Cattle in Ancient and Modern Ireland

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Farming Practices, Environment and Economy

Edited by
Michael O'Connell, Fergus Kelly
and James H. McAdam

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“In early times [in Ireland] wealth is not spoken of in terms of money, which was not in circulation, nor of ownership of land, but primarily in terms of livestock and chiefly of cows”

—From *Cattle in ancient Ireland* by A.T. Lucas (1989), p 223

“est scientia pecoris parandi ac pascendi, ut fructus quam possint maximi capiantur ex eo, a quibus ipsa pecunia nominata est; nam omnis pecuniae pecus fundamentum”

“there is a science of assembling and feeding cattle in such fashion as to secure the greatest returns from them; the very word for money is derived from them, for cattle are the basis of all wealth”

—From *De re rustica* by the Roman writer Marcus Terentius Varro (116–27 BC).
Published in the Loeb Classical Library, 1934; available online (original and translation) at:
http://penelope.uchicago.edu/Thayer/E/Roman/Texts/Varro/de_Re_Rustica/

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PREFACE AND ACKNOWLEDGEMENTS

The Agricultural History Society of Ireland (www.ahsi.ie) usually aims to hold its main annual conference at a location appropriate to the theme of the particular conference. In 2014 the conference title was *Cattle in Ireland: beef, bulls, butchers and biodiversity*. Given that title, suitable locations on the island of Ireland were many and diverse. Mullingar, in Co. Westmeath—the saying "beef to the heels like a Mullingar heifer" comes to mind; also that well-known chief executive of Ryanair and also cattle breeder, Michael O'Leary, who farms near Mullingar—was certainly high in the list. Equally, a location in the Golden Vale, which includes much of the fertile farmlands in the province of Munster, or possibly West Cork, e.g. Bandon where the former shambles still serves to define part of the townscape, or Armagh given its strong association with the *Táin bó Cuailnge*/The cattle-raid of Cooley and nearby *Eamhain Mhacha*/Navan Fort, were all distinct possibilities. Instead, the heritage town of Birr, Co. Offaly was chosen for reasons that will become obvious later.

For the overall conference theme thanks are due to Dr Helen Sheridan, an AHSI committee member who submitted the proverbial one-page document towards the end of 2013 in which she succinctly outlined her ideas for the conference as follows [the statistics relate to the Republic of Ireland]:

> Beef production is one of Ireland's most important indigenous industries. Specialist beef production is currently the dominant type of farming in Ireland, accounting for more than half of farm enterprises (current data show that ca. 100 000 farms have a beef enterprise). This sector of agriculture accounts for 30% of gross agricultural output. The national suckler herd is the major strength of the industry and ca. 50% of Irish beef is derived from our dedicated beef suckler herds.
>
> Given these figures, I believe that a conference dedicated to beef would have the potential to attract a lot of interest. Approximately 60% of the specialist beef production farms are located in the Border, Midland and Western region (so-called BMW region) of Ireland. The Midlands might be an appropriate location for the conference.

Concrete suggestions for topics that might be explored were proffered as follows:

> l) Grasslands, i.e. we currently have almost singular reliance on perennial ryegrass for reseeding grasslands. I think it might be really interesting to have a presentation that focuses on species that would have been present in grasslands in the past.
>
> 2) Animal breeds and how these have changed, i.e. which breeds were used in the past and the positive / negative attributes of these breeds?
>
> 3) Animal health and welfare, i.e. how did farmers address animal health issues prior to the widespread availability of pharmaceutical chemicals to treat various diseases?

For me, as the newly chosen AHSI Chairperson, these suggestions were literally a godsend in that they were both apposite and timely and, from a personal viewpoint, the ideas pandered to my general environmental interests and also coincided, at least broadly, with my specific interests in past environments and especially long-term farming impacts on vegetation and the environment generally. But, here and now, I admit to having no particular expertise in cattle!

A subcommittee, that included Professor F. Kelly, Dr H. Sheridan, Dr I. Stuijts and myself, was established with a view to planning the conference programme. Birr was chosen not so much for its location and connection with cattle but rather for its rich cultural heritage—including a second-to-none scientific heritage associated with Birr Castle and its owners the Parsons, the present owner being the Seventh Earl of Rosse. The wider countryside also has much to offer by way of natural and built heritage, including the important medieval monastic site at Clonmacnoise, the extensive callow systems (wet, winter-flooded grasslands) at Clonmacnoise and in the mid-Shannon region generally, and also dry, species-rich grasslands of the esker ridges—of last glaciation (Midlandian/Weichselian) age—and which, together with the many raised bogs, serve largely to define the landscape at both local and regional levels.

Saturday 15th June was devoted to lectures by Irish experts on a variety of topics relating to cattle in Ireland from earliest to recent times. A poster session gave updates on on-going research projects by British and Irish researchers (for details of these and other aspects see http://www.ahsi.ie/p/past-conferences.html; see Fig. 0-1 for a group photograph of participants). The friendly and efficient service provided by the staff of the County Arms Hotel, Birr, where the conference was based, is gratefully acknowledged.

For the full-day excursion on the Sunday, we were fortunate to have the services of several locally and internationally-recognised experts, including Dr John Feehan whose publications include *The bogs of Ireland* (1996; with G. O'Donovan) and *Farming in Ireland* (2003); Dr Caitriona Maher, botanist and dipteran specialist, who in her PhD

research (thesis title: *The river Shannon callows, Ireland* (2013)), investigated, *inter alia,* the hydrology and management of the callows in relation to biodiversity; and, Michael Martyn, agri-environmental consultant and specialist in ecological restoration. Local landowners who facilitated entry onto their land included (in the order of the itinerary): the Earl and Countess of Rosse who facilitated a visit to the ancient meadow on the grounds of the 'Giant Telescope' at Birr Castle, and gave us their personal insights into this unique cultural landscape and the exceptional biological system that the approximately two hundred-year-old hay meadow represents (see J. Feehan, this volume); the Moran family who gave permission to experience the species-diverse, dry-grassland esker flora and the impressive views of the Offaly countryside at Glaster, and the landowners at Clonmacnoise who facilitated inspection of the extensive wet meadows—in full flower—and pastures that constitute the callows in this exceptional, semi-natural habitat.

In an effort to further harness the enthusiasm that was so evident at Birr, it was decided that the AHSI Autumn Symposium for 2014 would also be devoted to cattle. The overall theme was *Cattle: a long-term mainstay of Irish farming and economy*. Seven lectures were presented, including a keynote lecture, *From the Táin to CAP: the importance of cattle in Ireland,* by Dr Edel Bhreathnach, Director, Discovery Programme. At this point, it is my pleasure to acknowledge, on behalf of AHSI, the long-term support provided by the Discovery Programme and the facilities for meetings, including the Autumn Symposium, made available by the Royal Society of Antiquaries of Ireland at their headquarters in Merrion Square, Dublin.

The present volume is thus the result of a conference and a symposium, both dedicated to various aspects of cattle in Ireland. During both prehistory and the historical period cattle were all-important to people living in Ireland and the Irish economy. Despite the exponential growth during recent decades in information technology and pharma and related industries and also tourism, farming and especially cattle continue to be major contributors to the economies in both Northern Ireland and the Republic of Ireland.

In this volume, while there are several references to milking and milk products, these important aspects, which are the basis of now major international brand-names such as Kerrygold, and also a substantial high-quality and rapidly expanding specialist-food industry, have not been treated in any detail. These are aspects that deserve and require further conferences and at least another specialist volume. It should, moreover, be pointed out that much of the present-day agri-business in Ireland is centred on milk, including the core activities of the AHSI sponsor, Carbery—a global leader in food ingredients, flavours and cheese (www.carbery.com).

Help received by individual authors during their research and the preparation of their contributions for this publication is acknowledged in the relevant chapters. Acknowledgement of copyright material (e.g. the poem, *A drover*, by Padraic Colum; also several illustrations and photographs) is given in the relevant text or in the detailed figure legends available at the end of each contribution.

Permission to reproduce copyright material—often given free of charge, in some instances on foot of a modest fee—is gratefully acknowledged. Online sources have been extensively consulted and used during editing, and especially the Internet Archive (archive.org), Google Books (books.google.com), Bibliothèque nationale de France (bnf.fr) and Project Gutenberg (gutenberg.org/), as well as National Library of Ireland (nli.ie) and British Library (bl.uk) online catalogues. Personal assistance received from staff in the Hardiman Library, National University of Ireland Galway (NUIG) and the National Library of Ireland is gratefully acknowledged, as are the facilities generously made available to me by the School of Geography and Archaeology, NUIG. The unstinting support of the Committee of the Agricultural History Society of Ireland is much appreciated and the valuable editorial assistance provided by Fergus Kelly and Jim McAdam at critical junctures during the editing process helped in no small way to bring this publishing project to fruition. I thank Máire for her tolerance as I indulged my interests in past times for hours on end, and for help with proofreading. Finally, the encouragement and help provided by the publishers, Cambridge Scholars Publishing, are gratefully acknowledged.

Michael O'Connell
Chairperson, Agricultural History Society of Ireland
January 2016

INTRODUCTION

This book, consisting of thirteen chapters, results from a two-day conference and a subsequent one-day symposium organised by the Agricultural History Society of Ireland in 2014. The topics for inclusion were chosen on the basis of representing ongoing and, in many instances, recently completed research into particular aspects of cattle and cattle husbandry in ancient and modern Ireland. The publication thus consists of contributions by specialists presented in a manner that makes the information accessible to a wide audience, rather than an attempt to cover all aspects and possibly not satisfactorily given the breadth of the topic. It is hoped that each contribution, in its own distinctive way will augment and complement the existing literature, including earlier landmark books such as *Cattle in ancient Ireland* (Lucas 1989; Boethius Press), *Early Irish farming* (Kelly 1997; School of Celtic Studies), *Farming in Ireland* (Feehan 2003; UCD, Faculty of Agriculture) and *A history of Irish farming 1750–1950* (Bell and Watson 2008; Four Courts Press), and recent publications such as *Early medieval agriculture, livestock and cereal production in Ireland, AD 400–1100* (McCormick et al. 2014; BAR Intern. Ser. 2647) and *Agriculture and settlement in Ireland* (Murphy and Stout (eds) 2015; Four Courts Press).

In Chapter One James Collins outlines the features of Irish geology and soils, that, in combination with Ireland's favourable climate, provide the basis for a cattle industry that traditionally has been based on grass and grazing in the open for much of the year. The history of manuring, initially using various naturally occurring resources such as sand, marl and seaweed, and of practices such as paring and burning are charted, as well as the transition to a more science-based approach that began in earnest in the Age of Enlightenment (eighteenth century) and led to the widespread use of lime and imported organic fertiliser, and ultimately chemical fertilisers.

In Chapter Two the complexities of the archaeological evidence relating to the introduction of cattle to Ireland, with particular reference to the Mesolithic/Neolithic transition, are presented and discussed by Peter Woodman. While there are still many uncertainties as to details regarding 'when, where and whence' cattle were introduced, the available archaeological evidence leaves little doubt as to the importance of cattle in the farming economy of the Irish Neolithic, the first cultural period to be characterised by farming and the use of pottery in most of Europe.

In Chapter Three the dynamic between farming and the natural environment, which prior to the start of farming consisted mainly of woodland, is reconstructed on the basis of a detailed pollen diagram from Ballinphuill Bog, Co. Galway. Karen Molloy and Michael O'Connell infer from the fossil pollen data that strong farming impacts are mainly the result of pastoral rather than arable farming. Cattle were undoubtedly of major importance in defining the vegetation cover through grazing, thereby checking tree growth and preventing natural regeneration of trees and shrubs, with the consequent expansion of grasslands. While the pollen data relate specifically to east Galway, the results are discussed in wider regional contexts, and also in relation to recently published macrofossil and pollen data from Ireland and further afield.

In Chapter Four Fergus Kelly details the rich sources of evidence available in the medieval Irish law-texts for the role of cattle in medieval Irish society and also for details of husbandry practices connected with the care and management of cattle. Interestingly, there are few references to the housing of cattle in the law-texts while, on the other hand, diseases and other disorders of cattle are well documented. The centrality of cattle in Ireland throughout most of the medieval period is demonstrated by the use of cattle as currency, a practice that persisted even after the invasion and expansion of the Normans in the late twelfth century.

The complexities and uncertainties attaching to the determination of sex ratios in cattle-bone assemblages from archaeological sites are discussed in Chapter Five by Louisa Gidney. During the course of research towards a PhD degree in the University of Durham, she chose as her comparandum for early prehistoric cattle-bone assemblages the Dexter breed, a nineteenth-century offshoot of Kerry cattle and usually, like the related Kerry cattle, regarded as similar in size to early—including Neolithic—cattle. On the basis of size measurements made on the modern-day Dexter bone samples, she suggests that osteologists studying Neolithic sites should be more cautious in their interpretations, especially as regards estimating overall size ranges of ancient cattle and also gender-ratios represented in prehistoric cattle-bone assemblages.

In Chapters Six and Seven the practice of booleying, i.e. a form of transhumance involving mainly cattle, as practised in western Ireland during recent centuries, is described. In Chapter Six, Theresa McDonald reports on her recently completed detailed research into booleying on the island of Achill and the nearby peninsula of Corraun, west Mayo. Evidence presented includes descriptions of the practice by travellers from the mid-eighteenth century onwards, documentation by map-makers (W. Bald in the early nineteenth century and, subsequently, the Ordnance Survey), and her own detailed surveys of long-abandoned booleying sites and also booleying sites that later developed into

permanent settlements. She shows that the system was characterised by considerable complexity and fluidity as it responded to various factors, including demographic and political pressures. Booleying sites were predominantly connected with cattle and especially cows, but not to the complete exclusion of other farming activities, including spring/summer cereal and potato growing.

In Chapter Seven Eugene Costello reports on his on-going investigations into booleying in Iorras Aithneach (Carna), south-west Connemara where the practice was widespread and persisted into the early twentieth century. He demonstrates that it was far from a 'free for all' but rather was highly regulated, with specific booleying sites in the upland interior being used by farm families who were permanently resident in coastal parts. It was a system that was community-based rather than imposed on the farming population by an outside authority such as the local landlord. It had many advantages, especially in that it reduced grazing-pressure near the permanent settlements during the height of the growing season and provided a balanced diet for the cattle through movement between coastal and inland habitats with their different soils, vegetation and capacities to provide the nutrients essential for animal health.

In Chapter Eight the considerable documentary evidence—including folklore and accounts by visitors from other parts of Europe—for the keeping of livestock in the same living quarters as people in early modern Ireland, is reviewed and discussed by Patricia Lysaght. The practice was common in western Ireland (from Cork to Donegal), and in a few places it survived, or at least remained in the folk-memory, until the mid-twentieth century. The architectural expression of the practice is to be found in the so-called byre-dwellings, examples of which are illustrated in the article, while actual buildings can be seen today reconstructed in open-air museums at Bunratty Folk Park, Co. Clare and the Ulster Folk and Transport Museum, Co. Down.

In Chapter Nine several insights into cattle husbandry—including herding of cattle on farms and to fairs, ownership including buying and selling of cattle, the division of labour on farms, and educational and related opportunities—are discussed from a gender perspective by Jean Walker. The analysis and conclusions are all the more interesting in that the study spans two periods that are crucial in modern Irish history; firstly, the period after the Great Famine (1845–1848) including the early twentieth century, and, secondly, the early decades of the newly established independent state that became the Republic of Ireland, i.e. the period from the 1920s onwards. It is suggested that systems and practices of the latter part of the nineteenth century, including the educational system, continued to have a major influence, at least as regards the role expected of men and women in rural life, and this extended well into the twentieth century. As in many spheres of life, there were exceptions which, however, may serve only to prove the rule.

In Chapter Ten Jonathan Bell and Meryvn Watson review the historical evidence for slaughtering cattle in Ireland during the last four centuries. A shift away from the Irish Longhorn breed towards the imported Shorthorn and the acceptance, mainly by well-to-do farmers, of the idea of pure-bred cattle with a known pedigree that occurred in the mid-nineteenth century, coincided with increased regulation and mechanisation of slaughtering. The history of the establishment of public slaughtering houses, beginning in the seventeenth century in large centres of population, to the building of shambles in many small towns, and ultimately the construction of large abattoirs in the mid and later nineteenth century is reviewed. Developments are also described that have led, in recent decades, to more or less complete abandonment of the slaughter of cattle at home or by local butchers, and the centralisation of slaughtering in a small number of large commercial slaughter houses that are governed by strict regulations and subject to regular state inspection.

In the final three chapters various aspects of grasslands, the foundation-stone of the recent and modern Irish cattle industry, are discussed. In Chapter Eleven, James McAdam traces the important role that Northern Ireland played, and continues to play, in grassland research on the local, regional (British/Irish contexts) and international stages since the 1920s. These research efforts, characterised by close involvement with the farming community, were supported directly by the Ministry of Agriculture (Northern Ireland) or indirectly through support to institutes such as the College of Food Agriculture and Rural Enterprise (CAFRE), the Agri-Food and Biosciences Institute (AFBI) and Queen's University Belfast (mainly the Department of Agricultural Botany). The major contributions by able and effective administrators and researchers such as J.S. Gordon, G.S. Robertson, P.A. Linehan and J. Lowe are detailed, and the continued relevance of results from largely forgotten but incisive research carried out in the 1950s and earlier is emphasised.

In Chapter Twelve Helen Sheridan focusses on grasses and on-going grassland research in the Republic of Ireland in the context of the project *SmartGrass*. This project takes a critical fresh look at how better to manage that all-important semi-natural resource, the grasslands of Ireland, not only in terms of productivity but also sustainability, maintenance of high biodiversity in grass swards and the attractiveness of local and regional landscapes, while at the same time providing cattle with the healthy balanced diet that species-rich grasslands can deliver.

In Chapter Thirteen John Feehan describes a living relict of the past, namely the species-rich meadow in the demesne of Birr Castle that was sown by the Third Earl of Rosse, who was also responsible for the construction of the giant telescope (the largest in the world until 1917) on the demesne grounds of the Castle in the 1840s. The author suggests that such meadows may—indeed should—once again become a dominant feature of the Irish landscape.

While the papers are presented in journal format, each presenter brings her/his own personal style that suits the subject matter. All papers have references and most have a substantial bibliography so that source material can readily be traced by future researchers. In addition, footnotes are liberally used in some of the articles that enable additional details and occasionally clarifications to be presented without unduly interrupting the text. The papers are illustrated by photographs, graphs, and 'old' illustrations from pre-photographic times, as appropriate to the subject matter. The illustrations are organised in a centrepiece and given abbreviated legends; comprehensive legends are available at the end of each article.

It is hoped that, while the contributions are from serious researchers many of whom are academics, the style, the subject matter and the many illustrations will result in the book finding favour with the interested public and ultimately reaching a wide readership within the island of Ireland and indeed further afield.

CHAPTER ONE

GEOLOGY, SOILS AND CATTLE PRODUCTION

JAMES F. COLLINS

Abstract Ireland's reputation as an agricultural country, based on grass and cattle, arises from many factors, chief of which are its bedrock geology and the soils derived therefrom and which are hence largely base-rich. Developed since the Ice Age, Ireland's young, moderately leached, biologically active soils, in combination with the equable, maritime climate, result in an environment particularly conducive to grass growing and cattle rearing. The 'love affair' of Irish society with cattle in ancient Ireland, especially with cows, has been admirably documented by several researchers and especially by A.T. Lucas. In this contribution, relationships between geology, soils and cattle production, based on documentary evidence mainly from the eighteenth and nineteenth centuries, are explored with reference to the physical resource background and changes in cattle management practices.

Keywords Soils • Soil fertility • Geology • Farming • Cattle rearing • History • Ireland

Introduction

Geology

A unique feature of the geology of Ireland is that limestone forms more than half of the bedrock, with outcrops occurring in all but one of the 32 counties that constitute the island of Ireland. This bedrock type varies from 'deep-water' limestones that are relatively high in calcium carbonate ($CaCO_3$; over 95% in places), to impure, 'shallow-water' limestones, admixed with organic-rich sediments. In places, the silica content is such that there is a gradation from 'silicious limestone' to 'calcareous shale'. Other extensive base-rich bedrocks include basalt, which occurs in parts of five Ulster counties, and Carboniferous shales in some counties. Ireland was repeatedly glaciated during the Quaternary period (Ice Ages). As the ice sheets waxed and waned, the ice sculpted, quarried and comminuted the bedrock over which it travelled and incorporated into its load fresh rock material and older soils and sediments. This material was widely deposited either unsorted as tills or, where meltwaters were involved, laid down in a sorted/stratified manner as gravels, sands, silts and clays. As well as creating material suitable for soil formation, it also resulted in the transfer of base-rich materials to areas devoid of limestone.

Soils

The most extensive Irish soil types are the grey brown podzolic soils (luvisols) (http://www.agresearch.teagasc.ie/johnstown/soil_maps.asp; Fig. 1-1; a selection of soil types within landscape and cattle-rearing contexts are shown in Figs 1-2 to 1-4). Their occurrence and extent are intimately associated with a widespread limestone parentage that facilitated clay movement and accumulation. Rivalling the grey-brown podzolic soils for versatility and productivity are the brown earth soils (cambisols), i.e. soils with equally good physical characteristics for pastoral agriculture, but arising from parent materials such as shales, siltstones and mudstones, which have limited reserves of basic cations. They share, with brown podzolic and podzolic soils (podzols), a tendency for their phosphate content to become unavailable. Gley soils (gleysols), often base-rich and nutritionally fertile, have wetness and watertable problems, resulting in short grass-grazing seasons, limitations that are exacerbated by higher rainfall at elevated altitudes. The soil veneer is broken on mountains and hilly areas, especially where the bedrock is granite, sandstone, gneiss or quartzite. Here there is resistance to weathering or, in the case of limestone areas, the purity of the rock is such that the residue after weathering is inadequate to form a thick soil mantle (rendzina) (Fig. 1-4).

Soil/water relations

Soils in Ireland and their productivity are in keeping with the country's mid-latitude, humid, oceanic climate that may be summarised as follows: mean annual temperature, ca. 10°C; mean annual rainfall (MAR), ca. 800–1200 mm; and potential evapo-transpiration (PET), ca. 500–600 mm. An excess of ca. 100–500 mm of MAR over PET (high in the west; low in the east) ensures that only the most coarse-textured and shallow soils suffer summer-moisture deficits. Excluding these, most Irish soils have a water-volume of ca. 10–25% and an available water-capacity (AWC) of ca. 50–180 mm (Keane and Collins 2004, Chapters 4, 6). Another critical property of soils—and often of the parent material beneath them—is the ability to transfer water from the surface downwards and also laterally (Fig. 1-2A).

Hydraulic conductivity (Ksat) values for most of the loamy productive soils range from ca. 0.1–100 mm per day; the rates for sandy and gravelly soils can be up to ca. 10^5 mm per day while soils with high-clay horizons/lenses can have a Ksat value as low as ca. 10^{-5} mm per day. Soils in the last mentioned category suffer from substantial wetness or water-logging, i.e. conditions not conducive to grass growth or its utilisation. The widespread occurrence of drumlins also contributes to a range of poorly drained, low Ksat soils, especially in some Ulster and Connacht counties (Gardiner and Radford 1980).

Soil nutrients

The Irish lowlands have long been characterised by rich grasslands, that in turn have supported predominantly pastoral farming, with cattle being of primary importance. Soils are fundamental for pastoral farming insofar as they supply a range of plant nutrients, retain and transmit water, and provide a supporting medium for grazing animals—not only cattle but also sheep, horses, and other domesticates and wild animals. A productive soil is expected to supply 16 essential nutrients to growing plants. As well as carbon (C), hydrogen (H) and oxygen (O), the three elements, nitrogen (N), phosphorus (P) and potassium (K), are regarded (in terms of quantity only) as major nutrients; calcium (Ca), magnesium (Mg) and sulphur (S) are next in importance and the remainder, i.e. iron (Fe), boron (B), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo) and chlorine (Cl) are micro or trace nutrients. Apart from B, the above elements, together with cobalt (Co), sodium (Na) and selenium (Se), are required by animals. In prehistoric and well into historical times, parent-material weathering, augmented by atmospheric accretion and natural recycling, supplied these nutrient requirements.

The main patterns as regards bedrock and soil fertility are as follows. Limestones, especially pure types, are inexhaustive sources of Ca and, in places, of Mg, and locally may be high in Mo. Basalts are high in Fe and Mg. The older shales are low in Ca but locally high in K and Mn. Younger shales yield more bases and P. High amounts of Se in some impure limestones (‘poisoned lands’) lead to toxicity in cattle and horses. Sandstones, especially the coarser sandstones in southern Munster, are base-poor while granites, despite their feldspar and mica contents, are prone to nutrient losses as a result of leaching, with Co being particularly susceptible to leaching. Locally, some soils developed from schists and granites are rich in K and Na but patterns are modified in coastal areas by atmospheric deposition. On release from their geological home, metal elements find their way into the soil solution, from which they may take part in cation exchange on surfaces of clay minerals or transfer directly to plant root-hairs. The type and amount of organic matter in the soil complicate the geographical distribution patterns of nutrient supply and availability (for geochemical details see Fay et al. 2015).

Maintaining output

Production is influenced by a wide variety of factors including changes in farming practices, developments in cultivation methods (implements, crops and cropping systems), export of produce and the size of population living off the land. Collins (2008), in assessing these and other factors, placed emphasis on the natural tendency of soils in a humid environment to become acid and nutrient-depleted over time. Animal manures can only return part of the nutrients removed in grazing and cropping and hence a search for ‘new’ materials, many of them geological, was, and continues to be, an unending task. Marls and calcareous clays at shallow depths were early targets for experimentation. Coastal areas were, and still are, prolific sources of ‘sea manures’, including sand, shell, coral and seaweed. Paring and burning the organic surface of soils was a ‘stop-gap’ measure to release Ca, Mg and K, but the element in greatest demand, both by crops and animals, was often phosphorus. The ancient practice of burning animal bones in mid-summer and scattering the embers and ashes on crops, indicates the need, long-recognised by farmers, to augment soil phosphorus. The strategies used to improve the supply of P (reviewed in Collins 2008), are described in early essays by Rye (1730), Madden (1739) and Kirwan (1793/4). Practices included burning (powdering), and chopping and acid treatment of bones in an effort to release their P content (Alford and Parkes 1953; Cooper and Davis 2004). With the passage of time, Irish and British agricultural literature became infused with experimental data (methods, rates, timing, crops, yields) as to how to benefit from new ‘portable’ manures and to mitigate wetness problems (furrows, trenching, open and closed drains, and cultivation ridges; see Bell and Watson 2008).

Gernon (1620) summed up Ireland’s natural resources as follows: its rocks as “bones of polished marble, the grey marble, the blacke, the redd, and the speckled”; its soil cover as “a softe and delicat mould of earthe”; hillocks with “milk-yielding grasse, and that so fertile that they contend wth the vallyes”; and its climate as “very temperate, never too hott, nor too could, and hath a sweet breath of favonian winde”. These are the physical resources that underpinned the country’s reputation as a cattle-rearing economy but in order to keep the grass tender, some of the ‘marbles’ had to quarried, burned or crushed; the bays, shores and waters searched for sand, shells and weed; and, the terrestrial marls and gravels uncovered, dug up and spread. Gernon’s rain may “weep for many days” and bring a cocktail of salts from the oceans with it, but no amount of recycling of organic wastes/manures could keep up with pervasive leaching losses under such a humid climate; losses were continually exacerbated by the export of agricultural produce. If he were to return two centuries later (joining a population that had peaked at ca. eight million), Gernon would be aghast at the greyness of the landscape as the “delicate mould” was now dominated by the blight-affected potato crop and showed clear signs of suffering from mineral deficiencies. The expression “soil exhaustion” appeared regularly in official

reports of the period (e.g. Anon 1848), with replenishment being slow and haphazard thereafter (Curran 1949; Sheehy 1949). A century-and-a-half later still, technology had ensured that these conditions were rectified and indeed not infrequently over-corrected. Better soils in Ireland may yield up to 15t/ha/y herbage and have livestock carrying capacity of up to three units per hectare but those who study the fates of applied phosphates and nitrates nowadays are well advised to recall Kirwan's (1793/4, p 161) observation that "a surfeit is as fatal as an absolute privation".

Literature overview

Early sources of evidence for soil improvement

As Irish woodlands were substantially, and in most areas, completely cleared, during the second millennium AD, the better soils were flush with nutrients, grasses thrived and if a deficiency occurred in soils under tillage, recourse was had to animal excreta. Kelly (1997, p 230), on the basis old Irish law texts, writes "the term *gert* was often used to include the two vital products of living cattle, namely milk and dung". He continues "As in later farming systems, manure from the sheds of cattle and other livestock is piled in a dunghill (*otrach*) in the farmyard. [...] In autumn, the manure is brought out to the fields in a cart". Despite the recycling of waste products to the soil, nutrients continued to be lost under the humid Irish climate even though nitrogen fixation, through the agency of clover (*semmar*) and other leguminous plants such as furze (*Ulex*), undoubtedly helped maintain adequate N levels in the soils. Kelly (1997, p 42), quotes the geographer Dícuill who, writing in the ninth century, cites Solinus to the effect "Ireland is so rich in pastures as to endanger the cattle unless they are now and then removed from their feeding grounds" (grass tetany/bloat/hypomagnesemia is suspected).

Norman lords favoured intensive demesne farming and vigorously promoted foreign trade (Murphy 2015). The accounts of the Constable and Provost of Old Ross, Co. Wexford (Hore 1900) suggest that by the late 1200s, the shale-derived soils of south-eastern Ireland were deficient in some nutrients and required sanding, manuring and surface burning. Stanihurst's view of Ireland following the Tudor takeover (he is writing in the sixteenth century; Miller and Power 1979) suggests the dominance of pasture-based farming:

> Irelande is stored of Cowes, of excellent horses, of hawkes, of fishe and of foule [...] the countrey is very fruiteful both of corne and grasse [...] The grass [...] groweth so ranke in the north parts, that oft times it rotteth their Kyne [cows].

The Tudor wars of the 1500s had a detrimental effect on output so that Fynes Moryson (personal secretary to Lord Mountjoy, governor of Ireland; quotations are from Miller and Power 1979) wondered why "so rich a kingdome should be so great a burthen on the State of *England*" (p 82). He noted that "the Pastures are greene [in winter] and Gardens full of Rosemary, laurell and sweete hearbes, which the Colde of *England* often destroyeth" (p 82), and "the wealth of *Ireland* consists especially in Cattel and victualls" (p 83). While remarking on the nomadic disposition of the Irish, he noted "howsoeuer they haue plenty of Corne, milke and Cattel" (p 38).

References to the use of sand as a fertiliser during these centuries are scarce but it was well entrenched by 1626 when the Corporation of Youghal (Caulfield 1878, p 130) ordained "That every lighter that comes to the harbour or key for sand [...] shall bring a lighter load full of great stones". Forty years later, the Corporation of Kinsale also had worries about harbour deterioration; new quays were needed to facilitate a thriving business based on sand dredging and carriage by lighters upriver to Innishannon (Caulfield 1879).

In a seminal publication on the natural history of Ireland, Boate (1652) showed a clear understanding of the interplay between geology, soils and cattle production. Boate writes (p 85):

> The fertile soil is in some places a blackish earth, in others clay, and in many parts mixt of both together: as likewise there be sundry places where the ground is mixt earth and sand, sand and clay, gravell and clay, or earth.

He noted the harmony between the limestone in the karstic Clare/Galway region and its soils as follows (Boate 1652, p 86):

> because the stone whereon the mould doth lye so thinly is not Free-stone, or any such cold material, but Lime-stone, which doth so warm the ground, and giveth it so much strength, that what it wants in depth, is thereby recompensed.

Though essential to the maintenance of soil fertility, the practice of organic manuring/dunging received little attention, as it was probably commonplace and hence taken for granted. Boate (p 92) writes:

> The commonest sort of manuring the lands is Ireland, is that which is done with the dung of beasts, especially of Cows and Oxen, and also of Horses mixed with a great quantity of straw, and having lyen a long while to rot and incorporate well together.

He then adds "whereof, as a matter every where known and usual, it is needless to speak further". Commentary of this type prevailed for at least another century!

Boate (p 96) noted that the practice of liming land was introduced, by the "English living in Queens-county" (Co. Laois) who came from Pembrokeshire, "for the manuring and inriching of their grounds" and that the practice quickly spread. He wrote substantial descriptions of the two main types of lime-kiln, now better known as running kilns (continuous feed, perpetual) and standing kilns (arch, flare, French), respectively (Figs 1-5, 1-6). He commented on kiln size and shape, on stone preparation and on fuel economy. His reference to a limestone outcrop near Mountrath, suggests that much of Co. Laois (possibly the Slieve Bloom area) needed liming (p 97), the "whole hill of stone, of that bigness, that if all the adjacent country did continually fetch from thence for the forenamed use, it would for ever hold out sufficiently."

Though paring and burning were known since Roman times, Boate (p 107) referred only to the beneficial aspect of burning the surface vegetation of dry heath (where leaching caused acidity and nutrient deficiency) "for as the heath being burnt [...] the land bringeth reasonable good and sweet grass, fit for sheep to feed on; and with a little extraordinary labour and cost brought to bear corn". Shells rather than sands were the liming/manuring agents in the Lough Foyle hinterland. In an essay attributed to King in a later exposition of Boate's treatise (Anon 1726, p 161) it is stated "they carry them by Boats as far as the Rivers will allow and then in sacks on horses, perhaps six or seven miles into the country".

Did the locals know something about the sodium (Na) requirements of animals when Boate observed that the shells that had been under salt-water were much better than those that had been left to dry on the strands? Judging by Boate's comments on the search for marl, many soils—especially sandier soils and/or soils at higher altitudes—were running low in nutrient supply and, in places, becoming decidedly acidic, so remedial action was already been taken. In King's County (Offaly) "not far from the Shanon [river Shannon], [the marl] where being of a grey colour, it is digged out of the Bogs" while in Wexford, near the sea, it was "a blew colour [...] but brittle and dusty when it is dry" (Boate 1652, p 101).

As the 1600s progressed, dung and slaughter-houses in cities and towns received more attention because of the accumulation of filth, lack of hygiene and dangers of infection. In 1670, the Corporation of Waterford stipulated (Pender 1964, p 78):

> from the abundance of excrement and dunghill in St Stephens street occasioned by slaughtering of cattle and keeping swine there, it is ordered that noe butcher or other person presume to slaughter any cattle in the said street, on paine of 5 shillings each head, nor keep any swine there.

The records of the Civil Survey from the mid-seventeenth century (Simington 1942) show that burning limestone was well entrenched countrywide, nowhere more so than in the Barony of Muskerry, Co. Cork where the soils on the sandstone hills had become acidic and nutrient depleted. Suitable quarries of good quality limestone outcropped in the river Bride valley and fuel for kilns, in the form of turf (peat), was near at hand. From the parish of Aghinagh it is recorded (Simington 1942, p 364) "The nature of y^{e} Soyle is fertille, temperate & proper for tillage, being commonly manur'd with Lyme & marble which are found on the S^{d} lands". The use of sea-sand/shell as a manuring agent extended inland from coastal areas, though not necessarily only on good land. Records regarding such practices include (from Simington 1961) "And for any kind of manureing it is scarce but sea sand which is remote if not carried by boates and that but to a part of this barony scituated by the river of Killmare (Barony of Dunkeran, Co. Kerry; p 85) and "The soyle is very cold and mountaneous [...] the land being manured with sea sand by boats afarr off and yields wheat and other corne for the crops continuance" (Barony of Beare and Bantry, Co. Cork, p 90). Chart (1908) accepts Petty's (1691) view that pasture greatly dominated over tillage in the late seventeenth century and he quotes with approval Petty's estimate of seven million acres (ca. 404 700 ha) supporting great flocks of sheep and herds of cattle (each estimated at three million).

Seaweed has played an important role in maintaining soil fertility and indeed creating soils in Ireland and particularly in coastal areas, e.g. on the Aran Islands. Seaweeds grow often profusely on, and are invariably anchored to, rocky substrates on most of Ireland's extensive coastline. Some species, e.g. the green algae, thrive in brackish waters, brown algae (mainly fucoids) typically occur on the intertidal zone of rocky shores, while red algae usually occupy rock pools and the lower parts of rocky shores. Grazing of seaweeds, especially by sheep, is well known for some Scottish islands, notably North Ronaldsay in the Orkneys and there are early medieval references to it being eaten by cattle in Ireland (see Kelly, this volume). Despite harvesting and collecting hazards and its heavy weight when wet, seaweed (also referred to as wrack, woar, etc.) has a long history of use in many coastal regions of Europe. There is some evidence that in prehistoric times it was used as a fertiliser but it is mainly from medieval and later times that there is considerable evidence, e.g. from France in the twelfth century, Devon in 1586 and Jersey in 1694 (Bell 1981). It was certainly used during the late seventeenth century in Connacht (Hardiman 1846). Solomon Richards, writing in 1682, suggests that its use made the Barony of Forth the "Granary of the County [Wexford]" (Hore 1862). There is also a long history of collecting seaweed, mainly in the summer months, and drying and burning it to produce kelp (cf. Forsythe 2006).

Soil improvement—new initiatives beginning in the 1700s

A change of emphasis from pastoral farming to tillage is apparent in a series of Acts of Parliament between 1716 and 1731, all aimed at improving unprofitable land and safeguarding against food shortages. Collins (2008) refers to writers of the 1720s who gave various comments, often widely diverging, on the state of agriculture in Ireland: too little or too much tillage; the need for draining and manuring, enclosing, sheltering and planting; the increasing importance of the potato, etc. The contributions of these authors were over-shadowed, however, not only by Rye (1730) but especially by Jethro Tull's celebrated *Horse-hoeing husbandry*, first published in 1731 with the title *The New Horse-Houghing Husbandry* and republished several times up to at least 1829 (Tull 1829; recently reprinted by various publishers including e-publishers Coastalfields Press). This publication was one of the first of many contributions to the embryonic agricultural sciences by the newly-formed Dublin Society (see below) that helped greatly in bringing Tull's findings to a wide readership.

Rye (1730) placed emphasis on tillage crops and on manuring options, and clearly showed the interdependence of tillage and animal husbandry in the following passage (Rye 1730, p 43–44):

> I have known that five hundred Sheep lodged on 20 Acres of ground for three Months, have so manured it, that it afforded a Crop of Potatoes, worth five pound an Acre, and afterwards two crops of very good Oats.

However, cattle rearing and butter/beef production were dominant in Munster, in response to high demand for wool, beef, bacon and butter. Chetwood and Luckombe (1748), who wrote under the pseudonym, Two English Gentlemen, describe Cork city as follows "The Trade of this Place consists chiefly in Beef, Hides, Butter, Tallow Etc, which merchandise is exported to most parts of the known World" and its slaughter-houses are referred to as follows "The last Slaughtering Season, as they term it, begins about the Middle of August and ends near Christmas: the Merchants killed nearly Ninety Thousand Head of Black Cattle" (see also Bell and Watson, this volume). This, and other references to agricultural exports (see Dickson 2005), suggest that there was probably strain on soil-nutrient reserves, especially on available phosphorus. It is no wonder that Rye (1730) wrote copiously on the use of calcareous sands, shells and coral (in coastal areas) and also lime-kilns including the "Furz-kills" and the arch-type "Turf one". His commentary on lime-kilns includes details relating to the ratio of fuel to stone, quality of both stone and fuel (furze; black turf/spongy turf; coal; culm), heat control and product output ("Roch-Lime", "Quek-Lime", etc.).

Rye (1730) also discussed both sides of the so-called sod-burning argument, claiming that it would be more acceptable if three mistakes were avoided, i.e. over-burning, incomplete burning and letting the ashes get wet. He noted (p 18) that "the Grass of burned Land is better liked by Cattle and is found to be better for both Milk and Flesh, than fields of the same Kind of Soil, that have not felt the Fire".

Rye (1730, p 11) was amongst the first to appreciate some of the chemical effects of the then current manures:

> Nitre, as it is sold with us, is a compound Salt, made of Alchalious Salt, an Urinous Salt and the Salts of the Air; but this Urinous Salt is of Animals that don't use Sea-salt. So that Ground, burnt or limed, and well folded by Sheep and other Cattle, must generate Nitrous salt; which may be one Reason why Grounds are generally fruitful after great Snows and Frosts.
>
> The Urinous Salt proceeds from the dung and Urine of Animals, and this and the preceding Salts open the Body of stiff Ground, they must ferment with all Acid Salts of what kind soever, and meliorate the Soil.

The gaseous losses (of N, S) on burning may not have been too detrimental if Wynn Baker's (1767) list of substances, likely to be received from the atmosphere, in which he includes sulphurous, saline, nitrous and bituminous, is taken into account. Johnson (1840) credits the German chemist, Glauber (1604–1670), with isolating a compound from such deposits that consisted of nitre, i.e. nitrate (see Rye above), and deriving the conclusion that it came from the accumulated dung and urine of animals and hence from their food/fodder (see also Fussell 1962).

Smith's treatises on counties Waterford (1746), Cork (1750a) and Kerry (1756) showed considerable understanding of the interconnections between geology, soils and cattle rearing, making full use of the contrasts between farming as experienced on the upland Devonian sandstones versus the lowland Carboniferous slates and limestones. As well as his pioneering map of Co. Cork (Fig. 1-7; Smith 1750b) and commenting favourably on the county's sources of limestone (Smith 1750a), he mused on the potential value of a soil map for the whole country. In his Co. Kerry treatise (Smith 1756) he defined "pure soil", "pure mould", "rich soil" and "gravelly soil" under the heading "Of Soils, Earths, and Clays" (pp 217–220), and elaborated on their potential for farming and other contexts. The use of "marles", including "Peat Marle" from the base of peat bogs, as a fertilizer is recommended (p 220). More definitions of soils followed in Rutty's history of Co. Dublin, in 1772, which was part of an overall increasing emphasis on the 'scientific approach', as can be seen also in Varley's writings (e.g. Varlo 1765, 1768, 1786). Varley (Varlo 1770, p 174; Varley wrote under the names Varlo and also 'A Real Farmer') was also one of many to extol the virtues of limestone gravel "A coat of this will change ling and heathy ground to shamrogs or wild clover". Varley (Varlo 1774, pp 129–130) mentioned another rough, round, gritty kind of limestone gravel "a bluish cast, it abounds much in salts: I have seen it

producing amazing great crops of corn and grass, for fifteen or sixteen years together". These comments were timely as more marginal land was being reclaimed and common land was increasingly expropriated. Varley, while extolling the virtues of different kinds of limestone gravels, assessed the pro and cons of the controversial practice of paring and burning and offered his ideas on reclamation and drainage. He reflected the growing interest at that time on the gaseous exchanges between the pedosphere and the atmosphere (e.g. Wynn Baker 1767).

Visiting 30 of the 32 counties of Ireland in the years 1776–1779, Young (1780, vol II, p 73, 74) summed up what he saw as regards soils as follows:

> the greatest singularity of Ireland, is the rockiness of the soil [...] But the rocks here are cloathed in verdure; those of limestone with only a thin covering of mould, have the softest and most beautiful turf imaginable.

However, Young was not slow to condemn the wide expanses of waste land and he makes reference to all the then-available nutritional ameliorants, including rarer types such as roasted subsoil clay and ashes of turf/coal, soap and peat. Drawing on his extensive travels and observations in Ireland, he commented on many aspects of the cattle industry including cows, dairying, butter production, working bullocks and stall-feeding. He emphasised the importance of crop rotation, including the use of turnips and promoting clover. His remark on the use—including possibly excessive use—of lime is interesting (Young 1780, vol I, p 356) "it brings the land infallibly to moss, which is so powerful as to choak the grasses" but he adds "but marle is an excellent manure". While Young observed few other relationships between geology and soils, he was interested in the causes of soil wetness, making this general statement about Co. Longford "The soil is, in general, a tolerable vegetable mould on the surface, for three or four inches deep; under that, two-inch thick of blue clay: which retains water under that yellow clay for two or three feet, and then every where limestone gravel" (vol I, p 294). He recorded the collection of street manures in the main cities ("The poor people near Galway are very industrious in buying the sullage of the streets of that town"; Young 1780, vol I, p 342), and he promoted sheep-folding as a means of providing manure for tillage.

Soil improvement—science and surveys

The Dublin Society (DS), which in 1731 became the Royal Dublin Society (RDS), made notable contributions to the science of agriculture from its earliest days. Its impact, however, was more pronounced from the 1790s onwards, not only on account of its own endeavours but also the contributions of several other unconnected individuals and organisations. Contributors to advancements directly connected with the Society included Kearney, Dease and Kirwan, Meade, Newenham, Radcliff and Shaw-Mason; others included the publishers of such titles as *Irish Agricultural Magazine*, *Irish Farmers' Journal* and *Munster Farmers' Magazine*. An important endeavour embarked on by the RDS was the Statistical Surveys of various counties that were published between 1801 and 1824. The authors of these Surveys (these are reports rather than statistical surveys in present-day parlance) made significant contributions to the understanding of the geology/soil/cattle interplay in various counties; e.g. Fraser (1801) (Wicklow), Sampson (1802) (Londonderry), Tighe (1802) (Kilkenny) and Townsend (1810) (Cork). Fraser (1801) and other Survey authors included details on the management of organic wastes/manures and on the pros/cons of green manuring, soiling and fold-yards. Townsend provided good insights into putrefaction within dungheaps but his claim that dung was superior to all other additions in the permanence of its benefits was an exaggeration.

An important innovation was the depiction of resources on maps, including rocks, surficial deposits, bogs and soils (Fig. 1-7). This practice was further developed in the reports of the Bog Commissioners (e.g. Anon 1811) and also later, finding its culmination in the maps produced by the Ordnance Survey, Board of Works and Geological Survey (Andrews 1975; Herries Davies 1983).

Kearney (1790), writing under the nom de plume 'A Country Gentleman', was amongst the earlier writers to favour a rare form of soil improvement, variously referred to as warping, floating, irrigation and watering. Other advocates of this method included Griffith (1798) and Townsend (1803). The latter wrote (p 52) "the water of a spring, made to trickle over a grassy surface, should change it to a deeper green, and excite a more luxuriant vegetation", and, where stream diversion was employed, he asserted "Of all the modes of producing grass, it is one of the cheapest, as well as the most effectual". While the practice continued to be mentioned periodically in the literature, including in Geological Memoirs (for upland soils especially), it ultimately yielded to new practices that involved use of portable materials such as quicklime and imported salts. The widespread problem of too much soil water also attracted the attention of farmers and government agencies. One of the most successful land-reclamation ventures begun in the 1830s/40s was the conversion of a large tract of sandstone-derived, acid peaty podzol soils, developed at Scrahan, Co. Waterford (now the Cistercian Abbey of Mount Melleray) on the southern slopes of the Knockmealdown Mountains, to productive farmland; reclamation involved scrub and stone removal, trenching, pan disruption and copious liming (Conry 1970; Fig. 1-8).

New methods and materials for improvement of soil fertility

Salt-petre and other saline materials

Salts containing Na, K, N and to a lesser extent P—often referred to as soda, potash, nitrate (also nitre) and phosphate, respectively—are naturally concentrated in soils, subsoils and sediments of warm and semi-tropical countries. The best known of these, salt-petre, an encrusted deposit rich in nitrate of potash (KNO_3), had long been exploited to improve the fertility of nutrient-deficient soils in north-west Europe. Interestingly, it was deposits (dung incorporated into straw, etc.) from cattle stalls that was instrumental in alerting the agricultural community to an alternative source of this manure. Johnson (1840) credits the German chemist, Glauber (1604–1670), with isolating a nitrate compound from such deposits and deriving the conclusion that it came from the accumulated dung and urine of animals and hence from their food/fodder (see also Fussell 1962).

By the mid-eighteenth century, the RDS was giving grants to farmers, at ca. £1 per lb, to produce salt-petre from their cattle-sheds. The first shipment of salt-petre to Britain from South America dates to 1813 (Johnson 1840) but there seems to be no pioneering users of "Saline Manures" (including common salt, nitrate of soda, carbonate, sulphate and muriate of ammonia) in Ireland until the 1840s.

Guano: alternatives and imitators

Despite being referenced in the Irish agricultural literature since 1818, imported guano did not attract great attention until it was vigorously promoted in the 1830s/1840s by various agricultural journals such as the *Irish Farmers' and Gardeners' Register*, *Irish Farmers' Almanac* and *Irish Farmers' Gazette*. Chemical analysis showed it to contain the important nutrients, N, P, Ca, Mg and especially P. Experimenters, applying it at various rates, found it very beneficial for many crops, and soon cheaper, adulterated, diluted and modified forms were being offered to farmers (diluents included sand, clay, sawdust and peat ashes). As South American sources of guano declined and became expensive, sources in Africa and south Asia came on-stream. A Peruvian phospho-guano competed for a period with manufactured forms of phosphatic fertilisers (Purdon's Practical Farmer 1863). As well as commenting generally on geology, soil and agricultural output, both Kane (1845) and Skilling (1846) were complimentary as regards the 'genuine article', the latter commenting on it most favourably (p 161) "No farmer is excusable now, who has not a sufficiency of green food for his cattle". The 1280-page first issue of the *Irish Farmer's Journal* (1845) included articles and notes on virtually every agricultural topic of the time including many on guano and also an article entitled "On the application of geology to agriculture" (p 213). The most inclusive contemporary work on this topic was the volume by Thomas Antisell (1846) in which he reviewed the works of Griffith, Hamilton, Oldham, Mallet, Wilkinson and Kane. Having discussed weathering in Chapter 3, the contributions of the various Irish rock types to soil formation were described in Chapters 4–10.

Recycling bones; bone manure

The word 'bonfire' ('bone-fire') is connected with the centuries-old tradition of burning animal bones in mid-summer, i.e. St. John's Eve on 23rd June, which, as in other parts of Europe, was marked in Ireland by bonfires and festivities. Ash from bonfires was applied to the growing crops, the impetus for this being to supply a very scarce pabulum, namely, calcium phosphate. The term 'bone dust' found its way into the agricultural literature during the early decades of the 1800s, Blacker (1834, p 9) advising, in the absence of lime, sea-sand, seaweed or marl "if all these fail, bone dust or rape cake will give excellent crops of turnips, which once produced, they will yield such an abundance of manure by home feeding cattle, it is the farmer's own fault if ever he is in want of manure again".

Likewise, editorials in the *Irish Farmers' and Gardeners' Magazine* in the 1830s claimed that fallowing could be circumvented on every kind of soil in all parts of Great Britain by the use of bone dust. While crushing and grinding machines improved the efficacy of bone dust as a source of P, the scientific advances of Davy (1813) and the practical research of James Murray (1778–1871) in Belfast during the years 1807–1818 (summarised by Alford and Parkes 1953, and others) were central to a significant chapter in agricultural history, namely, acid treatment of bone dust, vitriolisisation of bones and superphosphate manufacture. In the 1830s, various acids were experimented with, including nitric and hydrochloric acids, but sulphuric acid prevailed. The literature of the 1840s became crowded with the phosphate story especially when the results of the early research were commercialised by Sprengel and Liebig in Germany and by Lawes in England (for a critical overview of the pioneering research by Sprengel and Liebig into soil chemistry and plant nutrition, see van der Ploeg et al. 1999). By then, soluble calcium biphosphate had entered the commercial world as 'superphosphate', and 'chemical agriculture' can be said to have truly begun. Despite using sources such as battlefields and graveyards, the supply of bones became inadequate; slags, coprolites and, eventually, rock-phosphate sources were exploited (Fig. 1-9). During the rest of the century and indeed into the following, 'vitriolised' and 'sulphated' bone products also had to compete with imported guanos but despite the best efforts of farmers, governments and industry, soil phosphorus levels declined steadily. 'Aphosphorosus' or 'bog lameness', in most grazing animals, was one of the mineral nutritional imbalances that attracted the attention of the veterinary profession (Curran 1949). The system of short-term transfer of animals from acid peaty soils to recuperate on the

calcium and phosphate-rich grasses of limestone soils needed replacement (see also contributions by Costello, McDonald and Kelly, this volume).

Ground limestone

Many writers observed that some liming agents were the products of mechanical breakdown by, for example, ice, river action and wave energy, and that limestone grit, ground to dust under wheeled vehicles, also acquitted itself well. The long-established method of reducing hard rock to a powdery form involved burning (Figs 1-5, 1-6). The reduction in numbers of lime-kilns, from the 1830s/1840s to the 1890s/1900s, recorded in Ordnance Survey of Ireland (OSI) maps and also documented elsewhere (e.g. O'Sullivan and Downey 2005), reflects a sharp decline in this practice. The switch to ground limestone was, however, very slow especially in the marginal and coastal areas distant from appropriate outcrops. It was a question of the cost of grinding rock rather than a lack of understanding of the benefits as is clear from Parkinson's statement (1806, p 233) "for if lime-stone could be pounded by any device cheaper than fire, it would be nearly as good in some cases, as appears by the lime-stone gravel in this country [Ireland]".

The role of geology in agriculture and soil fertility was firmly established when Griffith (as Commissioner for Valuation) instructed his field staff on the recognition of soil-parent materials and on adjusting the rating of land accordingly (Herries Davies 1980; Lee 1890). As geological surveying progressed after 1845, the memoirs of the Geological Survey of Ireland carried many references to commercial possibilities of geological deposits, with Kinahan in particular advocating ground limestone as a fertiliser, e.g. Kinahan 1878, p 393:

> It ought to be more generally adopted, especially in those places where fuel is dear, as ground limestone will give nearly as quick, and much more lasting, returns than "quick lime."

Epilogue

It is rather fitting that some of the main insights into the relationships between geology, soil and cattle in an Irish context were those of the Irish geologist and naturalist, George Kinahan (1829–1908) (Kinahan 1878, 1885/9, 1908a, b; these are merely a sample of his prodigious output). In his booklet on soils (1908b), which concentrated on seaweeds as a fertiliser, Kinahan lamented the declining use of many native soil amendments. He believed that the sodium content of both seaweeds and sands contributed to the quality of milk and butter and to the fattening of beef cattle. The twentieth century saw many aspects of this three-sided story influenced by wars, international upheavals, trade embargos, surpluses and shortages, and disease epidemics. Pedological as well as commercial advances have enhanced the ability of the mineral- and organic-rich soils of Ireland to support and underpin a thriving grass-based cattle industry that has become the envy of the developed world (Fig. 1-8). It is, however, salutary to remember that cattle-rearing was not always profitable and that success comes at a price, as the old gaelic saying (*sean-fhocal*) reminds us: *an té a bhfuil bólacht ar cnoc aige ní bhíonn suaimhneas ar sop aige* (he who has cattle on the hill will not sleep easy). It is also worth recalling the pivotal role of cattle in the pre-industrial-age farming economy of Ireland, neatly summed up by the saying "No grass no cattle, no cattle no manure, no manure no crops" or, in the words of Arthur Young "The grand article of all husbandry is the keeping great stocks of cattle; for without much cattle, there can not be much manure" (Fraser 1908, p 408).

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Figure legends

Fig. 1-1 Soil map of Ireland showing the major soil groups (based on Gardiner and Radford (1980); after image at http://www.askaboutireland.ie/enfo/irelands-environment/environment-overview/land-and-biodiversity/land-use/soil/; accessed 9 November 2015)

Fig. 1-2 Photographs illustrating soils with contrasting hydraulic conductivity and resistance to poaching. **A** Intensive grazing on sandstone-influenced soils, Co. Cork (photo: B. McMahon; 11/06/2007); **B** Poorly drained, rush (*Juncus*)-infested soils on Irish Sea till, Co. Wexford (photo: P. Murphy; 26/06/2012)

Fig. 1-3 Photographs of contrasting soils and grasslands in the Shannon basin, Co. Offaly. A Species-rich, nutrient-poor, dry esker grassland (in the process of rehabilitation after recent quarrying for gravel extraction) at Glaster, south of All Saints Bog; B Species-rich wetland grasslands (so-called callows) on wet, organic-rich soils in the floodplain of the Shannon river. The extensive callows in this part of the Shannon basin are overlooked by the medieval monastic site at Clonmacnoise which is situated on a pronounced esker ridge (photos: M. O'Connell; 15/06/2014)

Fig. 1-4 Karstic landscapes at Cappanawalla, north-west Burren, Co. Clare. **A** View from Cappanawalla to the south across Rathborney valley showing high diversity in soils, vegetation cover and land-use. Fertile, relatively intensively farmed, drift-derived soils, supporting pastoral farming (mainly cattle), cover the valley floor. Thin skeletal soils that support scrub (mainly hazel) and species-rich grasslands (unfertilised) occupy much of the valley sides, while the upper reaches consist mainly of exposed limestone bedrock (karst) (photo: M. O'Connell; 17/07/2014). **B** The Burren uplands at Cappanawalla support grasslands that are used as 'winterage', i.e. winter-grazing for cattle. The thin organic-rich soils, though developed directly over limestone, tend to be acidic and frequently support low *Calluna* (ling) scrub as shown here (photo: M. O'Connell; 24/03/2007)

Fig. 1-5 Diagrams showing lime-kilns. The upper sketch shows a typical small kiln (after U. Mattenberger in O'Sullivan and Downey 2005). The lower drawing shows an industrial-type lime-kiln built by Count Rumford in Co. Dublin ca. 1800. Shaft dimensions (brick cavity walls) are as follows: 460 cm tall, diameters of 23 cm and 61 cm at the top and base, respectively. In effect this was a continuous-flare lime-kiln aimed at serving the building industry which had a requirement for ash-free lime (after Malcolm 1805, p 24).

Fig. 1-6 A disused limestone-constructed kiln in a limestone quarry near Ardfinnan, Co. Tipperary. The kiln is strategically sited vis-à-vis the topography to facilitate feeding the kiln with crushed stone and fuel via the elevated ground at the rear, and removal of the burnt product at the front (photo: T. Collins; 19/09/2003)

Fig. 1-7 Part of Smith's (1750) map of county Cork centred on the Boggeragh Mountains, south of the river Blackwater and south-west of the town of Mallow (near upper right hand corner). The text beneath "The Boggra Mountains" reads "This vast uncultivated Tract Consists of Heath and Bog, in Summer it is grazed by vast herds of Cattle" (see Costello, this volume; McDonald, this volume) (image derives from Smith 1750b)

Fig. 1-8 Introduction of new farming methods is a feature of the Cistercian monastic tradition. This continues at Mount Melleray, Co. Waterford, on the lower slopes of the Knockmealdown Mountains, where the Cistercian community, established in the 1830s, having reclaimed marginal lands (see text), in recent years support trialling of various cattle strains including new strains developed in New Zealand (photos: M. O'Connell; 03/08/2015; Cistercian farm at Mount Mellerary)

Fig. 1-9 Advertisement for bone manures by the fertiliser manufacturer, Goulding. The vitriol (sulphuric acid) works heralded the manufacture of superphosphate (source: *Irish Farmers' Gazette*, vol. 21(1), 1862)

CHAPTER TWO

THE INTRODUCTION OF CATTLE INTO PREHISTORIC IRELAND: FRESH PERSPECTIVES

PETER C. WOODMAN

Abstract This paper examines the evidence from Ireland for the presence of domesticated cattle in 'Pre-Neolithic contexts'. It evaluates each potential case and suggests that, while some are not reliable, a case can still be made for an early presence of cattle. The paper also lists the occurrences of cattle remains from, in particular, coastal, lacustrine and riverine contexts. It is suggested that these sites are more likely to be associated with the presence of farmers using parts of the 'wild landscape' rather than the persistence of hunter-gatherers into the Neolithic. Finally, the paper discusses the possibility that the role of cattle during the Neolithic may have varied within Ireland and that, in general, there may have been in many parts of Ireland a greater reliance on cattle than in the larger nearby island, Great Britain.

Keywords Cattle • Mesolithic • Neolithic • Mesolithic/Neolithic transition • Ireland

Introduction

Even today we know surprisingly little about how, why, and even when the culture and lifestyle associated with the Neolithic spread to Ireland. We know that it is identified initially by archaeologists from the appearance of a new range of artefacts such as ceramics, and new and different types of stone tools as well as monuments. From this we can see that there were very different life styles present and developing on the island of Ireland, and that this seems to have been happening around or shortly after 4000 cal BC. In summary, these economic changes involved the introduction of arable farming and domesticated animals, and notably in the case of Ireland the introduction of cattle and sheep. The consequences of the introduction of arable farming are well known as it led to various forms of land clearance which, over millennia, changed the Irish landscape. However, it was the introduction of cattle and perhaps to a lesser extent sheep that were to have more immediate and significant consequences (see Molloy and O'Connell, this volume).

This last assertion may seem rather startling. If one examines Ireland's distinctive ecological background there is one very significant reason why the introduction of cattle to Ireland was so important. Aside from the fact that several large mammal species were, and are, absent from Ireland, the crucial fact is that most of the large mammals present in mid-Holocene times in adjacent parts of Europe were not present in Ireland (Woodman 2014). Bear (*Ursus arctos*) and wild pig (*Sus scrofa ferus*) were present in Ireland during the Irish Mesolithic, but aurochs (*Bos primigenius*), European elk (*Alces alces*), roe deer (*Capreolus capreolus*) and probably red deer (*Cervus elaphus*) were absent. The initial inclination is to see these animals simply as potential sources of food but, as can be seen within assemblages from elsewhere where there is good organic preservation, numerous different tool types were made from bone or antler such as axes, wedges and projectile heads which often occur in profusion at other European archaeological sites, e.g. Star Carr (Clark 1954) or Polderweg (Louwe Kooijmans 2001). In Ireland, stone tools such as ground-stone axes seem to have been substituted. One also has to wonder about the many potential uses for the skins of some of these large animals. In some cases they might have been used for clothing and other forms of covers. The humble convex-end scraper, that suddenly appears in profusion from the beginning of the Neolithic, may be relevant here. Bamforth and Woodman (2004) have shown, from micro-wear analysis, that these were multiple-purpose tools with uses that included working the hides of various mammals.

Within Europe, the hunting of large numbers of the larger ungulates was of major significance throughout the Mesolithic period and this continued into the Neolithic. In many other areas it is likely that domesticated cattle, as well as sheep, assumed the roles of these large wild mammals from at least the Mesolithic/Neolithic transition onwards.

In the context of Ireland, therefore, at contact between farming and hunter-gatherer communities, especially on an island where large mammals were scarce, not suitable, or in the case of bears difficult to catch or trap, the presence of cattle would have been of crucial importance for farmers, while for the existing Mesolithic population it would have been an amazing addition. How they would have reacted is another matter. There are parallels. In Tierra del Fuego, when the Europeans arrived with their flocks of sheep, the Selknam, who hunted Guanaco, viewed the arrival of sheep