from a farming point of view. In predominantly arable areas where high yields are possible, the variable compensation rates may not provide sufficient incentives. Moreover many farms in predominantly arable areas simply do not have stock. In seeking to overcome such problems the special Avebury and Stonehenge Countryside Stewardship Scheme has been developed to provide special levels of payment as a stronger inducement for farmers to adopt reversion in these archaeologically important areas.

#### Archaeologically benign cultivation (Appendix D)

Work on the archaeological effects of different cultivation systems published over 20 years ago by the CBA and Department of the Environment (Lambrick 1977; Hinchliffe and Schadla-Hall 1980) showed clearly that forms of minimal cultivation, and especially direct drilling even then offered real potential for conserving archaeological sites within ongoing arable management. These techniques offer means of reseeding grass and growing crops that can be combine-harvested (mainly cereals, oil seeds, peas and beans) with much reduced or even no soil disturbance (Christian and Ball 1994; Rasmussen 1999). Cannell et al (1979) defined and mapped three classes of soils and climatic factors to define the relative suitability or unsuitability of areas for direct drilling of cereals:

#### Soil Suitability Class for Direct Drilling

- 1: Suitable for spring and winter cereals
- 2: Suitable for winter cereals only
- 3: Unsuitable

#### Soil and Climatic Factors

- Stable structure, well drained, low rainfall
- Stable structure, adequate drainage, medium rainfall
- Unstable structure, impeded drainage, high rainfall

From an archaeological point of view, a key feature of direct drilling is that the areas where the technique is most readily applicable coincide well with the areas assessed as being at highest risk of archaeological damage (see Appendix H). 49% of Class 1 direct drilling areas and 48% of Class 2 areas consist of areas mapped as being at higher archaeological risk (risk scores 8 and above), with a further 23% and 30% respectively falling within more moderate risk areas (scored 5.25-8). For Class 3 areas where the technique is not suitable, the figures are 40% higher risk and 20% moderate risk. The incidence of damage recorded by the MARS survey shows that 42% of recorded damage within areas categorised for suitability for direct drilling fall within Class 1 areas, 38% within Class 2 areas, dropping to 15% in Class 3 areas and only 5% in the unclassified (mainly non-arable) areas. This strongly indicates its geographical potential for remediating arable archaeological damage (see Appendix H).

There still remain some serious concerns that an entirely no-till cultivation system is not a long-term viable option, and that occasional subsoiling or pan-busting is needed. But some long-term trials where subsoiling has been restricted have proved successful (MAFF 1998a).

Integrated crop management systems (ICM) represent an approach to cultivation that specifically seeks to balance environmental protection with the safe and efficient production of food through sensitive application of crop rotations, cultivations, choice of crop

variety and careful use of inputs. This may benefit archaeological conservation if applied through minimum cultivation methods, but such systems are not designed to be archaeologically beneficial and may not be in practice. Non-inversion tillage and ECOTillage similarly offer possible, but not automatic benefits.

As with reversion, the environmental advantages of no-till and other minimum cultivation techniques are not just archaeological. Indeed they offer potential benefits in terms of economic and agronomic performance as well (MAFF 1998a; Monsanto 1999; Tebrugge and During 1999; Soil Management Initiative undated).

Economic advantages that have been claimed include:

- Reduced fuel costs (eg no-tillage only 17% of conventional ploughing)
- Reduced labour costs (eg ECOTillage only 48-60% of conventional ploughing)
- Reduced cost of agro-chemicals (eg fertiliser costs down 15%; herbicide fungicide and insecticides down 35-40%)
- Reduced maintenance and wear costs of machinery

These advantages generally - and sometimes significantly – outweigh the disadvantages of:

- Maintained or somewhat increased seed costs (eg +12%)
- Maintained or somewhat reduced yields (eg – 15% to +5% change)

Overall, with various 'no till' and 'minimum cultivation' systems it is possible in the right conditions to reduce inputs, deliver environmental benefits and still maintain profitability. While output may reduce, so does the cost of production. Furthermore, as grain prices fall, margins are not hit as hard with reduced cultivation systems as with conventional systems.

Agronomic advantages that have been claimed for reduced tillage systems include:

- Better soil structure and organic content (eg 43% increase in infiltration rate and 18% increase in moisture retention)
- Improved soil fauna and flora (eg soil organisms up 44%; earthworm biomass up 63%; more natural slug and aphid predators)
- Reduced machinery passes leading to less soil compaction
- Better timeliness of operations reducing risks of damage to soils

Environmental advantages that have been claimed include:

- Significantly improved archaeological conservation in the right conditions
- Potential in suitable conditions for creating arable weed habitats, conservation headlands, arable farmland bird habitats
- Reduced erosion (eg 48% reduced run-off and 68% less sediment loss)
- Improved soil chemistry (eg 81% reduction in loss of phosphate and 69% reduction in soil nitrogen depletion)
- Reduced carbon dioxide and other emissions to air
- Less use of fossil fuels (eg 35% reduction in energy consumption)

In relation to the benefits for soil management and run-off, the Environment Agency's guide to *Best Farming Practice* provides a number of costed illustrations of the measures identified by DEFRA to demonstrate that there are economic benefits to farmers in making these types of adjustment to their arable practices. There are clear linkages here to further work (Dwyer et al 2002) examining possible scenarios for a scheme to promote better soil management to address diffuse pollution issues.

In relation to possible benefits for farmland birds, the new Stewardship arable options suggest some potential for integration with minimum cultivation systems (see above) and the RSPB have noted (with reference amongst others to Basore et al 1986; Kladvik et al 1997; Lokemoen et al 1997):

*In summary, evidence from North America clearly suggests that NIT [non-inversion tillage] management of arable crops in the UK might be expected to improve soil invertebrate populations, and nesting opportunities for ground-nesting birds. To the extent that NIT leaves elements of the preceding crop stubble at the surface, seed-eating birds in winter might also be provided with additional seed food resources, but this hypothesis remains to be tested.*

Even without the benefit of improved long-term conservation of non-renewable archaeological assets, there thus appear to be other strong reasons for arable farmers to be moving their production systems towards the minimising of cultivation operations for combine-harvested crops where soil and other physical conditions allow.

There are also some very significant limitations and inhibitors which help to explain why, despite the economic and agronomic advantages, these systems have not been more universally adopted. The ability and willingness of farmers to adopt such methods are governed by a number of other factors, including farm size, labour availability and skills, existing cropping and rotation patterns, future expansion plans, machinery running costs and the residual value of existing machinery (Park et al 1997; Monsanto 1999; University of Cambridge 1998). The relative versatility of traditional cultivation techniques (eg for roots as well as combine-harvested crops), coupled with natural conservatism with regard to common, tried and tested techniques, represent further barriers to acceptance of reduced tillage systems.

As the need to reduce basic costs of arable farming becomes more critical, there may be more inclination for farmers to move to reduced tillage systems, but this is likely to be tempered by implications of having to put extra investment into capital equipment. Any support mechanism designed to promote the adoption of these techniques for environmental reasons must thus address not just their technical merits and performance in relation to running costs and yields, but also how the practical viability of different schemes for the farmer will relate to types of farm business, capital investment strategies and crop rotation systems. In this context, moves towards more cultivation through contractors, and more farm co-operatives and machinery rings sharing the costs of investment in capital, suggest that some of the current barriers to their adoption may be weakening. This has recently been exemplified by a consortium of arable farmers in Suffolk who have jointly invested in a reduced tillage system purely on a business basis (East Anglian Daily Times 23/6/01). However, it does not appear realistic to assume that such moves will rapidly become widespread without incentives, and any benefits for archaeological conservation will not be automatic but will need support linked to guidelines and controls on aspects of

practical application.

In addition to considerations of farm structure and cropping regime, there are further potential limitations on the likely efficacy of reduced cultivation systems:

- the continued measurable erosion of a long barrow over twenty years of reduced cultivation (Cromwell 2002), suggests that although this method is effective in slowing down erosion it does not offer a permanent solution.
- minimum cultivation (non-inversion tillage) methods do not necessarily limit erosion
- agronomic conflicts in terms of best farming practice for soils are likely to arise from restrictions on dealing with compaction issues
- apparent cost savings compared with reversion to grass may prove relatively illusory, since benign cultivation systems are likely to have to be applied to whole fields, rather than just the most archaeologically sensitive areas
- restrictions on deeper cultivation, subsoiling etc. would need to be enforceable and a simple means of monitoring of adherence to depth prescriptions is needed
- 5 year agreements would be too short to provide confidence in lasting remediation, but might provide an effective start.

It is thus clear that benign cultivation systems do not present a ready-made, generally applicable panacea for dealing with arable damage. Nevertheless there is potential for their use as a possible remediation prescription in the right circumstances, and the issues relating to how this might be encouraged and what restrictions would need to apply are worth exploring.

In terms of practical effectiveness, three objectives are critical: first, to minimise the depth of soil disturbance; second, to maintain or improve soil porosity while maximising vegetative cover to minimise erosion; third, to sustain these objectives on a long-term basis. Permanent reversion to grass clearly fulfils these objectives extremely well. Less certainly, continuous direct drilling with no cultivation or subsoiling can also fulfil these objectives for some time under ideal conditions. But shallow cultivation is much less likely to provide a long-term solution. For example, reducing the normal cultivation depth from 0.25m to 0.10m on a ploughed earthwork eroding at a typical rate of 0.02m per year with 0.25m of ploughsoil overlying the archaeology, would only avoid damage for about 7 years before tillage would again be likely to come in contact with the buried archaeology – and since earthwork erosion rates can be faster than this, it would be desirable to check the depth of uncultivated soil over archaeology every three years. With extra precautions to limit erosion the adoption of shallow cultivation might be effective for longer. However, no-till cultivation is likely to offer a significantly more sustainable solution. Taking the same parameters (which are realistic for chalkland barrows) the Rockbourne survey (Cromwell 2002) suggests that erosion rates might be reduced to 0.005m per year, and if direct drilling reduced depth of disturbance to c 0.02 to 0.05m it might be in the order of 40 years before the drilling came into contact with archaeological deposits. On this basis direct drilling could be regarded as potentially five or six times more effective than shallow cultivation as a remediation measure, and applicable to at least some earthwork sites. Minimum cultivation techniques should arguably only be promoted as an alternative solution for already flattened sites on flat or only gently sloping ground.

### Drainage, burrowing, ancillary works

To be fully effective any remediation scheme that alters the way in which sites are being damaged by cultivation should be accompanied by provisions to control other threats within the overall arable landscape. There is much standard practice for management of archaeological sites from which good practice on these matters can be derived (eg Berry and Brown 1994; 1995; Historic Scotland 1999).

For wetland areas, controls on drainage are an especially significant issue, and experience in the Somerset Levels, East Anglian Fens and Humberhead/ Axholme areas provides valuable experience in relation to both habitat and archaeological conservation (eg Brunning 2001; Van de Noort 1996 and 2001).

### Issues and possible application of reversion and benign cultivation as alternative best practice options

The foregoing discussion indicates the relative advantages and disadvantages of reversion to grassland, direct drilling and minimum cultivation as means of reducing the impact of cultivation on archaeological sites. These need to be balanced in developing an appropriate package of measures to address the issue, and are summarised below.

Issue	Reversion to grass	Direct drilling	Minimum tillage
General effectiveness as long term solution?	Very good (provided scrub, poaching etc controlled)	Good/medium – may significantly slow down/delay attrition for many years	Medium/poor – will only partly slow down attrition (best on flat, easily worked land)
Suitability for earthworks?	Yes	Yes, but not permanent (up to 20 years?)	No, assured benefits unlikely to last more than c 5-10 years
Implications for rotations and equipment availability?	May affect rotations, especially if large area	May limit crops used in rotations; likely to require contractor	May limit crops used in rotations; may require contractor
Potential for productive use?	Yes but limited to mixed farming system	Yes	Yes
Viability in organic farming systems?	Yes	No	Yes, but effectiveness may be restricted or negated by organic requirements
Do archaeological restrictions conflict with good practice?	No	Limitations on subsoiling and occasional cultivation may conflict with soil management	Limitations on subsoiling and deeper cultivation may conflict with soil management
Geographical limitations on applicability?	No	Yes, significant, but coincides reasonably with high archaeological risk	Not substantial; better on flatter ground and lighter soils
Potential to integrate with habitat/ wildlife enhancement?	High	Limited/ moderate (though may depend on timing and method of weed control)	Moderate (arable habitats and species)
Potential to integrate with soil protection?	High level of protection but may be limited in extent	Moderate to high	Low to moderate
Monitoring & verification by remote sensing?	Yes	No	No
Monitoring & verification by	Yes	Yes – with experience; difficult after harvest	No/difficult – especially to establish depth

Issue	Reversion to grass	Direct drilling	Minimum tillage
ground inspection?		and for absence of subsoiling	and absence of sub-soiling
Possible cost of incentive payments?	High, but can be restricted to only part of field	Low, but must be applied to whole field; availability of equipment is likely to be issue	Low, but needs to be applied to whole field; availability of equipment may be issue

On this basis, the following broad prescription framework for remediation of damage to archaeological sites in arable land use might be adopted to promote best practice.

- The preferred solution is to remove sites or parts of sites at significant risk of damage from cultivation through reversion to well-managed grassland (or permanent set-aside), and for this to be as permanent as possible. This solution is strongly preferable for earthworks and wetland sites where problems of erosion and desiccation are most serious.
- For reversion there should be general requirements to control scrub, poaching, and burrowing animals, and in wetland areas to re-establish high water tables
- As an alternative to reversion, direct drilling is much to be preferred to shallow cultivation methods, but should only be applied in Class 1 and Class 2 direct drilling areas with specific checks on depth of undisturbed soil over archaeology every ten years
- Use of shallow cultivation techniques should normally only apply to non-earthwork sites on flat or gently sloping land and subject to specific checks on depth in relation to archaeology every five years (or three years on steeper ground)
- Both forms of 'benign cultivation' should be subject to the following restrictions: no subsoiling, no deep ploughing, no use of root crops, maize, or energy crops; no autumn/winter sown crops except when direct drilled into stubble/grass in Class 1 direct drilling areas; maintenance of overwinter stubble/arable weed cover prior to spring sowing
- As general conditions for these prescriptions to be effective, there should be further requirements for avoidance of damage through ancillary works associated with arable farming (including environmental enhancement work) such as siting new field boundaries and permanent beetle banks etc across slopes on archaeological sites; avoidance of archaeological sites when digging irrigation lagoons, slurry pits, wildlife scrapes, removal of historic boundaries etc; avoiding disturbance of archaeological sites when building new tracks and farm buildings not requiring planning consent.

#### Geographical and other challenges to remediation: The case of the Fens and other wetlands

The practical viability and economics of different remediation measures will vary from one region to another. Of all areas under serious risk of damage, the East Anglian Fens and other areas of lowland peat in arable production probably present the greatest challenge (Appendix F). Well-preserved upstanding earthworks and gradually decaying waterlogged structures and deposits continue to emerge from beneath the peat which is shrinking in the Fens at a rate of 2 or 3 centimetres per year. The economics and logistics of (usually) exclusively arable farm enterprises engaged in high-value root crops unsuitable for minimum cultivation methods, mean that neither reversion nor benign cultivation systems offer obviously practicable or cheap solutions in agricultural terms. On the other hand, the cost of excavation, which is often thought of as the cheaper alternative to preservation *in situ* in the now well-established 'polluter pays' principle that operates under national and international standards applied through PPG16 in a development context, would be vastly expensive and probably logistically impossible to achieve across large tracts of wetlands. From this perspective relatively costly reversion targeted at key areas, perhaps combined with wetland habitat regeneration, would seem appropriate. A change to more benign cultivation systems (eg switching from conventional roots to direct drilled cereals) might help to slow down physical damage, but not the effects of shrinkage and desiccation. The eventual destruction of extremely well-preserved archaeological deposits may be slower than that caused by building and infrastructure development, but is arguably just as inevitable and will be far more extensive. More modelling of the detailed processes is needed, but the difference in timescales of threat between a typical few months to a year or two in the development context and at most a few decades in a wetland arable context is dwarfed by the geographical scale of the wetland threat, and this makes it no less urgent. The issue is not just an archaeological problem: the soils available for high value cropping are also disappearing, so the thorny question arises of whether – or which – irreplaceable archaeological deposits that have survived for millennia are to be sacrificed for the sake of gaining a few extra years or decades of arable production.

Other arable areas at significant risk of archaeological damage may not present quite so serious a challenge, but apart from the decay of waterlogged deposits below plough level that exacerbates the problem for the wetlands, the issues in other areas subject to root cropping and intensive cereal cultivation on erodible soils are hardly less significant.

#### ASPECTS NEEDING FURTHER RESEARCH

There is a need for further research to back up this work and to help develop some of the practicalities of delivering real conservation results that could provide a substantial basis for addressing the most extensive national challenge for preserving archaeological remains *in situ*. While the issue is bound up in much wider major policy issues for the future of the rural economy and reform of CAP, a number of specific studies are likely to inform particular aspects of the development of practical priorities and actions.

The introduction of suitable best-practice prescriptions, as outlined above, under existing arrangements is not critically reliant on, and does not need to be delayed to await the results of, such research, and some of it could usefully be carried out in parallel with any piloting of new prescriptions and incentives to promote best practice in this area.

1. To conduct a regional-scale study (building on this study and work by English Heritage in the East Midlands) to explore ways of developing a prioritised strategy for halting and/or reducing cultivation damage to archaeological sites with particular regard to:
  - Priorities, options and extent of mitigation needs
  - Farmers' attitudes to the archaeological heritage and its conservation. This will build on DEFRA Study BD 1702 (*Attitudes of farmers and land managers towards features of landscape and historic interest*), using a more detailed and practical approach
  - The continued development of the site-specific assessment model developed during BD1701 and the methodological implications of its use both for routine site-specific assessment and strategic approaches to targeting vulnerable areas, paying particular regard to:
    - application to whole farm situations, not just significant archaeological sites (to test coverage of minor sites)

- use by non-archaeologists (so far only archaeologists have trialled the assessment methods)
  - the need to merge the best features of these methods with those being developed by EH to arrive at final versions that can be recognised as a standard by DEFRA, EH (and preferably other UK state archaeological services), local authority archaeologists, and the National Trust
  - Addressing issues of archaeological management in arable landscapes on a whole farm basis
  - Policy implications arising from the range, scale and possible cost of identified mitigation needs
2. To demonstrate how methods of conserving archaeological resources can also benefit a wide range of other environmental and biodiversity resources, in order to assess potential for obtaining greater value for money in terms of environmental protection
    - to carry out a literature review using data already gathered for BD1701, recent DEFRA research on habitat regeneration and other archaeological and ecological literature on conservation and habitat regeneration
    - to identify existing case studies where integrated bio-diversity and archaeological conservation has been taking place (under ancient monument regimes and identified by other research, as well as agri-environment schemes) and how such cases fit into this framework
    - to review existing arable pilot schemes for the extent (and potential success) of integrating biodiversity and archaeological objectives
    - on the basis of the above to produce a framework of potential areas for integration indicating likely benefits and limitations
    - to make recommendations for how “added value” might be obtained through integration of archaeological conservation with habitat regeneration
    - to identify issues for further investigation through monitoring or trials
    - to assess the effect of using different techniques to protect the archaeological resource, eg reversion to grass, grass margins, uncropped wildlife strips, conservation headlands etc
    - to review aspects of value for money to look at whether combining these approaches can accrue savings in terms of the cost of environmental protection eg over-wintered stubble is good for birds as well as being environmentally advantageous to prevent winter soil erosion
  3. To conduct controlled trials of minimum cultivation methods on archaeological sites on a range of soil types to enhance understanding of
    - the likely relative effectiveness of different reduced cultivation methods to improve conservation of archaeological sites
    - the potential for using archaeological conservation to help deliver other soil conservation benefits
    - practical methods of monitoring the effectiveness of such techniques
  4. To evaluate the potential of air photography and remote sensing to assist with management of archaeological sites in arable landscapes
    - To review currently available methods of identifying active damage
    - To assess potential of remote sensing and air photography to monitor adherence to remediation measures (especially feasibility of distinguishing different types of minimum cultivation from conventional ploughing, and subsoiling)
    - To conduct field investigations to test reliability of aerial photography and remote sensing interpretations, including the burial of objects
    - To examine potential for integrating archaeological reconnaissance and monitoring with other agricultural uses of air photography and remote sensing.
  5. To assess the effects of the development of organic farming on the conservation of the archaeological resource and the historic environment and to develop best practice guidance to minimise any identified adverse effects
    - to review the needs and opportunities for archaeological conservation within organic arable production regimes
    - to develop best practice guidance, integrating approaches to both pastoral and arable aspects of organic mixed farming
    - to consider wider historic environment issues and opportunities for organic farming in relation to branding of organic production and diversification.
  6. To develop a more detailed assessment of the probable trajectory of loss of archaeological deposits and palaeo-environmental evidence in lowland wetlands, perhaps using the East Anglian Fens as an initial pilot
    - to bring together geological, hydrological and archaeological profiling of deposits and water tables with rates of shrinkage to establish model of rates of loss for different areas and holocene geological sequences
    - to predict the respective survival/destruction trajectories of palaeo-environmental evidence, archaeological deposits and cultivable soils
    - to develop a strategy for conservation of key areas of high archaeological potential
  7. To examine in more detail issues of archaeological sites revealed by surface finds in an area of high national risk, with particular reference to early Anglo-Saxon cemeteries and settlements in East Anglia, (representing an especially significant aspect of the region’s archaeology, where most of the evidence for sites arises from well developed liaison with metal detectorists, and there is a regionally high risk of archaeological damage) (*suggested by the Committee for Research in the East Anglian Kingdom*)
    - to establish physical evidence for damage to sites largely identified through metal detecting finds
    - to further develop predictive modelling of risk
    - to develop a conservation strategy for cemetery sites
    - to consider any implications for DEFRA’s and other organisations’ policies on metal detecting
  8. To determine whether the increased use of agricultural chemicals has accelerated the corrosion of archaeological metal artefacts in the ground (*suggested by Professor Mark Pollard, Bradford University*)
    - to derive soil solution and determine the quantities of agrochemicals which are retained by soil, and quantities available to

- interact with archaeological metals
  - to simulate accelerated corrosion of metal samples (ferrous and Cu-alloy) through contact with soils and soil solutions contaminated with fertiliser
  - to carry out theoretical modelling of sub-surface geochemical processes affecting corrosion of metals using the Geochemist's Workbench™
  - to relate results to levels and controls on use of agro-chemicals in relation to control of nitrates
  - to consider possible geographical extent of the problem in relation to the condition of metal-detected finds
9. To evaluate possible applications of precision cultivation techniques to control potentially damaging operations such as subsoiling and deep ploughing
- to establish transferability of technology
  - to assess practical feasibility and implications for cultivation methods and stages
  - to consider conditions that would influence take-up if shown to be feasible

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