19 Soils and Archaeology

Thomas Cummins, Helen Lewis, Clíodhna Ní Lionáin,
and Stephen Davis

Abstract

Archaeology is the study of the human past from its material remains, most of which are made of or found within soils and sediments. Past human actions impact the soil record, as seen through relics of changes in soil characteristics and qualities, changes to sedimentation, and the presence of archaeological features and artefacts preserved within modern soils. Soil and sediment conditions control what survives in the burial environment, what decomposes, and consequently influence all archaeological sites, artefacts, and ecological remains. The study of these remains, through survey, excavation, and post-excavation analyses, informs our understanding of past cultures and environments, providing insight into how people have interacted with the soil, both directly, through settlement, land use, and monument construction, and indirectly, by altering local ecosystems over time. Soils can be considered repositories of traces of human action, and in turn the soils of Ireland have formed under the continuous influence of people, up to the present day, when most land in Ireland is actively managed for agriculture, forestry, extraction or construction. Consequently, all land managers are stewards of soil-bound heritage, and have the opportunity and responsibility to recognize the archaeological heritage value of land in their care, and to participate in conserving this value as a public good. This chapter reviews some of the soil evidence for Irish landscape history, the heritage content of soils, archaeological work that has helped discover that heritage, and issues surrounding the management of the cultural heritage in soils.

Keywords

Soil heritage • Archaeological heritage • Cultural soils
Sediments • Geoarchaeology • Archaeological
prospection • Taphonomy • Dowth

19.1 Introduction

Archaeology is the study of the human past from its material remains, most of which are made of or found within soils and sediments. Past human actions impact the soil record, as seen through relics of changes in soil characteristics and qualities, changes to sedimentation, and the presence of archaeological features and artefacts preserved within modern soils. Soil and sediment conditions control what survives in the burial environment, what decomposes, and consequently influence all archaeological sites, artefacts, and ecological remains. The study of these remains, through survey, excavation, and post-excavation analyses, informs our understanding of past cultures and environments, providing insight into how people have interacted with the soil, both directly, through settlement, land use, and monument construction, and indirectly, by altering local ecosystems over time. Soils can be considered repositories of traces of human action, and in turn the soils of Ireland have formed under the continuous influence of people, up to the present day, when most land in Ireland is actively managed for agriculture, forestry, extraction or construction. Consequently, all land managers are stewards of soil-bound heritage, and have the opportunity and responsibility to recognize the archaeological heritage value of land in their care, and to participate in conserving this value as a public good. This chapter reviews some of the soil evidence for Irish landscape history, the heritage content of soils, archaeological work that has helped discover that heritage,

T. Cummins (✉)
UCD School of Agriculture and Food Science, University College Dublin, Belfield, Dublin 4, Ireland
e-mail: thomas.cummins@ucd.ie

H. Lewis · S. Davis
UCD School of Archaeology, University College Dublin, Belfield, Dublin 4, Ireland

C. Ní Lionáin
Devenish Nutrition, Belfast, Ireland

R. Creamer and L. O'Sullivan (eds.), *The Soils of Ireland*, World Soils Book Series,
https://doi.org/10.1007/978-3-319-71189-8_19

and issues surrounding the management of the cultural heritage in soils.

19.2 Irish Landscape History from the Soil and Sediment Record

The soil record in Ireland extends from the end of Pleistocene glaciation to the present day. During most of this time the island has been occupied by humans, and thus all Irish soils have developed with human influence along with natural soil formation factors. From the end of the last ice age, parent materials such as rock and glacial till have been constantly weathering and transforming into soil, affected over time by climate, topography and organisms (Jenny 1941; for studies in Ireland see e.g. Dimbleby 1965; Moles et al. 1995; Moles and Moles 2002). Since the arrival of humans into the Irish landscape at least 10,000 years ago (cf. Dowd and Carden 2016), their activities have influenced the factors of soil formation, especially those related to biota. The activities of early settlers and farmers, who felled trees for land clearance and introduced tillage crops and grazing domesticated animals, converted previously forested landscapes into long-term grasslands by at latest the end of the Neolithic period (O'Connell and Molloy 2001). Agricultural landscapes have been largely maintained to the present day, with varying intensity, focus and technology of farming practices. Expansion and contraction of settlement areas and alterations to drainage have caused soils to change over time, against a backdrop of larger-scale climate shifts. Effects of cultural activity on soil development are widespread in the archaeological and environmental record across northern Europe, highlighting the impact of human cultural practices on the environment over time (e.g. Roberts 2014).

Irish evidence suggests similar trajectories over time to those of the rest of northern Europe (e.g. Weir et al. 1971; Macphail 1986; Macphail and Robertson 1989). Soil changes related to erosion (soil loss and slope movement), altered drainage, intensifying tillage practices, the impact of settlement construction and of industry are among the most evident. Vegetation clearance, followed by centuries without forest canopy, has increased the impact of rainfall and erosion, leading to waterlogging of soils, reduced profile thickness, podzolisation, and, in some locations, the initial steps in peat formation (Clayton 1973–4; Cunningham et al. 1999). Through centuries of agricultural management, liming agents and nutrient-rich manures have been applied to fields (Collins 2008) to maintain a relatively high pH, active rooting and soil faunal activity, sustaining the productive capacity of the soil.

Soil exposure through deforestation, crop rotation and tillage practices may all increase soil erosion by wind and water action, particularly on slopes. Given the climate and topography of Ireland, erosion is seen today (e.g. O'Sullivan et al. 2014; McCormick et al. 2014; Drew 1983; Huang and O'Connell 2000) and in the archaeological record (e.g. Moles et al. 1999). A typical 'stable' grassland today would have seen at least one phase (but usually many) of past forest/scrub clearance, and often also several phases of past tilling, some prehistoric and some historic. The types of impact expected are surface (e.g. deflation, colluviation, crusting) and sub-surface (e.g. nutrient leaching, clay redistribution, size-sorting of inclusions). Identifying land clearance archaeologically requires rigorous modelling of soil profile changes over time, in addition to proxy environmental indicators such as pollen or charcoal records. Pollen records exist in ancient bogs and in lake and stream sediments found across Ireland (e.g. Jessen 1949; Mitchell 1951; Smith 1961; Thompson 1997; Lomas-Clarke and Barber 2004; Edwards and Whittington 2001; O'Connell and Molloy 2001; Turner et al. 2015; Mitchell et al. 2013), but little attention has been paid as yet to linking local soil records with these regional proxies of vegetation change over time (but see Verrill and Tipping 2010). Many archaeological soils in Ireland show localised indicators of past vegetation and turf clearance, breaking up of the ground, agricultural interventions, and the impact of amendments related to ancient tilled fields (e.g. Case et al. 1969). These are seen through physical disturbance indicators ranging from ridged field systems and lynchets to 'buried' spademarks to microscopic clay accumulation features typical of cultivation (e.g. 'agricutans') identified through soil micromorphology. Amendment indicators may include certain artefacts, manures, ash, seaweed inclusions, chemical alterations, and related morphological evidence such as of soil faunal activity (e.g. Barker 1985; Case et al. 1969; Courty et al. 1989; Jongerius 1983; MacPhail 1990; Romans and Robertson 1983).

In addition to the soil record, about one-fifth of Ireland has or had peat cover (cf. Hammond 1981). Peat consists of surface organic sediments created when plant litter production exceeds decomposition; the cool, moist Irish climate and high water retention, provide good conditions for plant growth, and poor conditions for decomposer organisms. Peat has formed in large shallow basins (former post-glacial lakes) in the midlands. In upland areas from the mid-Holocene Epoch on, blanket peats have formed, sometimes covering prehistoric fields and settlements (e.g. O'Sullivan and Sheehan 1996). The question has long been asked whether early agriculture or agricultural changes somehow caused blanket peat to start forming in the past (Mitchell 1972), or if peat formation was triggered by climatic change with an increased moisture surplus (either increased rainfall or decreased evapotranspiration—see Thorp and Glanville 2003). Caulfield et al. (1998) dated discontinuous peat formation to before the occupation of

Neolithic field systems at Belderrig, Co. Mayo, and matched the later date-range of pine trees rooted in peat across west Mayo with a synchronous event in Scotland. These lines of evidence suggest that peat development was due to climate change, and not agriculture.

19.3 Soil and Sediments as a Repository of Archaeological Heritage

In addition to providing information on landscape history, soils and sediments are the preservation environment for most archaeological artefacts and features. All of these elements of the archaeological record can be studied through survey, excavation and post-excavation approaches adapted to the specific soil, sedimentary and geological environment.

The archaeological heritage of Ireland is afforded statutory protection through the National Monuments Act (1930) and its subsequent amendments (1954, 1987, 1994, 2004), which provide for the establishment and maintenance of statutory inventories, including the Record of Monuments and Places (RMP), based on the Sites and Monuments Record (SMR). Known monuments and zones of notification for operations around monuments are shown on the maps of the National Monuments Service (NMS), and can be viewed on the NMS websites (www.archaeology.ie; www.heritagemaps.ie). Where sub-surface features are known, they may be similarly protected, and require consideration within planning processes. However, at present in Ireland these are not systematically included on the Sites and Monuments Record. These features may be found through various survey methods, and their states of preservation and potential significance should be assessed and then revised on a regular basis through auger and/or bulk sample analyses. Guidelines for reporting and protecting archaeological sites are available at www.archaeology.ie.

There are currently no guidelines available for soils in Irish archaeology. However, by understanding the characteristics of local soils, broad predictions can be made about the likelihood of preservation of aspects of archaeological heritage. For instance, an acidic, freely-draining soil such as a Podzol on granite is unlikely to preserve bones or unburnt organic remains, and may not respond well to certain geophysical survey techniques. A Cambisol soil over limestone and under tillage is likely to have disturbed artefacts, preserved but fragmented bones, no wood, and can be expected to deliver excellent magnetometry results. A Stagnic Groundwater Gley soil in a floodplain is likely to contain organic remains, with surface features masked by alluvial deposits. Technologies including aerial photographs, satellite imagery or LiDAR (Light Detection And Ranging) may allow larger features to be seen, appearing as anomalies based on variations in topography, soil moisture and plant growth. The predictive qualities of the soil and sedimentary record allow archaeologists to tailor assessment, conservation, and research activities. Soils are very locally diverse, however, and broad models do not allow for the variation often seen across just a few meters, thus restricting accuracy of zero-impact intervention approaches. Soil maps (e.g. Creamer et al. 2014), aerial photographs, LiDAR, geophysics and other remote-sensing approaches, while all useful for archaeology, also have limitations. Assessment of conservation environments is best achieved through localised methods such as soil auger survey, bulk soil analyses of surface samples, or by test-pitting. Around Ireland, there are tens of thousands of ancient remains preserved as features in the soil, a proportion of which also have above-ground remains, built of earth and/or stone. Earthen monuments vary from large and clearly visible structures, such as passage tombs, ringforts, hillforts or henge monuments (ditch and bank, sometimes with stone or timber circles), to remains with no surface expression. Earthworks and buried features survive from times with no written records, from diverse societies from whom little else remains.

The depth-limit of an archaeological excavation is usually set at the depth of construction disturbance, or at the level below which no further traces of human activity can be found. In Ireland, this is normally at the level of glacial deposits or rock. An artefact-free depth of alluvium or sand does not necessarily indicate the lack of earlier activity at the site, as these Holocene deposits can cover earlier activity. As such, archaeologists must also be aware of the sedimentary environment and history of a site, and tailor assessment strategies accordingly. Assessment and monitoring may also go further, in the case where a development will affect drainage, and thereby survival of deeper buried remains on and around the site (e.g. French 2004).

When survey and/or excavation are completed, finds are documented, conserved and stored, and the record of excavated contexts and features forms a permanent site description and stratigraphic record. The excavated soil is not preserved, although bulk samples may be taken for extracting biological remains, and undisturbed monoliths may be prepared for thin-section preparation. This process of "preservation by record" creates an intellectual resource that offsets the fact that interventions, including archaeological interventions, irreversibly disturb the deposits and soils studied. Excavation records are accessible through government libraries and the online services noted above, but the amount and detail of the soil and sediment information recorded is highly variable both in original recording and in publication. Soil and sediment characteristics underpin the archaeological record and so wider access to primary records is greatly needed (Fig. 19.1).

Artefacts and environmental remains decompose more rapidly in aerobic soil environments, leaving a biased

Fig. 19.1 Artefacts in their soil context at Belderrig, Co. Mayo. Left: Unconsolidated surficial deposits exposed by coastal erosion, post-glacially transformed at the surface into mineral soil. Blanket peat developed over the mineral soil, and was later cut away for domestic fuel, with the truncated peat remnant reclaimed as grassland by cultivation and liming. Archaeological excavation is seen inside the yellow fence. Right: A close-up of the upper soil profile shows stone artefacts associated with Mesolithic activity in two layers. At this site, evidence of Mesolithic activity is overlain by Neolithic field walls enclosing land over a large area, all below the former peat (Warren 2008). This specific cliff profile was not excavated, as it was unstable and unsafe for work; the status, identity, and heritage value of these particular objects, and the objects themselves, are now lost to the sea

residue of the most-durable materials, such as worked stone, charcoal, ceramics and glass. The survival of metals and bone is more variable, being very dependent on soil pH and redox potential, related to soil minerals and oxygen availability. Soil disturbance from fauna, flora and human land use also has a major impact on the condition of archaeological materials. The anaerobic conditions in bogs and other wetlands have led to a high level of preservation of organic remains, including ‘bog bodies’ (e.g. Kelly 2013; Bermingham and Delaney 2006), timber trackways (e.g. Raftery 1996; Moloney et al. 1995; Gowen et al. 2005), crannog-type lake settlements (e.g. Fredengren et al. 2010; Bermingham and Moore 2015), and objects like the Faddan More Psalter (Gillis 2012). However, in these environments objects such as low-fired pottery, bones and shells see variable or zero preservation.

The survival of human remains illustrates the different preservation potential of varying soil and sedimentary environments (Fig. 19.2). In the anaerobic, strongly-acid conditions of Irish peat bogs even soft tissues such as hair, skin, and internal organs may be preserved, including the gut contents of ‘bog bodies’. The rigid mineral material of bone, calcium hydroxylapatite, dissolves in the acidic solution of peat bogs, leaving behind a bone-ghost of collagen protein. In acidic but aerobic soil environments, complete decay of bone and soft tissues may occur, leaving no surviving human remains (Fig. 19.2, right). Bones in all soils are subject to decay, including in alkaline conditions such as over limestone, as rainwater, organic acids, and biota have an impact in all soil types. The decay process takes time, and more soluble materials decompose or alter first, e.g. organic components such as collagen often disappear before bone mineral, and porous bones decompose more quickly than denser bones. Animal bones and shells provide information regarding ancient human lifestyles and environments, and are subject to the same decomposition processes as human bones. Suitable preservation conditions with appropriate soil chemistry and little disturbance allow investigations on demography, diet, genetics, origins, health and lifestyles from the bone record (e.g. McKenzie et al. 2015; Knudson et al. 2012).

Other soil processes that greatly affect the archaeological record include burial by surface-casting earthworms, mineral weathering, leaching by rainwater, size-sorting by biota and water, and processes involved in the cultural practices of cultivation, especially tilling and amendment. For example, anecic earthworms generate a surface layer of granular soil

Fig. 19.2 Soil conditions lead to varying preservation. Left: Human remains preserved in the acid, anaerobic environment of a waterlogged peatland, a Dystric Histosol: fingers of Oldcroghan Man (reproduced courtesy of the National Museum of Ireland). Centre: Bones, consisting of mineral remains with the protein fraction—all soft tissues and a wooden coffin decomposed—in the alkaline aerobic burial environment of a probable Cambisol at St. Brigid's Hospital, Ballinasloe (Rogers et al. 2006). Right: Excavated grave cut with no human remains, following complete decomposition of organic remains and solution of calcium phosphate bone minerals in a strongly acid Podzol; Templeteenaun, Co. Wicklow (O'Sullivan et al. 2009)

crumbs by digesting and excreting soil particles creating surface casts. As they do not ingest larger objects, the latter travel downwards over time, forming a lower layer often recognized as a stone line in the soil profile, but which can also include pottery, bones—anything above the size of a sand grain. This process is frequently seen in Irish soils and affects the stratigraphy of the archaeological record, as do biomechanical processes more widely (Johnson 2002). Earthworms are typically most active in calcareous soils under stable grassland conditions. Tillage of such soils brings the size-sorted artefacts and stones into the upper part of the profile, meaning they are doubly disturbed in the vertical dimension. Tillage also moves objects horizontally, and this impact is especially strong on slopes, where objects also move due to gravity, and objects with less mass are moved further downslope by gravity and slope erosion than those with greater mass (Lewis 1998). As such, artefacts in alternating grassland and tillage, typical of much enclosed agricultural land in Ireland in recent centuries, can show substantial displacement and size-sorting vertically and horizontally. Understanding these dynamics, the relative locations of objects within the soil can also be used to identify ancient sites. Immediately after cultivation, organised surveys of ploughed soil by trained fieldwalkers can be used as a systematic method of recording artefacts to provide information on site types and chronology. In fields with little slope, or in combination with other survey approaches, this method can also be used to estimate the potential location of remains enclosed within the soil.

Ancient land use and soils can be modelled by understanding these processes. For example, where a pebble-free topsoil horizon is found underneath a monument, it can be suggested that it represents pre-monument earthworm sorting undisturbed by ploughing, at least in the immediate term before monument construction. This indicates that the monument was built in a grassland clearing or a pasture field that was grazed for some time (probably decades) prior to the construction of the monument. Earthworms and other soil fauna can also influence soil drainage and erosion, thus affecting the burial environment, and may cause organic remains such as charcoal to be broken up (Goldberg and Macphail 2006; Courty et al. 1989).

19.4 Geoarchaeology

Geoarchaeology combines earth science disciplines with the cultural approaches of archaeology to interpret ancient use of space, site construction and materials, landscape history and environmental changes. It makes use of many specialized physical, chemical and morphological approaches to identify deposited materials and the formation processes they represent. Few geoarchaeological studies have been undertaken in Ireland, compared to some other parts of Europe (e.g. Cornwall 1958; Keeley and Macphail 1981; Fédoroff and Courty 1987; Revel 1991; French 2003; French et al. 2007). Soils 'buried' under monuments and used as construction materials in earthen monuments were, however, a focus of Irish research in the early to mid-twentieth century. These early studies demonstrated the potential of Irish soil and sediment remains to reflect past landscape conditions and site histories. Buried soils and soils used in monument construction often reveal substantial landscape change over time, with monument soils indicating landscape characteristics different to modern conditions at the same location. Modelling how these changes occurred over time suggests that substantial soil erosion and alteration have occurred since at least the Neolithic Period across Ireland (e.g. Common 1940; O'Kelly 1951). For instance, a great deal of discussion focused on how variations in soil color can inform on monument and landscape history (e.g. O'Kelly 1951; Brade-Birks 1951; Proudfoot and Simmons 1958; Proudfoot 1960). Modern approaches to archaeological soils have become increasingly sophisticated: there are many more methods for studying ancient soils, and increased knowledge available from international research that allows a better interpretation of ancient soil history, human creation of sediments, and past land-use impact. The potential of past climate change to be related to these alterations in Ireland has been noted above, but the record of soil history is not well understood or dated on dryland soils, even where substantial monuments have been excavated. There are also many issues relating to pre-monument land use, the building of monuments, continuing and altered soil development, and the impact of a monument on the underlying soil profile (for some recent Irish examples see, e.g. Ostericher 2014; Ostericher and Lewis, in press).

19.5 Archaeological Prospection

Archaeological prospection enables certain aspects of the archaeological record to be characterised without damage. The preference of archaeologists is for heritage objects to remain buried and for non-destructive methods to be employed where possible, with excavation always a last resort (DoAHGI 1999). Non-destructive methods include the analysis of documentary sources, maps, aerial photographs, folklore and local knowledge, as well as non-invasive or low-impact fieldwork, such as walk-over survey and remote sensing (e.g. LiDAR, geophysical and geochemical survey). More invasive investigation is required in advance of development (e.g. buildings, roads), where at least the upper soil will be removed entirely, destroying any surviving remains. Archaeologists would also recommend investigation by field-walking for tilled fields, as these agricultural practices are constantly eroding, disturbing, and exposing new and deeper archaeological deposits. Even where excavation is required, archaeologists prefer to leave at least part of each site for future study. For example, the Viking settlement of Woodstown, which led to the establishment of Waterford city, was identified on the planned route of the N25 roadway (since re-routed) during a program of archaeologically-monitored test-trenching. As important finds were retrieved, further investigation was undertaken in small trenches, but most of the site was left in place (Russell and Hurley 2014).

LiDAR works on the principle of transmitting laser beam pulses and calculating distance by measuring the time taken for these beams to return, and record very low-profile surface topography, which may reveal archaeological features (Opitz and Cowley 2013; Crutchley 2010). Geophysical survey describes a range of remote sensing techniques (e.g. magnetometry, electrical resistivity, ground penetrating radar) used to map sub-surface features (Gaffney and Gaffney 2011; Gaffney and Gater 2003). Such approaches use soil, sediment and material properties to identify anomalies, which occur in patterns and types that may indicate archaeological features. While geophysical survey may be airborne (e.g. Gallagher et al. 2016) for archaeology it is usually ground-based owing to the spatial resolution required.

Geochemical surveys involve minor intervention, usually by sampling from the topsoil. Such geochemical survey can be multi-elemental; however, the main approach used in Ireland has been phosphate analysis (e.g. Ullrich 2010, 2013). Phosphate analysis is also of particular interest in agronomic nutrient management. In recent years, there has been an increasing degree of overlap between agronomic soil survey and archaeological prospection (e.g. Hoefer et al. 2009, 2012). For instance, the UK DART Project ('Detection of Archaeological Residues using remote sensing Techniques') aimed to quantify some of the variables responsible for the appearance of archaeological sites through remote sensing (cf. Donoghue et al. 2006; Stott et al. 2015). Other projects have explored the possibility of using

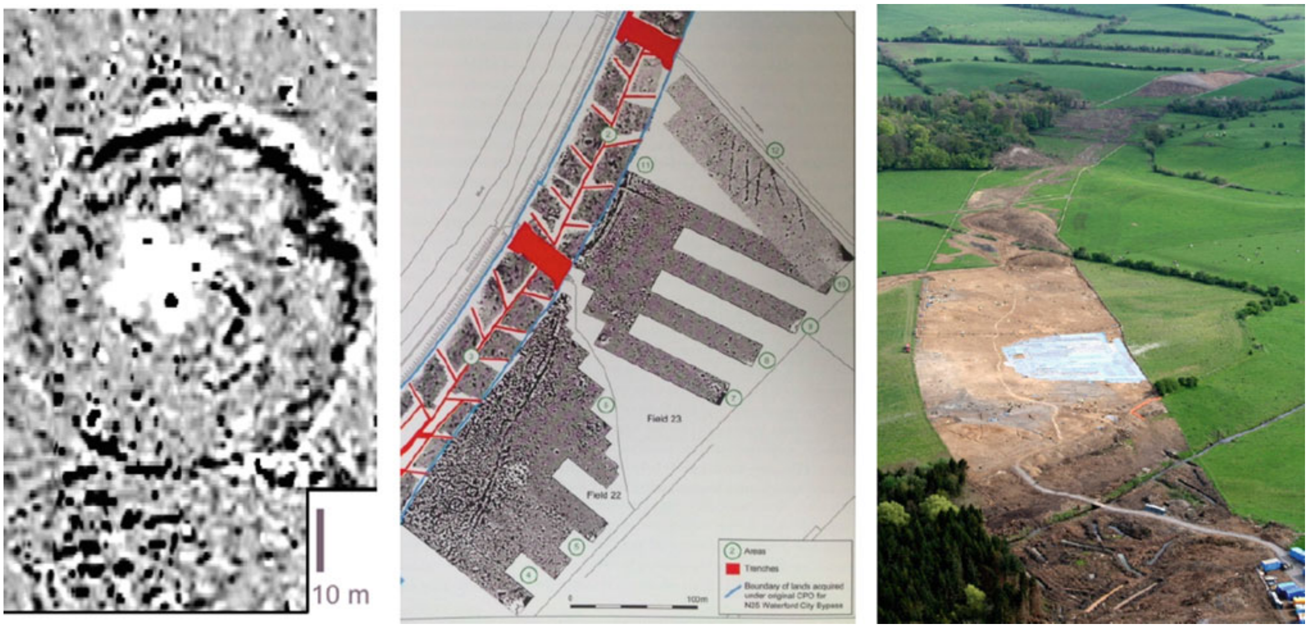


Fig. 19.3 Methods of archaeological prospection. Left: Geophysical prospection image from a fluxgate gradiometer survey of the top of Lyons Hill, Co. Dublin (Leigh 2010). Variations in the signal represent fluctuations in the local magnetic field, responding to soil materials such as burning and ditch fills. Centre: Test trenching at Woodstown, Co. Waterford (red) led to the discovery of an early Viking-Age settlement. Subsequent fluxgate gradiometer survey (stippled grey areas) revealed information about the layout of the site (Russell and Hurley 2014, Fig. 3.2). Right: Site of the Lismullen henge, showing the road-take land with the discovery site covered by plastic, stripped topsoil, test trenches, and also revealing subsoil colours with increasing organic-matter content from light to dark. Image Muireann NíBhrolcháin

multispectral satellite remote sensing data to identify archaeological features in grasslands as a function of vegetation health (Bennett et al. 2013), by employing methods derived from forestry applications (e.g. Tewari et al. 2003; Tuominen 2009). The use of hyperspectral imaging, especially in tandem with increasingly advanced UAV (Unmanned Airborne Vehicles, or 'drones') technology is likely to be significant in the future of precision agriculture, with the data also having significant and as yet untapped archaeological value (Doneus et al. 2014).

Surveys and excavations on construction projects during Ireland's economic boom greatly increased the number of recorded sites, and expanded our knowledge of the cultural materials contained in the soil (e.g. Grogan et al. 2007; McKenzie et al. 2015; O'Connell 2013; Russell and Hurley 2014). Even systematic investigation does not, however, always capture all sites. For instance, in Ireland it is standard practice to excavate trial pits and test-trenches, but pre-construction environmental assessment does not regularly include topsoil sieving or fieldwalking, and monitoring of topsoil stripping is variable. It is likely that many artefacts once held in the topsoil have been lost to the record because of this, despite otherwise rigorous assessment processes (Fig. 19.3).

Case Study 19.1 Farming Landscapes Through Time—Examples from County Meath

The Archaeological Ensemble of the Bend in the Boyne, more widely known as the Brú na Bóinne World Heritage Site (WHS), is one of only two UNESCO archaeological WHS in Ireland. It was inscribed in 1991 owing to the scale and extent of its passage tomb cemeteries, its long history of settlement and burial, and its exceptional megalithic art. Brú na Bóinne occupies c. 3331 ha, divided into a core area of 770 ha, with buffer zones to the north (798 ha) and south (1763 ha) (UNESCO 1993). Brú na Bóinne is known worldwide for its Neolithic monuments, in particular its concentration of more than 41 passage tombs dating to the Middle Neolithic (c. 3600–3100 BC), including the 'megatombs' of Knowth, Dowth and Newgrange, marking the pinnacle of the passage tomb tradition in Ireland (Eogan and Doyle 2010). The area is also agriculturally rich, with Meath having the second highest proportion of dry, lowland mineral soils in Ireland (Lee 1974, 152–3) and one of the lowest proportions of 'marginal' land (<20%—ibid., 154). Modern land use is predominantly pastoral, with only 41 ha of the core area under arable agriculture (Lydon and Smyth 2014). However, agriculture in Brú na Bóinne is of much greater antiquity, extending back to the early Neolithic (c. 4000–3600 BC), associated with the construction of large rectangular houses, the remains of which underlie the great tomb of Knowth (cf. Smyth 2011; Eogan and Roche 1997). The first farmers practiced arable and pastoral agriculture (McClatchie et al. 2014) and flourished for a brief time (c. 3700–3600 BC) (McSparron 2008). It has been suggested that this early Neolithic 'boom' was followed by a middle Neolithic 'bust', with a decrease in agricultural activity and a change in domestic architecture to less substantial structures (Whitehouse et al. 2014). However, this argument should be balanced against the enormous increase in monument construction at this time (Smyth 2014).

In the late Neolithic (c. 3100–2500 BC), the focus moved away from tombs towards the building of large ritual spaces, possibly for seasonal gatherings. Brú na Bóinne continued to be a major focus of monument construction, incorporating a high density of monuments, including at least seven embanked enclosures and four post-circles (Stout 1991). Evidence for later prehistoric activity within the area is scant. The Bronze Age (c. 2500–500 BC) has been interpreted as a time of reduced monument construction within Brú na Bóinne, although in the early part of this period significant settlement activity has been identified (Mount 1994; O'Kelly et al. 1981). Iron Age (c. 500 BC to AD 400) activity is less elusive, with burials at Knowth (McGarry 2012) and suggestions of Iron Age activity at Newgrange (Ó Néill 2013).

Besides the surveys and excavations in the area, there has been a little work on using soils and sediments to better understand the prehistoric landscape of the area. For instance, preliminary studies of the geomorphology and environmental records of the region have revealed a post-glacial landscape history that fits with a regional model of Neolithic landscape clearance, and have suggested potential relationships between monument siting and aspects of the river system (such as one round barrow possibly having been built on an island at Newgrange—Foster and Turner 2009). A recent soil micromorphology study of soils at Knowth (Ostericher 2014; Ostericher and Lewis, in press) has developed a model of land use and monument construction at the site, and explored issues of soil change over time. Despite the demonstrated strengths of soil micromorphology for interpretation of earthen monuments and archaeological landscapes (e.g. Courty et al. 1989; French 2003; French et al. 2005, 2007; Goldberg and Macphail 2006; Macphail 2007), the approach has been applied only rarely at Irish sites (e.g. Ellis 2002; Lewis 2003; Verrill 2006; Verrill and Tipping 2010).

At Knowth the buried soil showed a history of stable vegetation, probably Mesolithic forest, which was disturbed locally, probably related to pre-monument settlement activity (e.g. Eogan and Roche 1997), and monument construction (Ostericher 2014). Variations in turves used to build the monument showed wetter grassland soils as well as tilled soils, reflecting local land use at the time of the monument's construction. Evidence of scarping and turf stripping were found in the soil profiles, while pre-passage tomb surfaces and use of space were also discussed (Ostericher 2014; Ostericher and Lewis, in press). The findings augment our understanding of the site and its landscape history, demonstrating the value of advanced analytical soil approaches for archaeological interpretation in Ireland.

In the Early Medieval period (c. AD 400–1000) a number of large, complex sites are known at Brú na Bóinne. These include at least five multivallate (more than one rampart) enclosures, likely to have been of high status and potentially under the control of Knowth, the seat of kings of Northern Brega from the 7–10th centuries AD (Swift 2008; Mac Shamhráin 2004). While there is little direct evidence for agricultural practice in Brú na Bóinne at this time, studies of Early Medieval agriculture in Ireland show an intense focus on cattle, especially in the earlier part of the Early Medieval period, with cultivation of barley, oats and wheat intensifying from the 8th century AD onwards (e.g. O'Sullivan et al. 2014; McCormick et al. 2014). Field systems appear to have clustered around settlement enclosures (ringforts), but the land use in these fields has yet to be systematically investigated. Later in the medieval period, field systems with a thoroughfare and associated house structures or enclosures appear. These 'Deserted Medieval

Fig. 19.4 Left, Dowth Henge. Image Ken Williams. Right, magnetic Gradiometry Survey showing field system on the Lands of Dowth Hall. (Data courtesy of Dr. Knut Rassman and the Römisch-Germanische Kommission)

Villages' (DMVs) are widely recorded across Ireland (Glasscock 1971; O'Connor 1998; Barry 2002), with some examples recently identified by lidar survey in the Boyne Valley (e.g. Dowth; Wardstown—Davis 2011).

A Palimpsest of Farming Landscapes on the Lands of Dowth Hall

Located around 7 km east of Slane village, the lands at Dowth Hall represent one of the largest land-holdings (c. 174 ha) in the Brú na Bóinne WHS. These represent a remarkably intact demesne landscape, which has retained its integrity since at least the 13th century AD, mostly under the ownership of the Netterville family (early 14th–early 19th century; Byrne et al. 2008). The land is currently under pasture, and has been home to a variety of farming landscapes from the Neolithic on. The Neolithic presence is most apparent from two small passage tombs and Dowth Henge (Site Q), located on a prominent east–west shale ridge. It is thought that most Irish henges were made by scarping the enclosed area for the construction of the earthen banks (Stout 1991), an interpretation corroborated by recent soil micromorphological study at Rath Maeve near Tara (Ostericher 2014), but Dowth Henge has both internal and external ditches, which may have provided much of the earthen material used in its bank (Fig. 19.4).

Present-day land management strategies, focused primarily on restoring the fertility of the land, have helped in the discovery of medieval farming landscapes at Dowth Hall. Systematic estate-wide soil analysis for agronomic nutrient management identified unusually high phosphate levels in three areas. Enhanced phosphate levels relative to the surrounding area can reflect past human activity, with potential cultural sources including human and animal waste, refuse, burials, and wood ash (Holliday and Gartner 2007, 301–5). Geophysical survey was subsequently carried out over the Dowth Hall phosphate anomalies (Davis 2013), leading to the identification of two concentric, multivallate enclosures (early medieval ringforts), one of which has an associated field system, and a later medieval settlement (DMV).

The DMV is located immediately south of Dowth Castle and church, and consists of a series of plots aligned either side of a natural break of slope that probably functioned as a thoroughfare. The Dowth DMV has been entirely levelled, but it persists as anomalies in soil characteristics, both physical (e.g. soil depth owing to ditch features) and chemical (e.g. variations in soil magnetic properties; variations in organic matter content). Soils of DMV sites preserve residual traces of past agricultural regimes and land management practices, which can be revealed through geophysical survey, geochemical survey, and LiDAR.

However, chronological resolution can only be provided by more invasive techniques, such as excavation or augering (Eogan 2008).

In the 18th century AD, another farming landscape emerged at Dowth Hall, which deliberately referenced both its medieval and prehistoric past. The demesne landscape surrounding the neoclassical villa of Dowth Hall incorporated features of an earlier medieval manor, including fish ponds and possibly the deer park, and referenced monuments created by prehistoric farmers, most notably Dowth Henge. The main drive has deliberately exploited the henge by skirting its edge to incorporate visible elements from the prehistoric, medieval, and 18th century landscapes. The desire to incorporate the historical narrative into later landscapes continues with the vision of the current landowners to create a living, sustainable, heritage and farming landscape, and to raise awareness of the farmers of Dowth who came before them.

19.6 Managing Soil Heritage

Managing the cultural heritage of Irish soils and sediments requires an understanding of the palimpsest-like nature of our landscape. Recognising heritage value in earth-bound materials must develop through an understanding of and engagement with people and their values in the lived landscape. One example where this has been achieved is the Burren Programme, which has established cooperation in managing cultural and biotic heritage in an Irish living agricultural landscape (Dunford 2016). Country-wide agri-environmental payment schemes (REPS, AEOS and GLAS) have aimed to protect visible archaeological monument heritage. The GLAS scheme at the time of publication pays €120 annually per monument in grassland, or €146 in tillage, for one to twenty monuments under the heading "protection and maintenance of monuments". Since eligible monuments must be "visible in the opinion of the [agricultural] advisor", no soil-bound or ploughed monuments are recognised or protected from cultivation, scrub removal, grazing pressure or other disturbances during agriculture (DAFM 2015) (Fig. 19.5).

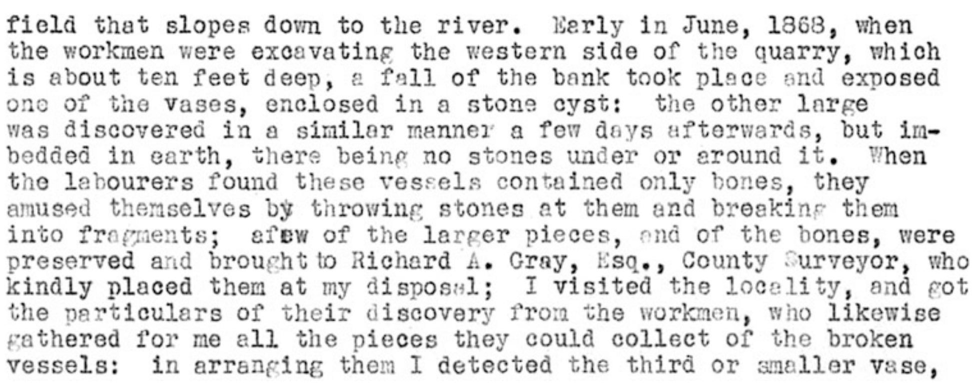
Land managers involved in farming, forestry, recreation and ecosystem services should be aware of the need to identify and protect upstanding monuments, and their obligations under the relevant statutory legislation. Between the known monuments, and throughout the soil profile, there are discontinuous phases of small features, dispersed artefacts, and undiscovered monuments, from a landscape of continuous occupation. In Ireland, the National Monuments Acts 1930–2004 clearly protect all artefacts, ecofacts, soils, sediments and constructions of archaeological significance, and land managers are required to be aware of this legislation. However, there are major gaps in protection. For instance soil disturbance is not controlled where it is related to agricultural activity outside designated protected zones. In such areas, field-walking programmes could be important.

One of the goals of archaeological heritage management is to preserve the archaeological record in situ. This is difficult in the face of changing climate and land use practices, and particularly where drainage and tillage regimes are altered. Soil environments change naturally over time, and it is not possible to preserve soil and sediment contexts as they were when they were first deposited. However, we can endeavour to prevent major changes that would lead to accelerated decay and loss. It is known that building construction, quarrying, mining, and road development will greatly change nearby soil conditions, especially drainage, resulting in increased decay of many types of archaeological objects and deposits (e.g. French et al. 1999; French 2004). It is also known that continued practices, some traditional, can lead to accelerated erosion and loss of the archaeological record. For instance, repeated ploughing leads to increased erosion and destruction of buried archaeology by deflation and impact of soil disturbing implements. Where assessment suggests degradation, many approaches to conservation can be proposed. One approach to retaining waterlogged conditions, where desired, is to prevent lateral drainage by using impermeable rigid sheeting inserted vertically around a site, leaving a wet island inside. This has been done at Corlea, Co. Offaly, where an 80 m stretch of a 1 km Iron Age trackway has been preserved for a length of 80 m. Timber from the remaining 920 m of known trackway was destroyed during peat extraction and presumably continues to degrade elsewhere in drained sections of the bog where the water table fluctuates.

Monitoring using geochemical sensing, as well as repeated sampling of biotic remains, has been the basis of management in many locations (e.g. PARIS1–5), and preservation in situ can offer visitors the possibility to connect with a site in ways that are not provided by dislocated museum exhibits. Dublin's Viking city is at least partly preserved by record (Wallace 2016), while parts of the Viking city of York in England are preserved in situ. Current work on a Roman boat preserved under Guy's Hospital in London, UK, demonstrates the state of the art (Van Walt 2016), with monitoring of redox potential and other parameters for five to eight years, and access kept open, to be followed by a backup plan of excavation and preservation by record if the materials deteriorate.

One of the most important ways of protecting our soil heritage is through education. From an early age, people should be made aware of the potential of soil as an

Fig. 19.5 Fieldwalking to look systematically for artefacts turned up by cultivation at Tlachtga, Hill of Ward, Co. Meath, 2015. This method, with plotting of individual artefact locations, can be used to characterize the spatial arrangement of dispersed artefacts in topsoil. It may indicate hot-spots for further investigation, but also reveal subtler distributions that reflect wider processes in the ancient cultural landscape. Image Katherine McCormack



field that slopes down to the river. Early in June, 1868, when the workmen were excavating the western side of the quarry, which is about ten feet deep, a fall of the bank took place and exposed one of the vases, enclosed in a stone cyst: the other large was discovered in a similar manner a few days afterwards, but im-bedded in earth, there being no stones under or around it. When the labourers found these vessels contained only bones, they amused themselves by throwing stones at them and breaking them into fragments; afew of the larger pieces, and of the bones, were preserved and brought to Richard A. Gray, Esq., County Surveyor, who kindly placed them at my disposal; I visited the locality, and got the particulars of their discovery from the workmen, who likewise gathered for me all the pieces they could collect of the broken vessels: in arranging them I detected the third or smaller vase,

Fig. 19.6 Extract from a file of the National Museum of Ireland relating the account of discovery of a Bronze-Age cist with ceramic vessel containing human bone material, during quarry operations at Palmerstown in west Dublin. It is important that everyone understands about soil-bound archaeological heritage, since it may turn up unexpectedly, as recorded here

archaeological and environmental store of heritage information, and have a sense that 'strange' objects found in the ground can potentially be important (Fig. 19.6). In the nineteenth century, soil heritage consisted of treasure in most people's minds; in the twentieth, cultural materials and stratigraphic sequences became generally understood; now we are increasingly recognising the landscape and post-deposition processes too.

References

Barker G (1985) Prehistoric farming in Europe. Cambridge University Press, Cambridge

Bennett R, Welham K, Hill RA, Ford A (2013) Airborne spectral imagery for archaeological prospection in grassland environments—an evaluation of performance. Antiquity 87:220–236

Bermingham N, Moore C (2015) The Drumclay crannog-dwellers: revealing 1000 years of lakeside living. Current Archaeol 299:30–37

Bermingham N, Delaney M (2006) The bog body from Tumbeagh. Wordwell, Bray
Brade-Birks SG (1951) Addendum. In: O'Kelly MJ (ed) (1951) Some soil problems in archaeological excavation. J Cork Hist Archaeol Soc LVI: 40–42
Byrne FJ, Jenkins W, Kenny G, Swift C (2008) Excavations at Knowth, vol 4: Historical Knowth and its hinterland. Royal Irish Academy, Dublin
Case HJ, Dimbleby GW, Mitchell GF, Morrison MES, Proudfoot VB (1969) Land use in Goodland Townland, Co Antrim, from Neolithic times until today. J R Soc Antiqu Irel 99:39–53
Caulfield S, O'Donnell RG, Mitchell PI (1998) 14C dating of a Neolithic field system at Céide Fields, County Mayo, Ireland. Radiocarbon 40(2):629–640
Clayton B (1973–4) Palaeoecological investigations at Crossnacreevy, Co. Down. Ulst J Archaeol 36/37:42–51
Collins JF (2008) Quickening the Earth: soil minding and mending in Ireland. UCD School of Biology and Environmental Science, Dublin
Common RH (1940) The blue layer. In: Herring IJ, May AmcL, Cloghnagalla Cairn, Boviel, Co Londonderry. Ulst J Archaeol 3rd Ser I:48–49 http://www.jstor.org/stable/20627310
Cornwall IW (1958) Soils for the archaeologist. London
Courty M-A, Goldberg P, Macphail RI (1989) Soils and micromorphology in archaeology. Cambridge University Press
Creamer R, Simo I, Reidy B, Carvalho J, Fealy R, Hallett S, Jones R, Holden A, Holden N, Hannam J, Massey P, Mayr T, McDonald E, O'Rourke S, Sills P, Truckell I, Zawadzka J, Schulte R (2014) Irish soil information systems: integrated synthesis report. Environmental Protection Agency, Wexford. http://erc.epa.ie/safer/resource?id=1bfe6109-3b92-11e4-b233-005056ae0019, with survey mapping at http://soils.teagasc.ie/
Crutchley S (2010) The light fantastic. Using airborne lidar in archaeological survey. Historic England
Cunningham D, Farrell EP, Collins JF (1999) Soil responses to land-use change ± a study in south-west Ireland. For Ecol Manag 119:63–76
DAFM (2015) Green, Low-carbon, Agri-environment Scheme (GLAS) Specification for Tranche 2 Participants 31st December 2015. Department of Agriculture Food and the Marine. Available at http://agriculture.gov.ie/farmerschemespayments/glas/glastranche2/, accessed 11 Sept 2016
Davis S (2011) The unseen Hill of Ward: new insights from LIDAR data. Archaeol Irel 25(4): 36–40. http://www.jstor.org.ucd.idm.oclc.org/stable/41550248
Davis S (2013) New geophysical surveys at Dowth Henge, Brú na Bóinne. PAST Newsl Prehist Soc 75:2–3. http://www.prehistoricsociety.org/files/PAST_75_for_website.pdf
Davis S, Lewis H, Turner J, Foster G, O'Donnell L, Collins B, McClatchie M, Allen MJ, McCormick F (in press) Environmental evidence from Knowth and its landscape setting. In: Eogan G, Cleary K (eds) Excavations at Knowth, vol 6. Royal Irish Academy, Dublin
Dimbleby GW (1965) Post-glacial changes in soil profiles. Proc R Soc B(161):355–362
DoAHGI (1999) Framework and Principles for the Protection of the Archaeological Heritage. Department of Arts, Heritage, Gaeltacht and the Islands. Dublin: the Stationery Office
Doneus M, Verhoeven G, Atzberger C, Wess M, Rus M (2014) New ways to extract archaeological information from hyperspectral pixels. J Archaeol Sci 52:84–96
Donoghue DNM, Beck AR, Galiatsatos N, McManus KB, Philip G (2006) The use of remote sensing data for visualising and interpreting archaeological landscapes. In: Baltsavias E, Gruen A, van Gool L, Pateraki M (eds) Recording, modeling and visualization of cultural landscape. Taylor & Francis, London, UK
Dowd M, Carden RF (2016) First evidence of a Late Upper Palaeolithic human presence in Ireland. Quat Sci Rev 139:158–163. https://doi.org/10.1016/j.quascirev.2016.02.029
Drew DP (1983) Accelerated soil erosion in a karst area: the Burren, western Ireland. J Hydrol 61:113–124
Dunford B (2016) The Burren Life Programme (BLP) 2016 Progress Report. Burren Life Programme, Carran. http://www.burrenprogramme.com/wp-content/uploads/2015/12/Burren-Life-Progress-Report-2016.pdf
Edwards KJ, Whittington G (2001) Lake sediments, erosion and landscape change during the Holocene in Britain and Ireland. CATENA 42:143–173
Ellis C (2002) Ráith na Ríg, Tara: soil micromorphological and bulk sample analysis. Discovery Programme Reports: 6. Royal Irish Academy/Discovery Programme, Dublin, 127–165
Eogan G (2008) Excavations at Knowth 4. Royal Irish Academy, Dublin
Eogan G, Roche H (1997) Excavations at Knowth 2. Dublin, Royal Irish Academy
Eogan G, Doyle P (2010) Guide to the Passage Tombs at Brú na Bóinne. Wordwell, Bray
Fédoroff N, Courty MA (1987) Paléosols. In: Miskowsky J-C (ed) Géologie de la préhistoire. Masson, Paris, pp 251–280
Foster G, Turner J (2009) The fluvial geomorphology of the lower Boyne valley. In: Lewis H, Gallagher C, Davis S, Turner J, Foster G, Courtney L, Goucher K, Scaife R, Langdon C, Holmes N, Mulroony G, Allen MJ, Brady C, Guinan L, Brown A, Cummins T, Meehan R (eds) An integrated, comprehensive GIS model of landscape evolution and land use history in the River Boyne vally. Phase II report 2009, Appendix XII. Published online at: http://www.heritagecouncil.ie/fileadmin/user_upload/INSTAR_Database/GIS_Landscape_and_Landuse_History_in_Boyne_River_Valley_Progress_Report_09.pdf
Fredengren C, Kilfeather, Stuijts I (2010) Lough Kinale: studies of an Irish lake (The Discovery Programme Lake Settlement Project: Discovery Programme Monograph No. 8). Wordwell, Bray
French C (2003) Geoarchaeology in action: studies in soil micromorphology and landscape evolution. Routledge, London
French C (2004) Hydrological monitoring of an alluviated landscape in the lower Great Ouse valley at Over, Cambridgeshire: results of the gravel extraction phase. Environ Archaeol 9:1–12
French C, Davis M, Heathcote J (1999) Hydrological monitoring of an alluviated landscape in the lower Great Ouse valley, Cambridgeshire: interim results of the first three years. Environ Archaeol 4:41–56
French C, Lewis H, Scaife R, Allen M (2005) New perspectives on Holocene landscape development in the southern English chalklands: the upper Allen valley, Cranborne Chase, Dorset. Geoarchaeol Int J 20(2):109–134
French C, Lewis H, Allen MJ, Green M, Scaife R, Gardiner J (2007) Prehistoric landscape development and human impact in the upper Allen valley, Cranborne Chase, Dorset. McDonald Institute for Archaeological Research, Cambridge
Gaffney C, Gaffney V, (2011). Through an imperfect filter: geophysical techniques and the management of archaeological heritage. In D Cowley (ed.) Remote sensing for archaeological heritage management in the 21st century. Europae Archaeologiae Consilium. 117–128
Gaffney CF, Gater JA (2003) Revealing the Buried Past: geophysics for archaeologists. Tempus, Stroud
Gallagher V, Knights K, Carey S, Glennon M, Scanlon R, (2016) Topsoil Ebook—Atlas of Topsoil Geochemistry of the Northern Counties of Ireland Data from the Tellus and Tellus Border Project. Geological

Survey of Ireland, 2016. https://jetstream.gsi.ie/iwdds/delivery/GSI_Transfer/Tellus/EBook_Topsoils_Final_03Feb2016.pdf
Gillis J (2012) The methodology used for dewatering the vellum from the Faddan More Psalter. J Inst Conserv 35(2):137–151. https://doi.org/10.1080/19455224.2012.744678
Goldberg P, MacPhail RI (2006) Practical and theoretical geoarchaeology. Blackwell, Oxford
Gowen M, Ó Néill J, Philips m (eds) (2005) The Lisheen Mine archaeological project 1996—8. Wordwell, Bray, p 5
Grogan E, O'Donnell L, Johnston P (2007) The Bronze Age landscapes of the Pipeline to the West: an integrated archaeological and environmental assessment. Dublin, Wordwell
Hammond RF (1981) The Peatlands of Ireland. An Foras Taluntais, Dublin
Hoefer G, Lueck E, Ruehlmann J, Gundelach V Bachmann J (2012) Comparison of non-destructive geophysical methods to predict the heterogeneity of subsoil compaction. In: 2nd international conference on hydropedology, Leipzig 22–27 July 2012
Hoefer G, Gundelach V, Ruehlmann J, Bachmann J (2009) The capability of non-destructive geophysical methods in precision agriculture to capture subsoil mechanical strength. In: Precision agriculture '09, 7th European conference on precision agriculture, Wageningan, 6–8 July 2009
Holliday VT, Gartner WG (2007) Methods of soil P analysis in archaeology. J Archaeol Sci 34:301–333
Huang CC, O'Connell M (2000) Recent land-use and soil erosion history within a small catchment in Connemara, western Ireland: evidence from lake sediments and documentary sources. CATENA 41:293–335
Jessen K (1949) Studies in the Late Quaternary deposits and flora-history of Ireland. Proc R Irish Acad 52B:85–290
Leigh J (2010) Lyons Hill County Kildare Licence No. 10-R-119 15/10/2010, Client: Kill History Group. J.M. Leigh Surveys, unpublished
Jenny H (1941) Factors of soil formation. Soil Sci 52(5):415
Johnson DL (2002) Darwin would be proud: bioturbation, dynamic denudation, and the power of theory in science. Geoarchaeology 17 (1):7–40
Jongerius A (1983) The role of micromorphology in agricultural research. In: Bullock P, Murphy CP (eds) Soil micromorphology, volume 1: techniques and application. In: Proceedings of the 6th international working meeting on soil micromorphology, London 1981, 111–38. AB Academic Publishers, Berkhamsted
Keeley HCM, Macphail RI (1981) A soil handbook for archaeologists. Bulletin No. 18, 225–241. Institute of Archaeology, London
Kelly EP (2013) An archaeological interpretation of Irish Iron Age bog bodies. Archaeol Violence Interdiscip Approaches 2:232
Knudson KJ, O'Donnabhain B, Carver C, Cleland R, Price TD (2012) Migration and Viking Dublin: paleomobility and paleodiet through isotopic analyses. J Archaeol Sci 39:308–320. https://doi.org/10.1016/j.jas.2011.09.014
Lee J (1974) An analysis of land potential for grazing in Ireland with particular reference to farm size relationships. J Stat Soc Inq Soc Ireland 23:149-182
Lewis H (1998) The characterisation and interpretation of ancient tillage practices through soil micromorphology: a methodological study. Unpublished Ph.D. thesis, University of Cambridge
Lewis H (2003) Soil micromorphology and geoarchaeology at Parknabinnia Court Tomb (Clare Megalith 153), Co. Clare, Ireland. Unpublished manuscript. Available at: http://hdl.handle.net/10197/4533
Lomas-Clarke SH, Barber KE (2004) Palaeoecology of human impact during the historic period: palynology and geochemistry of a peat deposit at Abbeyknockmoy, Co., Galway, Ireland. The Holocene 14 (5):721–731
Lydon K, Smith G (2014) CORINE landcover 2012 Ireland final report. Environ Prot Agen. Available from http://www.epa.ie/pubs/data/corinedata/CLC2012_IE_Final_Report.pdf
Macphail RI (1986) Paleosols in archaeology: their role in understanding Flandrian pedogenesis. In: Wright VP (ed) Paleosols: their recognition and interpretation. Blackwell, Oxford
Macphail RI, Robertson L (1989) The application of micromorphology to the understanding of Holocene soil development in the British Isles; with special reference to early cultivation. In: Federoff N, Bresson, LM, Courty MA (eds) Soil micromorphology: INRA, pp 647–656
Macphail RI (2007) A Pre-Barrow Thin Section. In: Benson D, Whittle A (eds) Building memories: The Neolithic Cotswold Long Barrow at Ascott-under-Wychwood, Oxfordshire. Oxbow, Oxford
Macphail RI (1990) Soil micromorphological evidence of the impact of ancient agriculture. In: 14th international congress of soil science transactions, vol 7. International Society of Soil Science, Kyoto, pp 264–69
Mac Shamhráin A (2004) The island of St Patrick: church and ruling dynasties in fingal and meath, pp 400–1148. Four Courts, Dublin
McClatchie M, Bogaard A, Colledge S, Whitehouse NJ, Schulting RJ, Barratt P, McLaughlin TR (2014) Neolithic farming in north-western Europe: archaeobotanical evidence from Ireland. J Archaeol Sci 51:206–215
McCormick F, Kerr TR, McClatchie M, O'Sullivan A (2014) Early medieval agriculture, livestock and cereal production in Ireland, AD 400–1100. British archaeological reports international series 2647, Archaeopress, Oxford
McGarry T (2012) Late Iron Age burials at Knowth. In: Eogan G (ed) The archaeology of Knowth in the first and second millennia AD. Excavations at Knowth 5. Royal Irish Academy, Dublin, pp 687–693
McKenzie CJ, Murphy EM, Donnelly CJ (2015) The science of a Lost Medieval Gaelic Graveyard. The Ballyhanna research project. Transport Infrastructure Ireland, Dublin
McSparron C (2008) Have you no homes to go to? Neolithic housing. Archaeol Irel 22(3):18–21
Mitchell GF (1951) Studies in Irish Quaternary deposits: No. 7. Proc R Irish Acad 53B:111–206
Mitchell GF (1972) Soil deterioration associated with prehistoric agriculture in Ireland. In: Proceedings of the twenty fourth international geographical congress (Montreal), Symposium 1. Ottawa, Geological Survey of Canada, pp 59–69
Mitchell FJG, Stefanini BS, Marchant R (2013) A catalogue of Irish pollen diagrams. Proc R Irish Acad 113B:1–31
Moles NR, Moles RT (2002) Influence of geology, glacial processes and land use on soil composition and Quaternary landscape evolution in The Burren National Park, Ireland. Catena 47(4):291–321
Moles NR, Moles RT, O'Donovan G (1995) Evidence for the presence of Quaternary loess-derived soils in the Burren karstic area. Ir Geogr 28:48–63
Moles RT, Moles NR, Leahy JJ (1999) Radiocarbon-dated episode of Bronze Age slope instability in the southeastern Burren, County Clare. Ir Geogr 32:52–57
Moloney A, Bermingham N, Jennings D, Keane M, McDermott C, Ocarroll E (1995) Blackwater survey & excavations atrefact deterioration in Peatlands Loughmore Co. Mayo. Irish Archaeological Wetland Unit: Transactions Volume 4. Crannóg Publications, Dublin
Mount C (1994) Aspects of ritual deposition in the Late Neolithic and Beaker Periods at Newgrange, Co. Meath. Proc Prehist Soc 60: 433–443
O'Connell A (2013) Harvesting the stars. A Pagan Temple at Lismullin Co. Meath. Wordwell, Bray

O'Connell M, Molloy K (2001) Farming and woodland dynamics in Ireland during the Neolithic. Biol Environ Proc R Irish Acad 101B:98–128

O'Kelly MJ (1951) Some soil problems in archaeological excavation. J Cork Hist Archaeol Soc LVI 29–39:44

O'Kelly MJ, Cleary RM, Lehane D (1981) Newgrange, Co. Meath, Ireland. The Late Neolithic/Beaker period settlement. British Archaeological Reports 190, Oxford

Ó Néill J (2013) Being prehistoric in the Irish Iron Age. In: O'Sullivan M, Scarre C, Doyle M (eds) Tara—from the past to the future. Wordwell, Dublin, pp 256–266

Opitz R, Cowley D (2013) Interpreting archaeological topography. Oxbow, Oxford

Ostericher I (2014) Soil micromorphology of Rath Maeve and Knowth: landscape and monumentality in prehistoric Ireland. Unpublished MA Thesis, University College Dublin

Ostericher I, Lewis H (in press) Chapter 8. Soil micromorphology of Knowth. In: Eogan G, Cleary K (eds) Excavations at Knowth, vol 6. Royal Irish Academy, Dublin

O'Sullivan A, Sheehan J (1996) The Iveragh Peninsula: an archaeological survey of South Kerry. Cork University Press, Cork

O'Sullivan A, McCormick F, Kerr TR, Harney L, Kinsella J (2014) Early medieval dwellings and settlements in Ireland, AD 400–1100. British archaeological reports international series 2604, Archaeopress, Oxford

O'Sullivan A, Warren G, McDermott C, Lyne E (2009) Archaeological excavations of a medieval church and graveyard at Templeteenaun Ballinagee townland, Co. Wicklow 2004–2008, UCD School of Archaeology, University College Dublin

PARIS1–5, conferences on Preserving Archaeological Remains in Situ, held in 1996, 2001 (Museum of London Archaeology Service), 2006 (VU of Amsterdam, 2008), 2011 (Conservation and Management of Archaeological Sites, 2012 vol 14(1–4)), and 2015 (Conservation and Management of Archaeological Sites, 2016 vol 8(1–3)

Proudfoot B (1960) Appendix I: Report on soils and stratigraphy at Castle Skreen. In: Dickinson CW, Waterman DM, Proudfoot B, Mitchell GF Excavations at Castle Screen, Co. Down, Ulst J Archaeol 23:63–77

Proudfoot B, Simmons IG (1958) Appendix 3. Soil report. In: Waterman DM, Excavations at Ballyfounder Rath, Co.Down. Ulst J Archaeol 21:54–61

Raftery B (1996) Trackway excavations in the Mountdillon Bogs, Co. Longford. Irish Archaeological Wetland Unit Transactions 3. Dublin. Crannóg Publications

Revel JC (1991) Pédologie et archéologie. In: Guilaine J (ed) Pour une archéologie agraire. Armand Colin, Paris, pp 323–343

Russell I, Hurley MF (2014) Woodstown a Viking-Age settlement in Co. Waterford. Four Courts Press, Dublin

Roberts N (2014) The Holocene. Blackwell

Rogers T, Fibiger L, Lynch LG, Moore M (2006) Two glimples of nineteenth-century burial practice in Ireland: a report on the excavation of burials from Manorhamilton Workhouse, Co. Leitrim, and St. Brigid's Hospital, Ballinasloe, Co. Galway. J Ir Archaeol 15:93–104. http://www.jstor.org/stable/20650852

Romans JCC, Robertson L (1983) The general effects of early agriculture on the soil profile. In: Maxwell GS (ed) The impact of aerial reconnaissance on archaeology. Council for British Archaeology research report No. 49. Council for British Archaeology, London, pp 136–41

Smith AG (1961) Cannons Lough, Kilrea, Co., Derry: stratigraphy and pollen analysis. Proc R Ir Acad 61B:369–383

Smyth J (2011) The house and group identity in the Irish Neolithic. Proc R Irish Acad 111C:1–31

Smyth J (2014). Settlement in the Irish neolithic: new discoveries at the edge of Europe. Oxbow Books

Stott D, Boyd DS, Beck A, Cohn AG (2015) Airborne LiDAR for the detection of archaeological vegetation marks using biomass as a proxy. Remote Sens 7(2):1594–1618. https://doi.org/10.3390/rs70201594

Stout G (1991) Embanked enclosures of the Boyne region. Proc R Irish Acad 91C:245–284

Swift C (2008) The early history of Knowth. In: Byrne FJ, Jenkins W, Kenny G, Swift C, Excavations at Knowth: historical Knowth and its Hinterland, vol. 4. Royal Irish Academy, Dublin, pp 5–42

Tewari S, Kulhavý J, Rock BN, Hadaš P (2003) Remote monitoring of forest response to changed soil moisture regime due to river regulation. J For Sci 49:429–438

Thompson AD (1997) A lake sediment record of late glacial and Holocene environmental change from Molly's Lough, Co. Clare, Ireland. Ph.D. thesis, University of Wales, Aberystwyth

Thorp M, Glanville P (2003) Mid-Holocene sub-blanket-peat alluvia and sediment sources in the upper Liffey valley, Co., Wicklow, Ireland. Earth Surf Proc Land 28(9):1013–1024. https://doi.org/10.1002/esp.517

Tuominen J, Lipping T, Kuosmanen V, Haapanen R (2009) Remote sensing of forest health. In Ho PGP (ed.) Geoscience and remote sensing. InTech, Rijeka

Turner JN, Holmes N, Davis SR, Leng MJ, Langdon C, Scaife RG (2015) A multiproxy (micro-XRF, pollen, chironomid and stable isotope) lake sediment record for the Lateglacial to Holocene transition from Thomastown Bog, Ireland. J Quaternary Sci 30 (6):514–528. https://doi.org/10.1002/jqs.2796

Ullrich JM (2010) Geochemical contributions to the archaeological examination of promontory forts: the use of phosphate analysis techniques on Achillbeg and Achill Islands, Co. Mayo. Ph.D. Thesis, School of Archaeology, University College Dublin

Ullrich JM (2013) Assessing interior and exterior divisions of space using phosphate analysis spot test methods. Assem Sheff Grad J Archaeol 12:43–56. http://www.assemblage.group.shef.ac.uk/journal/issue-12

UNESCO (1993) Brú na Bóinne—Archaeological ensemble of the bend of the Boyne. Inscriptions on the World Heritage List, 17th session of the Committee Decision code CONF 002 XI. http://whc.unesco.org/en/decisions/3335

Van Walt (2016) Roman boat at Guy's Hospital. Van Walt Environmental Connect. http://www.vanwalt.com/blog/2016/05/van-walt-putting-your-name-in-lights-saving-your-money/

Verrill L (2006) Later prehistoric environmental marginality in Western Ireland: Multi-proxy investigations. Unpublished Ph.D. thesis, University of Edinburgh

Verrill L, Tipping R (2010) A palynological and geoarchaeological investigation into Bronze Age farming at Belderg Beg, Co., Mayo, Ireland. J Archaeol Sci 37(6):1214–1225

Wallace P (2016) Viking Dublin. The wood quay excavations. Irish Academic Press Limited

Warren G (2008) Fieldwork in Belderrig, Co. Mayo 2004–2008 04E0893. UCD School of Archaeology. http://hdl.handle.net/10197/3524

Weir AH, Catt JA, Madgett PA (1971) Postglacial soil formation in the loess of Pegwell Bay, Kent, England. Geoderma 5:131–149

Whitehouse NJ, Schulting RJ, McClatchie M, Barratt P, McLaughlin TR, Bogaard A, Marchant R, Gaffrey J, Bunting MJ (2014) Neolithic agriculture on the European western frontier: the boom and bust of early farming in Ireland. J Archaeol Sci 51:181–205