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GIS MAPPING OF ANTHROPOGENIC SOILS IN SCOTLAND: INVESTIGATING THE LOCATION AND VULNERABILITY OF SCOTTISH PLAGGEN-TYPE SOILS

Abstract - Research has demonstrated that «plaggen» soils – anthropogenic deposits, sometimes over 1 m thick, resulting from sustained manuring over long periods – retain significant archaeological information from which early arable land management practices can be interpreted. However, as areas of enhanced fertility, plaggen-type soils attract intensive modern-day agricultural activity. This paper presents the first phase of a project which aims to a. investigate the distribution of plaggen-type topsoils throughout Scotland and b. establish the impact of present-day land management, and the diversity of modern land cover, on the retention of this soil-based cultural record. An ArcView GIS database has collated relevant historical, geographical and archaeological information, creating a map indicating areas with a strong likelihood of anthropogenic deep topsoil deposits. Survey through these areas has identified sample sites for modern impact study, while this unique database explores the historic, economic and geographical factors influencing the formation of these soils in Scotland.

Key words - Anthrosols, plaggen, land management, GIS, Scotland.

Riassunto - *Cartografia GIS dei suoli di origine antropica in Scozia: studio dell'ubicazione e della vulnerabilità dei suoli a* plaggen *scozzesi*. Precedenti ricerche hanno dimostrato che i suoli a «plaggen» – depositi antropogenici talora spessi più di 1 m derivanti da intensa concimazione durata a lungo – contengono informazioni archeologiche rilevanti dalle quali si possono trarre ipotesi sulle antiche pratiche di gestione dei terreni agricoli. Questo lavoro presenta la prima fase di un progetto i cui obiettivi sono: a) individuare la distribuzione dei suoli a plaggen in Scozia; b) definire l'impatto dell'uso attuale del territorio e della vegetazione moderna sulla conservazione del record culturale nel suolo. Dati storici, geografici ed archeologici sono stati raccolti in un database ArcView GIS creando una mappa che indica aree ove è maggiore la probabilità di rinvenire spessi orizzonti superficiali antropogenici. Ricognizioni in queste aree hanno identificato siti-campione per studi sull'impatto delle attività moderne; inoltre il database esplora i fattori storici, economici e geografici che hanno influenzato la formazione di questi suoli in Scozia.

Parole chiave - Antrosuoli, plaggen, gestione del territorio, GIS, Scozia.

INTRODUCTION

Deep anthropogenic topsoils, or «plaggen» soils, have seen considerable research into their chemistry, geography and anthropogenic origin, most notably in the Continental European areas whose medieval land management systems give these soils their name (*e.g.* Pape, 1970; Van de Westeringh, 1988; Spek, 1992). Within Britain, research into these deep topsoils has centred on Ireland, where extensive plaggen-type deposits have been identified in the south-west coastal areas (*e.g.* Conry & Diamond, 1971; Conry, 1974). However, although there is evidence that similarly augmented soils are distributed throughout Scotland (Glentworth, 1963), there has so far been no systematic research into the nature and frequency of this distribution and its relationship to the historic landscape. This paper discusses the creation of a database which integrates historical, geographical and archaeological information to investigate this distribution. The effectiveness of this database is tested by a subsequent survey programme undertaken to identify sample sites from which to study the effect of modern agricultural practices on deep anthropogenic topsoils.

Scottish anthropogenic soils: previous work

Scottish studies into anthropogenic soil are generally connected with archaeological investigations and are thus predominantly site-based, concentrating in particular on the Northern Isles. As a consequence of this focus on settlement sites, Scottish studies have tended to investigate a range of anthropogenic soil formations, from buried soils (Dockrill *et al.*, 1994; Simpson *et al.*, 1998) to farm mounds (Davidson *et al.*, 1983), and from large-scale agricultural land modification (Simpson, 1997) to soils within settlement areas and midden deposits (Guttmann, 2001).

Deep anthropogenic topsoils, comparable to Continental plaggen deposits and established over large areas, have however been identified in mainland Orkney (Simpson, 1994, 1997). These cover approximately 150 ha to maximum depth of 0.70 m. Thin section micromorphology and lipid biomarker analyses have identified inputs of turf composted with mainly ruminant manure and seaweed (Simpson, 1997; Simpson *et al.*, 1998). Like the plaggen deposits, the Orkney soils relate to infield settlement patterns and show similar dates, starting in the late Norse period (*c.* 1200 AD) and continuing until the agricultural changes of the late nineteenth century (Simpson, 1997: 375).

While other anthropogenically-modified Scottish soils do not compare so directly in depth and extent to those on the Continent, chemical and micromorphological analyses show that their makeup is similar, and it is this which suggests that the intensive manuring systems which lead to deep topsoil formation were to be found throughout Scotland. Buried soils formed by

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intensive application of grassy turves and domestic midden date to the Bronze Age at Toft's Ness, Sanday, Orkney (Dockrill *et al.*, 1994; Simpson *et al.*, 1998). More recent work at Papa Stour, Shetland, has identified deep anthropogenic topsoils associated with the run-rig system situated within localised infield areas (Guttmann, 2001: 81).

Mapping Scottish deep anthropogenic topsoils: an interdisciplinary study

There is a variety of source data that informs upon anthropogenic soil modification – scientific, historical, geographical and archaeological. The GIS database created in this project combines these very different sources of evidence to indicate potential areas of deep topsoil distribution throughout Scotland. In particular, research was focused upon the substantial body of historical literature of the «improvement period» of the eighteenth century, and the geographical datasets of the Soil Survey of Scotland which map deep topsoils throughout several Scottish regions. The connection of these datasets is augmented by archaeological information taken from both survey and excavation projects.

This synthesis – particularly the analysis of historical records – is an innovative use of source data which stands as an original contribution to this field of research in Scotland. This geo-referenced database provides a useful platform for future work in this area and, with its emphasis upon the archaeological and historical background to these soils, investigates the human decision-making influencing the formation of these soil features. The variability of these decision making processes is illustrated in the survey undertaken – despite widespread evidence for intensive manuring systems throughout pre-improvement Scotland, deep anthropogenic topsoils are clearly not apparent to the same degree. This is as much a question for historical research as for archaeological investigation, illustrating the interdisciplinary base required for sufficient understanding of landscape and soilscape development which is increasingly recognised in geoarchaeological study. By integrating these different strands of evidence for influences that contribute to the development of deep topsoils, we begin to build up a picture of the «synergy» (Whitehead, 1998) between human and nonhuman influences on the Scottish agricultural landscape.

METHODOLOGY: DATABASE CREATION

Data sources 1: Historical

Advances in agricultural technology throughout the eighteenth century saw Scotland move from subsistence-level agriculture to a productive, market orientated regime. One of the main changes made during this time was in fertilising methods, as lime began to make a widespread impact, beginning the shift away from bulk fertilisers – dung, earth and peat, agents which contribute to deep topsoil formation – towards the artificial fertilisers used today. These changes were chronicled by a government keen to acquire data on its most important resource, resulting in the County Agricultural Reports (1785-1814), and significant portions of the First Statistical Account of Scotland (1791-1799). These record aspects of agricultural management such as cropping, land rental, livestock and manuring practices at county and parish level and thus provide information on the traditions that would have influenced the development of deep anthropogenic topsoils during pre-improvement era Scotland.

Details of references to manuring inputs and related data for these sources were compiled as a database, resolved to parish level. This was then imported into ArcView and linked to a parish map by the creation of a five-figure code for each parish to act as a common field. From this, a classification system was developed relating evidence for different manuring practices in each parish to the likelihood of deep topsoil formation. This set was graded from 0 (no manuring reference) to 6 (direct reference to «plaggen» type systems indicating topsoil augmentation), and then added to the ArcView database. The system attempts to grade parishes according to whether they appear to concentrate on the more «traditional» organic manures, or the more «modern» methods – the sole use of lime taken as being furthest away from direct evidence of traditional plaggen activity. This classification was then used to indicate whether parishes were «very possibly», «possibly» or «unlikely» to show deep topsoils – a necessarily broad classification, given the idiosyncratic nature of the data. A representation of this distribution in ArcView is seen at Figure 1.

A major disadvantage to the historical dataset is the variability in data quality between parish accounts. This has implications for its use to «map» manuring traditions using GIS. Of 876 parishes, 341 give no direct information on manuring, and 39 of these give no agricultural information and are therefore a blank in the database. In the absence of supporting data, it must be remembered that the subjective and sometimes piecemeal evidence provided by these accounts can only indicate a level of potential for anthropogenic deep topsoil formation.

Data sources 2: Geographical

The Soil Survey of Scotland, undertaken from 1946, covered much of the Scottish mainland and islands, concentrating on the eastern parts of the country. Although the Survey did not map human-modified soils, these records represent the most extensive geographical indicator for deep topsoil location, and were used in sourcing deep topsoils in Orkney (Simpson, 1997).

These indicators take three forms. Firstly, although the survey aimed only to map natural soil types, several surveyors noted «deep phases» of topsoil within certain soil series, distinctions which were included upon several final Soil Maps. Secondly, the original field notes of the surveyors, in recording the vertical profile of each auger point, show topsoil depth for each survey point taken. Finally, the descriptions of each soil series and its associate-level variations accompanying each map discuss the suitability of each soil for agriculture, giving values for properties such as phosphates. Occasionally, surveyors note the propensity of soil associations to develop anthropogenic topsoils (Glentworth, 1963: 172).

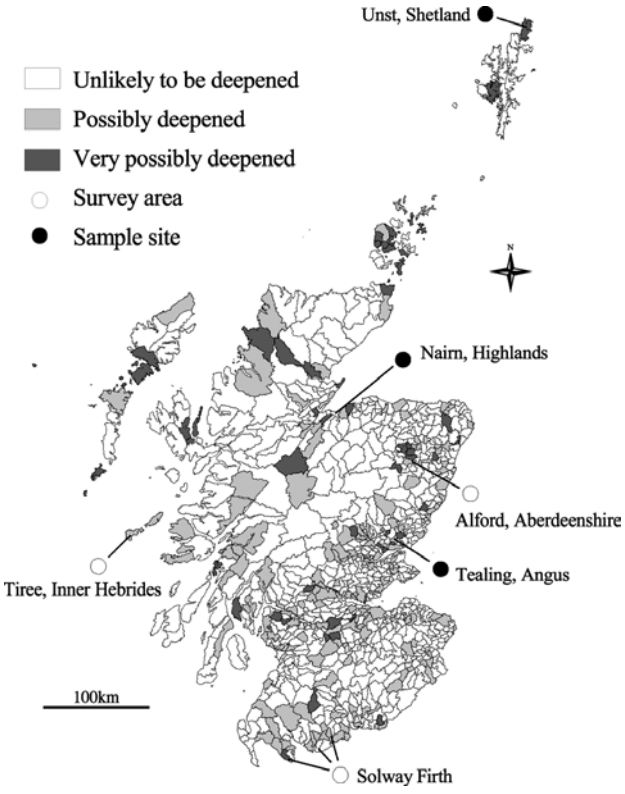

Fig. 1 - Map of Scotland showing the «manuring classification»: parishes rated for the likelihood of showing deep topsoils according to the historical dataset. Over this is shown the survey and sample areas investigated for this project.

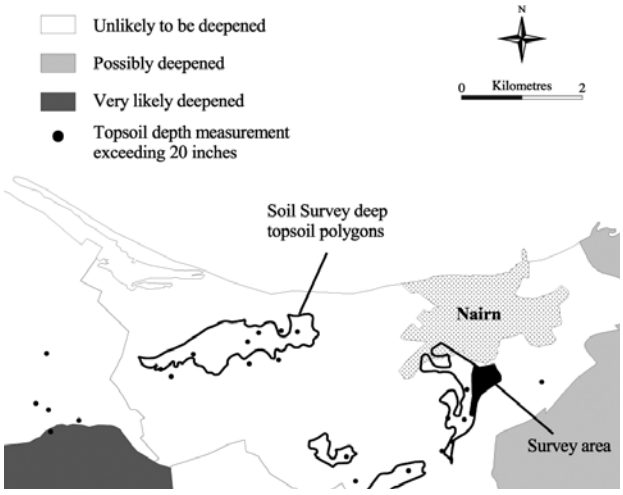

Fig. 2 - Nairn and surrounding area, showing the parish database at Figure 1 overlain by Soil Survey data showing the location of putative anthropogenic deep topsoil polygons and points. An anthropogenic topsoil deposit located within one of these polygons (south of Nairn) was sampled over a range of land cover types.

To integrate this information with the ArcView database, this information was transformed into a digital format. The outlines of deep topsoil phases shown on final Soil Maps were digitised and imported into the ArcView dataset. Remaining survey records containing auger point data in the Survey archive were located and the complete auger point record traced from the original maps – approximately 115 maps, covering approximately 1000 m each, with the number of topsoil points varying from two to over 500 per map. This point data was digitised and imported into the ArcView database. These points could then be filtered so as to highlight those areas with a preponderance of deeper topsoil points.
Figure 2 shows the integration of this geographical information with the historical dataset for Nairn, Highlands, with the polygons of deep topsoil and the original Soil Survey points giving topsoil depth shown against a background of the parish map seen in Figure 1.

Data sources 3: Archaeological
Scotland has several extensive archaeological survey databases, information from two of which has been added to this database. Both of these relate to the rural economy of the «pre-improvement» period. The First Edition Survey Project (FESP), a six-year programme undertaken by the Royal Commission on the Ancient and Historical Monuments of Scotland, is a survey of the unroofed buildings recorded by the first edition of the Ordnance Survey 6-inch map (1843-1878), and provides a spatial dataset recording the pattern of rural settlement and abandonment for the period during which traditional manuring systems were superseded by modern fertilisers (RCAHMS/Historic Scotland, 2002).
The Historic Land Use Assessment (HLA) project, also undertaken by the Royal Commission on the Ancient and Historical Monuments of Scotland, gives mapped information for land use patterns for the same period (Bruce *et al.*, 1999).
The inclusion of these datasets illustrates the compatibility of this manuring database with other spatial archaeological databases, and thus the potential of this project to be complemented by spatial data collected by both commercial and research excavations. Such data can provide the resolution lacking from, for example, areas of Scotland with no Soil Survey data available. Figure 3 shows FESP data for the parish of Barvas in the Isle of Lewis, again against a background of the parish map at Figure 1. Within the areas with strong evidence for deep topsoil manuring, we can see that settlement patterns relating to the period during which these manuring methods would have proliferated – and thus the likely distribution of deep topsoils – is concentrated along the coastline.

ANALYSIS: TESTING THE DATABASE

With the ultimate aim of locating sample sites from which to study the effect of modern agricultural practices on deep anthropogenic topsoils, a programme of

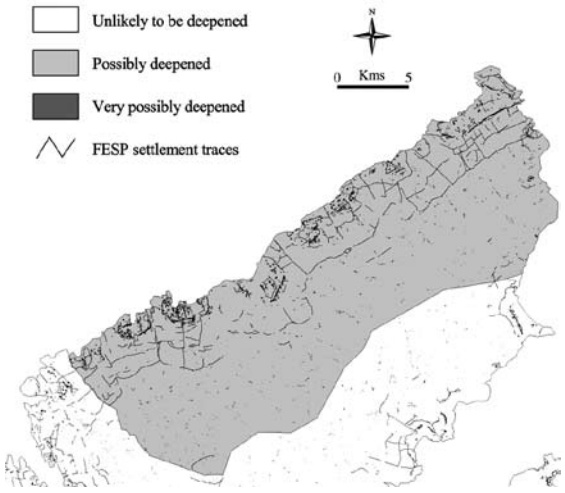

Fig. 3 - Parish of Barvas, Lewis, Western Isles. The parish manuring database is shown overlain by First Edition Survey Project data, showing the proliferation of rural settlement, and thus intensively manured areas, along the coastline.

auger survey was undertaken, using this database to identify areas with a likelihood of deep topsoil formation. Six areas were chosen, through which both the reliability of the database and its potential for interaction with other sources of information was tested. The survey areas were chosen across a range of geographical areas and urban to rural contexts, and across areas with varying levels of data quality and resolution according to the manuring database. The areas chosen are seen at Figure 1.

Survey 1: Nairn, Highlands

This survey was undertaken to investigate the nature of the «deep topsoil phase» polygons shown on the final Soil Map for the Nairn area (Soil Survey for Scotland, 1974), some of which correlate with parishes showing documentary evidence for anthropogenic soils (Fig. 2). Most polygons located along the coast were raised beach deposits, however, auger points taken within the polygon immediately to the south of Nairn itself identified a deep (up to 0.85 m), dark anthropogenic topsoil, developed on fluvoglacial sand (Pl. 1a).

Direct information for manuring tradition in Nairn is absent from the Statistical Account, but the County Agricultural Report of 1794 describes an input system consisting of turf, sand and dung, composted through use in the byre (Donaldson, 1794: 14). If so, the manure, with its high mineral content, would have resulted in a thickening of the soil, and the formation of a topsoil comparable in anthropogenic origin to the plaggen deposits of the Continent.

Survey 2: Alford, Aberdeenshire

This survey was undertaken to investigate an area for which historical and geographical data converged, indicating a «hotspot» for deep topsoil, with a cluster of points up to 30 inches deep through an area surrounded by «high-rated» parishes from the manuring database. However, auger survey failed to locate topsoils deeper than *c*. 10 inches. This discrepancy is possibly due to poor alignment of traced topsoil maps with the ArcView database.

Survey 3: Dundee and surrounding area, Angus

With extensive Soil Survey auger point coverage, this area was used to investigate correlation between the Soil Survey point data and the manuring database, following the Alford survey. Five parishes of different ratings, with a high number of deep topsoil points (over 15 inches) was selected for an auger survey through arable areas surrounding the main settlements within the parish. The correlation between the Soil Survey points and the parish database was uneven. Although higher rated parishes did show on average deeper topsoil points than those rated lower, overall few deep topsoil points throughout the survey area were located. Again, this could indicate problems with alignment of the Soil Survey data.

However, the parish of Tealing indicated several deep points, mainly located around Tealing village, which were identified as anthropogenic topsoils of approximately 0.50-0.70 m depth. More detailed survey identified an extensive polygon of deep topsoil centred on Tealing House, the focus of a late sixteenth/early seventeenth century farming estate.

Unlike the sandy Nairn subsoil, the Tealing polygon is on imperfectly drained loam to clay loam, in an area with a high groundwater table. The creation of a deep anthropogenic topsoil as a response to these soil conditions may parallel that seen at Welland Bank, Cambridgeshire, England (French, 2003: 152-157). Here, a pre-Iron age plaggen soil had been formed on a poorly-draining fenland palaeosol, presumably as an agricultural strategy designed to offset the effects of the poor subsoil drainage capacity and overbank flood episodes to which the Welland Bank area would have been prone (Pl. 1b).

Survey 4: Unst, Shetland

This survey investigated an area highly rated by historical sources but lacking locational data to resolve this past parish level. Shetland exemplifies how unspecific the parish dataset can be, as Shetland parishes habitually cover entire islands. Two of these were rated likely to have deep topsoils, of which the soils of Unst were superior in suitability for agriculture (D. Johnson, SEERAD, pers. comm.). Historical sources agree (Evershed, 1874: 192). In the absence of Soil Survey data, it was decided to survey the «Westing», confirmed as the most cultivable area of the island. With the highest incidence of Norse «farmstead» settlements and Iron Age brochs on Unst, the Westing showed extensive evidence for continuous cultivation, and therefore the likelihood of deep topsoil development. Furthermore, the isolation of this northernmost isle may have ensured that traditional manuring systems survived for longer.

Several polygons of deep topsoil were identified. The most extensive of these was a deposit of up to 1.15

m depth located at Underhoull: an archaeologically complex area, with a large broch and Viking-period longhouse (Small, 1966) within close proximity. Surrounding these are several Norse period farmsteads, plus a network of abandoned croft houses testifying to intensive cultivation during the nineteenth and early twentieth century (Pl. 1c, 1d). Historical sources indicate manuring practices which closely parallel those of the «plaggen» regions (Mouat, 1791; Sinclair, 1794), only discontinued in the 1920s (A. Smith, pers. comm.). However, the archaeological provenance of the deep topsoils near the Iron Age broch and Viking house is likely to be more complex. It is possible that comparison between profiles taken for this project and other Northern Isles samples could inform upon the various manuring techniques in use at Underhoull during these periods.

Survey 5: Tiree, Inner Hebrides
Tiree was the subject of an agricultural inspection commissioned by the landowner from James Turnbull (Turnbull, 1769). This survey was undertaken to investigate the usefulness of using early surveyed data of this kind to indicate possible deep topsoils within the areas indicated as farming townships by the Turnbull survey.
Current arable production in Tiree is limited to specific areas, many corresponding to those surveyed under Turnbull. Auger survey throughout these indicated some anthropogenic soil augmentation, with several topsoil polygons, on average c. 20-30 cm in depth, located around past farming townships. The largest, a polygon of dark, deep topsoil of 0.40-0.55 m. was recorded over an area of approximately 30 m^2. As this area had no range of modern land cover, this area was not sampled.

Survey 6: Medieval settlements, Solway Firth
This survey explored the possible contribution of the archaeological survey data included in the project. While the FESP data identifies settlement concentration, HLUA data shows larger scale land use, identifying changing cultivation patterns over different periods. The Solway Firth is noted for a number of monastic settlements along its coastline, notably at Whithorn, Dundrennan and New Abbey. These early economic and agricultural bases (Smout, 1969: 25) were focus for the survey, plus a deserted medieval village (Dunrod) with an extensive surviving rig-and-furrow system.
Survey through these sites showed little or no augmentation of the topsoil. At Whithorn, a survey of the area immediately around the abbey was contrasted with a survey of a portion of the farmland identified by the HLUA data as possibly representing the arable base for the town: no notable difference in topsoil depth was identified. At Dundrennan, one polygon of extremely dark topsoil with a maximum depth of 0.65 m was identified adjacent to the abbey.

DISCUSSION

Deep topsoil frequency in Scotland
The survey programme undertaken for this project suggests that, although deep topsoils are found in a variety of Scottish geographic and economic contexts, they are comparatively rare. No deposit as extensive as those found in Orkney was located, with three of the six surveys showing little or no topsoil augmentation in areas where source data indicates that they would be most likely to exist. The relative rarity of these important cultural soils in Scotland highlights the need for their conservation and protection as an important cultural resource.

Inputs, location and context
The significant feature of this database is that it allows us to see the variety and distribution of manure inputs used throughout Scotland. Prior to agricultural mechanisation, fertiliser inputs largely depended upon the availability of a source to each area, and so the types of material used as fertiliser were a reflection of an area's economic base. Identification of fertiliser inputs, and analysis of the makeup of anthropogenic soils is therefore of interest to inter- and intra-site archaeological studies alike. However, recognition of input traditions on a larger scale allows for a wider historical picture to be constructed. For example, the well-organised «plaggen» system is seen as an expression of the need to secure as much fertiliser as available, especially during time of agricultural growth, paralleled in other areas such as Ireland. There is also a strong element of land reclamation and settlement growth connected to «plaggen» development – at their deepest around settlement areas, augmented topsoils gradually thin towards more distant areas of poorer land (Pape, 1970: 237). The importance of these traditions to the developing agricultural landscape is reflected in the high level of organisation supporting the system, with laws controlling sod-cutting and grazing rights for waste lands (Blume, 1998: 1).
Scotland, however, presents a more complex picture. The variety of inputs into Scottish soils reflects not only available resources, but also the varied landscape and soil environments of different arable areas and the differing fertiliser requirements of each – varying combinations of which, as demonstrated by these surveys, are seen to result in deep topsoils – in contrast to the sand-based «plaggen» system. Furthermore, whilst there is documentary evidence for social organisation (Simpson, 1997: 378) and legal statutes connected to manuring such as turf-cutting restrictions (Birnie, 1791: 456), the distribution of anthropogenic deposits identified by this survey indicates that there was no single agricultural system linked with the development of deep topsoils. While Unst represents a «typically» rural intensive manuring system, Nairn is an essentially urban context, with waste material from the town being a major soil input. The third sample site at Tealing shows yet another economic context: a semi-rural system, near to the large urban area of Dundee. The highly devolved nature of the pre-industrial Scottish

agricultural economy further complicates this picture (Dodghson, 1998: 15, 55-56). Only by considering the complex relationship between inputs, location and context through collating the wide range of sources available, can we understand the intricate relationship between these environmentally-determined and human-induced factors.

CONCLUSIONS

This survey programme, by indicating the potential rarity of deep topsoil deposits in Scotland, highlights the importance of constructing a conservation strategy for these culturally significant soils. The second part of this project, by investigating the effect of continuing land use on these deposits, will further contribute to understanding these requirements. The database, in creating an archive which places these soils in their wider historical and archaeological context, provides a framework for the management of this cultural resource by examining the range of historic and environmental contexts within which Scottish deep topsoils were created.

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