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STUDIES IN AGRICULTURAL TECHNOLOGY IN NINETEENTH- AND TWENTIETH-CENTURY ENGLAND

by

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DOCTOR OF PHILOSOPHY

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CONTENTS

Declaration

All of the work submitted herein was carried out while the candidate was employed by the University of Plymouth in the Seale-Hayne Faculty of Land, Food and Leisure (as it now is).

Brassley, P. (1995a) Agricultural Research in Britain, 1850-1914: failure, success and development, *Annals of Science* 52, 465-480

This was submitted in September 1994 and written during the previous year.

Brassley, P. (1995b) 'A Pioneer in Everything': Primrose McConnell, 1856-1931, *Journal of the Royal Agricultural Society of England*, 156, 172-8

This was written in the spring of 1995, following an interview at Birch, near Colchester, Essex, on March 30th, 1995, with Miss Kathleen Kelly, McConnell's granddaughter.

Brassley, P. (1996) Silage in Britain, 1880-1990: the Delayed Adoption of an Innovation, *Agricultural History Review* 44(1), 63-87.

This was written in 1994 and 1995, following research carried out over the previous three years.

Brassley, P. (2000a) Output and Technical Change in twentieth-century British Agriculture, *Agricultural History Review* 48(1) 60-84.

The first version of this was prepared as a paper to be delivered to the Economic History Society conference at Brighton in 1997. This was then redrafted over the following two years and submitted at the end of 1999.

Brassley, P. (2000b) Agriculture, being part II of E.J.T. Collins (ed.) *The Agrarian History of England and Wales, vol. VII, 1850-1914* Cambridge University Press, 453-649.

This was the last of the works to be published (in December 2001) but parts of it were the first to be written. The author was first invited to contribute to this volume in the late 1980s, and the bulk of the research and writing of chapter 7, parts A and D-J, and chapter 8 was carried out in the early 1990s. Most of the evidence was available in the faculty library at Seale-Hayne or the libraries of the universities of Plymouth and Exeter, or through inter-library loans. The author was later, in about 1995, invited to write chapter 6 parts A-C, and this work was completed by about 1997.

Paul Brassley
July 2001

ABSTRACT

Four published papers and several parts of a book are presented herein, together with a previously unpublished short paper explaining the intellectual background against which they were written and summarising their findings on the development of agricultural technology in England in the nineteenth and twentieth centuries. This outlines the contribution of economic and sociological theories to the study of technical change, but makes the point that historical studies, although clearly influenced by these theories, tend to use a multifactorial approach which avoids privileging any single explanation. Nevertheless, several themes arising in all of this material are identified, especially the gap between innovation and the adoption of technology, and the influence upon it of scientific, systemic, and socio-economic changes.

Brassley (1995a) examines the criteria against which the success of agricultural science should be judged, and concludes that for most of the nineteenth century in Britain it was a failure. It identifies the establishment of the university departments of agriculture in the 1890s, and the Development Commission in 1910, as the main factors which reversed this trend, and, in an appendix, examines the impact of changing output prices upon the supply curve. In Brassley (1995b) the life of a single farmer, Primrose McConnell, is considered. In adoption-diffusion theory terms, McConnell is a classic example of an innovator, and this paper reveals the various ways in which, as a writer and a practising farmer, he influenced the agricultural industry of the late nineteenth and early twentieth centuries. Brassley (1996) concentrates on a single example of technical change, in this case silage, and explains why its widespread adoption took about a hundred years. The principal conclusion is that silage, like many examples of agricultural technology, is not a single change but a complex system of interacting individual components, all of which need to be available or in place before widespread adoption can occur. The significance of this process is studied in Brassley (2000a), which examines the relationship between technical change and output in the late nineteenth and twentieth centuries, and concludes that innovation was not necessarily as important as the adoption of pre-existing technology in accounting for output expansion.

Brassley (2000b) is divided into three parts. The first introduces the concept of farming systems in late nineteenth century England and Wales and analyses the principal arable and pastoral systems of the period; the second examines individual aspects of farming technology, with the exception of farm buildings and machinery; and the third traces the development of agricultural science and education in England and Wales between 1850 and 1914. Clearly these three are inter-related, in that science and education had some impact on techniques, which, in turn, influenced farming systems, but one of the main themes to emerge from this study, as from the other papers in this collection, is the restricted rate of change and the gap between technical leaders and laggards.

STUDIES IN AGRICULTURAL TECHNOLOGY IN NINETEENTH- AND TWENTIETH-CENTURY ENGLAND

Introduction

The study of technical change has been one of the more persistent preoccupations of agricultural historians, from the early classic work of Lord Ernle (1912) to the present day, and in this they are no different from other kinds of economic historian (Mokyr, 1990). This is not to say that they are exclusively interested in technology, or that technical change has provided all the answers they have searched for in attempting to explain the development of agriculture. But few accounts of rural social, or economic, or cultural development have been able to ignore it completely. The chapters and articles to which it is the purpose of this paper to provide an introduction focus almost entirely on agricultural technology and its associated science and education, and discuss other issues only insofar as they help to shed light on the reasons for technical change and its impacts and effects. They deal with technical change in its widest sense, which means that the term is taken to include the processes of discovery or invention, innovation, adoption, and diffusion.

The present paper begins with a brief survey of the historiographical and theoretical approaches to technical change, from which it is possible to derive a selection of possible explanations for it or methods of studying it. Since no single approach emerges as dominant it seems permissible to use a variety of them, together with simple description, and the following section of the paper locates the various paradigms used in the chapters and articles under consideration. The final section draws together the overall conclusions which emerge and makes some suggestions for further work.

Technical change, historians, and social scientists

Whether or not theory has a role in history opens up more questions than could usefully be dealt with here (they are discussed, for example, in Tosh, 1984: 127-51); what is indisputable is that explanation certainly does have a role, and in order to explain technical change some theoretical approaches may be useful. The two principal disciplines in the social sciences which have been used to investigate technical change are sociology and economics. Katz, Levin and Hamilton (1963) identify a period of sociological and anthropological studies of the diffusion of culture and innovation beginning in about 1914 and ending in about 1940. There was then a revival of interest in the late 1950s by sociologists of communication, but they discovered that American rural sociologists had, in the period 1940-1960, completed 'several hundred' studies of new farm practices (Katz, Levin and Hamilton, 1963: 239). Some of the more influential sociological concepts emerged in this period. The idea of a normal distribution of innovation, with innovators, early adopters, an early and late majority and laggards is reported by Rogers (1958), and he subsequently went on to write one of the classic works on the topic, *The Diffusion of Innovations*, in 1962. At the same time Rogers and Beal (1958) argued for a 5 stage adoption process, with the potential adopter moving from awareness to interest to evaluation, trial and adoption. These ideas spread fairly rapidly among advisers and extension workers and even agricultural economists: Jones (1963) used Rogers's normal distribution hypothesis in a study of five agricultural innovations in England and Wales, the Presidential Address to the Agricultural Economics Society in 1970 concerned the mechanisation of British farming from 1910 to 1945 (Whetham, 1970), and numerous others since (e.g.Opio-Odongo, 1980; Napier et al, 1988; and Miller and Tolley , 1989) have touched on various aspects of the topic. So great was the volume of work that a comprehensive survey would be impractical: by 1995 Rogers had counted 3,810 diffusion research publications spread over a wide range of fields from anthropology to public health and marketing (Rogers, 1995:xv; Ruttan, 1996: 52). Nevertheless, the overall conclusions are clear: the adoption and diffusion of an innovation is likely to be determined by the interaction of the personal and social attributes of the innovators and adopters with the characteristics of the innovation (see Rogers, 1962: 306).

At first sight the methodologies used recently by historians of science and technology are not very different from this. For example, Grant's (1998) study of the diffusion of the herringbone milking parlour identified farmer age, tenancy, size of farm and use of Friesian cows and artificial insemination among the explanatory variables, although he examined the economic as well as the sociological implications of his findings. One of the most fruitful approaches has been the idea that technology is socially constructed. Pinch (1996:19), for example, distinguishes between two versions of the social construction of technology (SCOT): the mild and the radical. Mild SCOT simply draws attention to the social components of science and technology, as in the work of David Nye (1990), which revealed the various ways in which electricity acquired meaning as a commodity in the U.S.A. between 1880 and 1940. Radical SCOT goes further, based on the premise that both the workings of technology and technical options may be socially constructed, and uses various examples from the bicycle to the missile (Pinch, 1996:20). Other historians of technology have focussed on the importance of complexity in systems, so that a lagging element can prevent the advance of the whole system (Fox, 1996: 5), and it is this strand which is most relevant to the work discussed here. Interestingly, complexity was one of the innovation characteristics identified by the adoption-diffusion school, but there seems to be little evidence that their insights have had much direct impact on the work of the technical historians. Although, to be fair, the adoption-diffusion school never set out to inform the historical debate and the SCOT school was not concerned with the practical problems of promoting innovation, it was perhaps this mutual unawareness that led Ruttan (1996) to conclude that the sociological approach was in decline. In this he was supporting Rogers himself, who concluded that interest in diffusion research declined by the late 1960s because it had answered its major theoretical questions (Rogers, 1995: 60). Ruttan himself argued that the sociological approach was superseded by the economic. There were, he wrote, three reasons for this: the interest of development agencies in technical change; the failure of convergence in productivity between rich and poor countries; and the work of agricultural economists in particular on the impact of 'broader economic forces' on invention and adoption (Ruttan, 1996: 66).

These broader economic forces are changes in demand (and consequently output price) and changes in relative resource endowments (and consequently input costs). The cost-based approach can be traced back to the work of Hicks (1932), who suggested that changes in relative resource endowments would produce changes in relative factor prices, which would in turn stimulate innovation. This became known as 'induced innovation', and produced a large volume of work, among which some of the more influential was that produced by Hayami and Ruttan (1971) (but see also Binswanger and Ruttan, 1978; and Koppel (ed.), 1995). It was still provoking revisionist work in the 1990s. Olmstead and Rhode (1993), for example, suggested that many of their generalisations were simply regional phenomena, and Tiffin and Dawson (1995) found that factor price changes explained not changes in factor ratios, as Hayami and Ruttan suggested, but the *rate* of change in factor ratios. From a different theoretical perspective, Hogg (2000:68-9) criticised Hayami and Ruttan's tendency to ignore the actions of farmers and the impact of cultural change on the adoption of technology. The demand-based approach essentially began with the work of Griliches (1957), although to be precise he measured the effect of profitability rather than price.

Historians have commonly been less willing than economists or sociologists to argue for unifactorial explanations of economic growth. Crafts (1985: 82), for example, examining the growth of the British economy between the early eighteenth and early nineteenth centuries, attributed 30 per cent of it to productivity increases, twenty per cent to capital formation, and 50 per cent to increases in other factor inputs. Mokyr contends that technical change is rarely the orderly research and development process implied by economic theory and so also rejects 'one line' explanations (Mokyr, 1990: 229). He suggests instead the use of evolution as a metaphor (see also Mokyr, 1996). Dealing with more recent technical changes, Castells (2000: 76) writes of 'the complex matrix of interaction'. Turning specifically to agriculture, Overton (1996: 207) attributes the agricultural revolution he identifies as occurring between 1750 and 1850 to such multifactorial causes as 'the integration of local markets and a new willingness of farmers to exploit commercial opportunities [which] provided the impetus for innovation and enterprise which led to the agricultural revolution'. Turner et al (2001) also espouse a multifactorial explanation, although they identify 1800-1850 as the crucial period. O Grada (1994: 152-6) uses economic techniques and the terminology of the adoption-diffusion school in examining technical change in late nineteenth-century British agriculture, although his discussion is limited to the reaper-binder, and Macdonald (1979) specifically investigates the diffusion of agricultural knowledge. It is interesting to note that Walton's early (1979) investigation of innovations in farm machinery uses a multivariate analysis of social and spatial variables which is clearly influenced by the adoption-diffusion school, whereas his more recent (1999) work on varieties adopts a more discursive approach. In other words, historians of technical change do not always base their work on such clear theoretical underpinnings as sociologists or economists. However, as Fox (1996:8) points out, 'even the barest narrative conceals profound historiographical assumptions and so is itself dependent upon theory, albeit unspoken theory'.

Thus the justification for the foregoing brief attempt to identify the main theoretical strands in the analysis of technical change is to clarify the assumptions, sometimes unspoken, in the papers presented herein. To summarise, it is possible to identify several possible explanations for technical changes and their adoption: changes in input prices; changes in product prices; the different roles of various social groups (such as big or small farmers); the interactions of the components of complex systems; the impact of exogenous scientific change; and various possible institutional and cultural changes. No single one of these could guarantee a complete and satisfying explanation of the changes observed; equally, each of them might be expected to suggest fruitful avenues for exploration by the historian of technical change.

Technical change in English agriculture since 1850

The material included in this collection might indeed claim to explore many of the avenues outlined above. The first (in the order in which they were written, as opposed to their published order) is Brassley (2000b), which comprises part or the whole of three chapters, all concerned with the period 1850-1914. The first (chapter 6 parts A-C) is essentially a brief survey of farming systems and rotations and is more descriptive than concerned with technical change. The second (chapter 7 sections A and D-J) examines changes in farming techniques, and is clearly influenced by the adoption-diffusion school, in that it places much emphasis on the lag between the development of new techniques and their adoption by the majority of farmers (e.g. p.569 re livestock breeds: 'As with many other aspects of the development of agricultural technology in this period, the relationship between the elite and ordinary farmers needs further investigation'). The third (chapter 8) is concerned with the development of agricultural science and education, and pays particular attention to their impact on output. Thus it examines not only what happened, but also what effect it had on farm practice. Not much, immediately, was the conclusion, but more in the long term, after 1914.

The subsequent papers attempt to take further the issues raised in this account of the state of technology and the main changes therein: why was science not more influential; how can the gap between innovation and widespread adoption be explained; how is the impact of technology best measured; and what were the personal characteristics of the innovators? The first of these issues, on the problems of agricultural science, is discussed in Brassley (1995a). This paper argues that the period 1870-1910 was a crucial one, which saw the transformation of British agricultural science from a small-scale amateur activity to something rather larger and more professional. It takes issue with the significance accorded to Lawes and Gilbert, the founding fathers of the Rothamsted experimental station, in Russell (1966), the standard history of agricultural science in Britain, arguing instead that the efficacy of science increased with its post-1890 expansion which was associated with the foundation and growth of university agricultural departments. This is explained using a model first applied to research in Germany (Grantham, 1984) which identifies the importance of scientific literacy among the relevant bureaucracy, plentiful scientists, state funding, and some disposition to be interested in research and its dissemination on the part of farmers' organizations, all of which were largely

absent in Britain before 1890 and gradually more prevalent afterwards. In economic terms, all of these factors influence the expected marginal return on investments in research: more scientific discoveries or useful explanations might be expected to increase output or productivity or both. But the sale price of outputs would also affect expected marginal return, so output or productivity changes can only be used to measure scientific success in a stable price environment. This is the identification problem, which means that it is impossible to determine whether observed combinations of prices and quantities represent static technology responding to price changes or technical changes occurring simultaneously with price changes (see Sloman, 1991: 65). The analytical complications of this are explored in the appendix to this paper. The important question which emerges from this is: did supply increase because the available technology changed, or were technical changes a response to the demands of farmers who wanted to produce more? There are several ways of approaching this question, three of which are explored in these papers. One is to examine a specific technical change over a long period (Brassley, 1996); a second is to examine technical change under different price conditions (Brassley, 2000a); and the third involves a case study of one innovatory farmer (Brassley, 1995b).

The specific technical change chosen for examination is silage as a method of fodder conservation. Its particular attraction is that it exemplifies a technical change in which there is a big gap between the original innovation and its eventual widespread adoption. Silage was effectively introduced into England in 1882, and by the later 1880s there was at least one silage maker in each of the English and Welsh counties, yet it was not until 1971 that the tonnage of silage produced exceeded that of hay and not until the 1970s and early 1980s that silage production increased to its present dominance. Brassley (1996) examines the reasons for this gap between innovation and adoption, and concludes that it is another example of the effect of system complexity (i.e. the absence of a single component can delay the adoption of the whole system), which of course is one of the features identified by both the historians of technology and the adoption-diffusion school (see above). But silage is only one example, if one of the

more egregious, of several cases of a gap between initial innovation and eventual widespread adoption. As was pointed out above, the late nineteenth century provides many instances of technologies that were known and widely discussed but not widely adopted, or not adopted to the extent that they would be subsequently: fertilizers and feedingstuffs are prime examples. Hence the case for examining the impact of technical change in general over an extended time period covering different price conditions, which is the approach adopted in Brassley (2000a). The initial problem to be overcome herein was the measurement of total output, which necessitated the construction of a new long-run output series measured in volume terms. This revealed that the period of maximum output growth was the twenty years between 1946 and 1965. Since land and labour input changes could not account for this output increase, several technical changes were examined. The overall conclusion was that the rapid adoption of pre-existing technology had the greatest impact, and it is interesting that this occurred at a time when agricultural prices, in real terms, were higher, over a sustained period, than they had been since the 1880s. In contrast to early adopters, innovators (to judge from Primrose McConnell, whose life is examined in Brassley, 1995b) appear to be motivated by their personal characteristics rather than their responses to price trends.

Conclusions and suggestions for further work

The studies presented here examine technical change from a variety of theoretical perspectives, basically historical, but informed by relevant aspects of sociology and economics. The principal conclusion which emerges is the significance of the gap between innovation and adoption. The history of agricultural science, as told here, demonstrates that the innovations it produces may not be adopted immediately. The rate of adoption is in part determined by the level of education and training in the farming community, as the work of the diffusion school would suggest, but it is also, and to a greater degree, determined by price levels and system complexity. Adoption appears to be enhanced more by high prices than reduced costs, other things being equal. But the reason why other things are not always equal is the wide range of individual-technology-specific factors which can be included under the term 'system complexity'. Thus further work on agricultural technology in the previous two centuries should use both sociological and economic approaches and recognize that different techniques have different system implications. Individual aspects of technology require further studies of the type presented here on silage (Walton (1999) is another example), which incorporate all relevant factors from science to product markets. Complementary studies of individuals as adopters over the course of their farming careers would also be useful. The following chapters and papers set out the evidence for these conclusions and show what this approach can begin to achieve.

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Agricultural Research in Britain, 1850–1914: Failure, Success and Development

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Summary

The development of agricultural science in the period 1850–1914 is described in the context of various methods of deciding whether or not it was successful. It is concluded that it was more successful after 1890 than before, and an explanation of this is offered, using a model first applied to agricultural research in Germany. In the light of these conclusions there are also comments on the role of the Development Commission in promoting agricultural research.

Contents

1. Introduction

Robert Olby's article on the establishment of the Development Commission in *Annals of Science* makes a detailed and convincing case for the importance of that body in promoting agricultural research in Edwardian Britain.[1] Yet, instrumental and influential as the Commission may have been, it was only a part, albeit a vital and conclusive part, of the story of the development of scientific research in agriculture in Britain in the period before 1914. Olby sets the Development Act of 1909 and the resultant Commission in its political context, but it might also be argued that its role in the development of agricultural science cannot be fully understood unless it is also set in its agricultural and scientific context. And that is what this paper attempts to do.

There is an interesting hiatus in recent writing on the history of agricultural science in Britain: Sarah Wilmot covers the period up to about 1870, and Palladino and Olby deal with the period after about 1910.[2] But, as I seek to demonstrate in the following

[1] Robert Olby, 'Social Imperialism and State Support for Agricultural Research in Edwardian Britain', *Annals of Science*, 48 (1991), 509–26.

[2] Sarah Wilmot, *'The Business of Improvement': Agriculture and Scientific Culture in Britain, c. 1700–c. 1870*. Historical Geography Research Series, No. 24 (1990); P. Palladino, 'The Political Economy of Applied Research: Plant Breeding Research in Great Britain 1910–1940', *Minerva*, 28 (1990), 446–68; P. Palladino, 'Between Craft and Science: Plant Breeding, Mendelian Genetics, and British Universities, 1900–1920', *Technology and Culture*, 34 (1993), 300–23; Robert Olby, 'Scientists and Bureaucrats in the Establishment of the John Innes Horticultural Institution under William Bateson', *Annals of Science*, 46 (1989), 497–510; Olby (note 1).

pages, it was the period *between* 1870 and 1910 that saw agricultural science in Britain begin to change from a small-scale activity in which few people commanding slender resources met with little success, to a more substantial enterprise in which more people, with more money, produced significant results, and began to develop an administrative and institutional structure for research that is still recognizable today.[3]

Until this recent work appeared, most writers on agricultural science in Britain appear to have followed Russell's well-known account.[4] For much of his working life Russell was Director of the Rothamsted Experimental Station in Hertfordshire, which had been established by Sir John Lawes in 1843. If a serious work of science history can be said to have heroes, then Lawes, his co-worker Dr (later Sir) Henry Gilbert, and Rothamsted itself are the heroes of Russell's book. More recently, Dyke has also argued for their importance.[5] But if Lawes and Gilbert were as successful as Russell and Dyke appear to believe, then the present-day observer would expect them to have attracted Government funding, and other scientists to work with them. Yet they did not, or, at least, not to any great extent, and it seems worthwhile to ask—why not?

The obvious answer is that the expectations of the present-day observer may be unrealistic when transposed to the very different circumstances of the mid-nineteenth century. To some extent this is true: Alter has demonstrated that for much of the nineteenth century science in Britain could expect little Government support.[6] On the other hand, this may be too simple an explanation. Successful agricultural scientists in Germany and the USA in the second half of the nineteenth century did attract both Government funding and additional scientists.[7] If this is to be explained simply in terms of differing Government attitudes, then it is necessary to show why those attitudes differed,[8] and to explain why reluctance to support agricultural research in Britain before *c.* 1890 was transformed into acceptance of, and perhaps even enthusiasm for, such support in the 20 years after 1890. Therefore this paper attempts to deal with two main questions: was agricultural science in Britain in the second half of the nineteenth century successful; and why did the research effort, measured in people and money, change so little before 1890 and so much thereafter?

2. The Success of Agricultural Science in Britain?

Both 'success' and 'agricultural science' are imprecise terms, and putting them together is therefore potentially dangerous in the absence of some clearer statement of what is meant by each of them. For the purposes of this paper it may be easier to define

[3] José Harris argues that this same period was one of significant change in many other ways, including demography, urban life, food production, retailing, finance, education, and culture, in *Private Lives, Public Spirit: Britain 1870–1914* (London, 1994), 252–53.

[4] E. J. Russell, *A History of Agricultural Science in Great Britain* (London, 1966). J. D. Sykes, 'Agriculture and Science', in *The Victorian Countryside*, 2 vols, edited by G. E. Mingay (London, 1981), I, 260–72, and R. Brigden, *Victorian Farms* (Marlborough, 1986), 198–201, are among those who follow Russell.

[5] G.V. Dyke, *John Bennet Lawes: The Record of his Genius* (Taunton, 1991); *idem*, *John Lawes of Rothamsted: Pioneer of Science, Farming and Industry* (Harpenden, 1993).

[6] Peter Alter, *The Reluctant Patron: Science and the State in Britain 1850–1920* (Oxford, 1987), 248.

[7] G. Grantham, 'The Shifting Locus of Agricultural Innovation in Nineteenth-century Europe: The Case of the Agricultural Experiment Stations', in *Technique, Spirit and Form in the Making of the Modern Economies. Essays in Honor of William N. Parker*, edited by G. Saxonhouse and G. Wright. Research in Economic History, Supplement III (Greenwich, 1984), 191–214 (192); M. W. Rossiter, *The Emergence of Agricultural Science: Justus Liebig and the Americans, 1840–1880* (New Haven and London, 1975).

[8] Olby (note 1), 510–11; Alter (note 6).

agricultural science in terms of what it was *not*. Thus model, example, or demonstration farms, agricultural consultants, and agricultural societies would be removed from the category of agricultural science because they were concerned with the diffusion of knowledge or the recommendation of best practice, and not with *explaining* why the best practice was so, or in finding out how things worked in order to produce *better* practice.[9] Consultants were scientists, but they were not necessarily involved in scientific *research*. Dr Augustus Voelcker, consulting chemist to the Royal Agricultural Society, spent much of his professional life analysing samples of purchased feeding-stuffs and fertilizers to find out whether the purchaser has been defrauded: important work, and scientific work, but hardly research.[10] In contrast, Lawes and Gilbert at Rothamsted, or, later, Biffen at Cambridge, attempted to explain how things worked by the application of skills or techniques not generally available to farmers in order to benefit the community in general. Science, for the purposes of this discussion, was explanatory, professional, and disinterested.

To explain what is meant by success in agricultural science or scientific research is, at first sight, more straightforward. Conventionally, there are three ways of judging success:

(1) by determining the effects on output or productivity;
(2) establishing whether scientists made discoveries or produced useful explanations of agricultural problems; and
(3) assessing contemporary and recent opinions, i.e. a peer review.

To these three it might also be interesting to add a fourth: to what extent did scientists succeed in developing institutions that increased their professional competence, such as university departments, laboratories and research institutions, libraries, learned journals, and learned societies? These four approaches are considered in what follows.

First, the effects on output or productivity. A recent survey of the economics of agricultural research states unequivocally that 'the principal objective of research in agriculture is to increase agricultural productivity', and at first sight this is an attractive and quantifiable measure of scientific success.[11] Scientists and technologists spend money on research and development [hereafter R&D] to produce new or improved techniques that are adopted by farmers who consequently produce more per unit input of land, labour, or capital. Thus the most effective science or technology produces the greatest increase in productivity (i.e. output per unit of input) for the smallest R&D expenditure. However, output is not only determined by the state of technology. In the short term it may be affected by weather or disease, and in the long term by changes in the objectives of farmers and changes in the rate at which they adopt innovations. Thus when product prices are low, the incentive to expand production is reduced, and when they are high it is enhanced. Therefore productivity changes are only usable as a measure of scientific success if the economic environment within which the producers are operating is stable over the period in which the productivity changes occur (this is explained in greater detail in the Appendix). In practice, economic conditions before

[9] S. Macdonald, 'Model Farms', in *The Victorian Countryside* (note 4), 214–26, argues persuasively that 'At no time was the model farm of any great significance as a means of influencing even the effective innovation leaders, never mind the mass of the farming community' (224).

[10] N. Goddard, *Harvests of Change* (London, 1988), 96.

[11] W. Lesser and D. R. Lee, 'Economics of Agricultural Research and Biotechnology', in *Current Issues in Agricultural Economics*, edited by A. J. Rayner and D. Colman (London, 1993), 179.

1875 were different from those that existed between 1875 and 1914.[12] Consequently, producers may have chosen to reduce other inputs at the same time as they adopted science-based innovations, and so the evidence of yield or output figures, even when they are available, is indeterminate: they may indicate scientific success, or they may hide it.

The second approach, which is more robust in the face of changing economic conditions, is to ask what science discovered or explained.

In 1840 the German chemist Liebig produced a report on *Organic Chemistry in its application to Agriculture and Physiology*. He argued that the nitrogen to be found in plants was derived from the ammonia in the air, and that the mineral constituents of each plant, especially phosphate and potash, came from the soil as it was broken down by weathering. Therefore, he argued, harvesting a crop led to the removal of these minerals, and so if the fertility of the soil were to be maintained they would have to be replaced. Inorganic fertilizers would be perfectly adequate for this purpose. Within a few years Liebig's patent manure was being made and distributed by Muspratts of Liverpool. Liebig had been careful to make the phosphate and potash insoluble so that it would not disappear in the drainage water. As a consequence, it was unavailable to the plant. Liebig's patent manure was a failure. And his views on nitrogen were being questioned by Lawes and Gilbert.[13]

Within two years of the appearance of Liebig's report, Lawes began work at Rothamsted. He recruited Gilbert, one of Liebig's pupils, and in 1843 the Broadbalk field experiment on the continuous growth of wheat was set up. It was soon possible to demonstrate a response to nitrate fertilizers and so disprove Liebig's assertion that plants obtained their nitrogen from the air. Liebig's theory 'received its death-blow from the experiments of Mr Lawes', according to Philip Pusey. But the experiments went on, and within a few years there were similar trials with barley, oats, roots (at first turnips, and then mangolds), and hay.[14] Lawes and Gilbert produced an immense amount of reliable basic data about fertilizer response, which was probably their major contribution to agricultural science.[15] They were not as good at explaining their results as they were at obtaining them. They never worked out why they obtained different responses to nitrogen from legumes (the Germans, Hellriegel and Wilfarth, demonstrated the presence of nitrogen-fixing bacteria on the roots of legumes in 1886), and even in 1895, when Robert Warington, one of their co-workers, had already demonstrated the complexity of the soil–nitrate relationship, they continued to assume that all the nitrogen produced in the dung of grazing animals would be available to the roots of crops.[16] After their successful challenge to Liebig, their main interests were (with the possible exception of their work on animal nutrition) more practical than theoretical. For example, none of the twenty-two conclusions of their main paper on ensilage touches on the chemical or bacteriological processes by which ensilage

[12] This has been the subject of a well-known controversy, some of the more significant work on which has been reprinted in *British Agriculture, 1875–1914*, edited by P. J. Perry (London, 1973).

[13] Russell (note 4), 97–100. It is commonly stated that Liebig's book was a report written at the request of the British Association for the Advancement of Science, but there is some doubt about whether this was in fact the case, according to W. H. Brock and S. Stark, 'Liebig, Gregory, and the British Association, 1837–1842', *Ambix*, 37 (1990), 134–47.

[14] E. W. Russell, *Soil Conditions and Plant Growth*, 10th edn (London, 1973), 13–14.

[15] This material was summarized in A. D. Hall, *The Book of the Rothamsted Experiments* (London, 1905).

[16] This point is made in Dyke, *John Lawes of Rothamsted* (note 5), 74.

preserves vegetation.[17] The range of this practical work was enormous: from bread reform and the effect of malting on the feed value of barley, to sewage and compensation for unexhausted improvements. Moreover, Lawes ran (until 1872) a fertilizer manufacturing company, another chemical works making citric and tartaric acids, and a sugar plantation in Queensland, Australia. He spent several months each year fly-fishing and deer-stalking in the Scottish Highlands, and between 1850 and 1900 he published, on average, one article every 40 days.[18]

So dominant were Lawes and Gilbert in the mid-nineteenth century that it sometimes seems as if they were the only agricultural scientists at work in Britain. They were not, although the list of the others is not a long one. James Johnston, reader in Chemistry and Mineralogy at the University of Durham until his death in 1855, is best remembered as a writer: his *Catechism of Agricultural Chemistry and Geology* went through 33 editions in his lifetime.[19] Charles Daubeny, who at various times held chairs of chemistry, botany, and rural economy at Oxford, proposed the idea of available and unavailable nutrients in 1845.[20] J. T. Way, in the few years (*c.* 1846–57) in which he worked in agricultural science, demonstrated the absorption of nutrients in the soil.[21] By 1850 many of the fungal pests of crops had been described, although there were no major breakthroughs in control methods. In 1860 John Curtis published *Farm Insects* and in 1881 Eleanor Ormerod published her *Manual of Injurious Insects*, so that subscribers to the services of the Royal Agricultural Society could discover what was eating their crops, although there was little that they could do about it.[22] The many papers on drainage that appeared were mainly written on the basis of practical experience rather than experimental results. Farm mechanization was much the same. Even at the end of the century, plant breeding could be described as 'a game of chance played between men and plants, with the chances in favour of the plants'.[23]

But if the achievements of British agricultural scientists were not extensive before 1890, by the end of the century things had begun to change. One of the main reasons for this was the foundation of the university departments of agriculture. Bangor was the first (1889), followed by Leeds (1890), Newcastle (1891), Nottingham (1892), Reading, and Wye (both 1894).[24] Somerville at Cockle Park (a research farm run by the department at Newcastle) from 1896 demonstrated the use of basic slag as a cheap and effective way of improving upland grassland. His successor, Gilchrist, pioneered the use of wild white clover in the Cockle Park seeds mixture for long leys.[25] At Cambridge, Biffen used Mendelian methods to breed Little Joss wheat in 1910, Wood took up the animal nutrition work started by Kellner in Germany and Armsby in the USA (his co-director at the Animal Nutrition Research Institute was Frederick Gowland Hopkins, who had just discovered vitamins), and F. H. A. Marshall worked on the physiological aspects of animal breeding.[26] John Percival, at Reading, virtually

[17] Ibid., 155–58.

[18] Ibid., 3, 6.

[19] G. E. Fussell, 'James Finlay Weir Johnston, 1796–1855', *Agricultural Progress*, 57 (1982), 35–40.

[20] Russell (note 4), 88.

[21] Ibid., 116–22. I am grateful to an anonymous referee for this point.

[22] G. Ordish, *The Constant Pest* (London, 1976), 153.

[23] Russell (note 4), 209.

[24] S. A. Richards, 'Agriculture Science in British Higher Education 1790–1914'. Unpublished MSc thesis, University of Kent at Canterbury, 1982, 117–22.

[25] Russell (note 4), 244–46, 250, 392–94.

[26] Ibid., 209–13, 260–63, 283–85; P. McDonald, R. A. Edwards and J. F. D. Greenhalgh, *Animal Nutrition*, 3rd edn (Edinburgh, 1981), 228–29.

defined the scope of agricultural botany when he published his book of that title in 1900, although Fream had started experiments in grassland ecology in 1888.[27] Stapledon carried on in this area after being appointed to Aberystwyth in 1912.[28] Winifred Brenchley, the first botanist to be appointed to the staff of Rothamsted (in 1906), also adopted an ecological approach to competition between crops and weeds. She was one of the scientists involved in a renaissance at Rothamsted after the deaths of Lawes and Gilbert, after which Hall, and then Russell, took over as director.[29] Hall and Russell together produced one of the first regional soil surveys, and Russell worked on soil fauna.[30] Both Hall and Russell had been at Wye College, again emphasizing the importance of the university connection. One of the few exceptions to this was F. J. Lloyd, a consulting chemist with a London practice, who worked on cheesemaking (at the Bath and West Society's cheese school at Frome) and milk hygiene.[31] Little work was done on farm management and agricultural economics, although Hall devised a system of full cost accounting, albeit too complicated to be of any practical use, and the Agricultural Economics Research Institute was established at Oxford in 1913 with C. S. Orwin as Director.[32]

Thus it appears that British agricultural science had some limited success before 1890, and rather more extensive success afterwards. This method of judging success is admittedly impressionistic and perhaps even Whiggish, in that it gives most prominence to the work that, with hindsight, seems most important. Therefore it is important to compare it with contemporary and recent opinions—the peer review process.

The conclusions of some recent commentators have already been mentioned. Russell, Dyke and Sykes[33] have tended to emphasize the successes of science. Mepham has drawn attention to the developments in quality control techniques that increased public confidence in the safety and palatability of milk by the end of the nineteenth century.[34] Offer's straightforward conclusion from reading Russell was that 'agricultural research in Britain was undertaken on a tiny scale by amateurs'.[35] Sarah Wilmot concluded that 'the evidence for the practical contribution of science to agricultural improvement during the period under examination [up to 1870] was not impressive', and suggested that the 'philosophic and ideological enthusiasm' for agricultural societies and journals might be the result of changes in scientific culture and society.[36]

Contemporary opinion was also divided. Ernle was quite convinced that 'the new alliance of science with practice bore rich and immediate fruit. Science helped practical

[27] J. Percival, *Agricultural Botany* (London, 1900); W. Fream, 'The Herbage of Pastures, *Journal of the Royal Agricultural Society of England*, 3rd series, 1 (1890), 359–92.

[28] J. Sheail, *Seventy-Five Years in Ecology: The British Ecological Society* (Oxford, 1987), 54–55.

[29] Russell (note 4), 219.

[30] A. D. Hall and E. J. Russell, *A Report on the Agriculture and Soils of Kent, Surrey, and Sussex.* Board of Agriculture and Fisheries, Miscellaneous Publication No. 12 (London, 1911).

[31] K. Hudson, *Patriotism with Profit* (London, 1972), 119.

[32] E. H. Whetham, *Agricultural Economists in Britain 1900–1940* (Oxford, 1981), 1–40.

[33] See notes 4 and 5.

[34] T. B. Mepham, 'The Emergence of Dairy Science in England', 12. Paper presented to a conference on the history of agricultural science and education held at Rothamsted Experimental Station, 12 May 1990. I am grateful to Dr Mepham for supplying me with a copy of his paper.

[35] A. Offer, *The First World War: An Agrarian Interpretation* (Oxford 1991), 101.

[36] Wilmot (note 2), 30; similar conclusions for earlier and later periods are adduced by J. Lerner, 'Science and Agricultural Progress: quantitative evidence from England 1660–1780', *Agricultural History*, 66 (1992), 11–27 (12); and Palladino (note 2).

farming in ways as varied as they were innumerable.' ... and so on for another eight pages.[37] *Nature* in 1879, noticing the forthcoming Royal Show at Kilburn, predicted that 'in every direction we shall learn how beneficial has been, and may still be, the influence of the scientific method upon the agricultural art'.[38] Lawes and Gilbert especially were noticed favourably in the public prints. Thomas Baldwin described Lawes as 'a private individual who, unaided by the state, or by any scientific body, has made a greater number of useful experiments than all the experimental farms of European Governments put together', although he admitted that 'Mr Lawes has not had an unqualified success, especially in drawing inferences from his facts. But his writings afford ample evidence of great earnestness of purpose.'[39] Caird, in 1878, wrote that 'to Mr J. B. Lawes the agriculture of this country is more indebted than to any other living man'.[40] Another prominent figure in late nineteenth-century agriculture, Sir Henry Rew, writing in 1897 was quite convinced that the work of Lawes and Gilbert 'has permeated farm practice and has influenced every phase of the cultivation of the soil and the treatment of livestock'.[41] Ernle was another enthusiast: 'On their work has been built the modern fabric of British agriculture'.[42]

On the other hand, Lawes himself was not quite so convinced. In 1881 he told a Royal Commission that science had yet to reach the standard of perfection required to teach everything about agriculture, although it might help another generation; in the meantime it was no substitute for a 'good thorough business-like knowledge' of farming.[43] Not everyone admitted the existence of agricultural science. Regent J. M. Gregory of the Illinois Industrial University argued in 1869 that 'looking at the crude and disjointed facts which agricultural writers give us, we come to the conclusion that we have no science of agriculture. It is simply a mass of empiricism.'[44] Caird, reviewing in 1878 the progress of the previous quarter century, felt that 'the change has been not in any considerable progress beyond what was then the best, but in the general upheaval of the middling and the worst towards the higher platform then occupied by the few',[45] Morton, an agricultural journalist, and Jenkins, secretary to the Royal Agricultural Society, conceded, in the 1880s, that the best practice of the time owed little to science and had little to learn from it; at about the same time Voelcker considered that the main challenge was increasing the relevance of science to agriculture. Malden and Wrightson, two of the leading agricultural scientists and educators in the 1890s, were similarly sceptical.[46]

Looking back, from the perspective of the late 1930s, J. C. F. Fryer observed that 'at the beginning of the twentieth century agricultural entomology and phytopathology

[37] Lord Ernle, *English Farming Past and Present*, 6th edn (London, 1961), 364ff. The first edition of this work was published in 1912.

[38] Anon., 'Science and Agriculture', *Nature*, 20 (1879), 189–90.

[39] T. Baldwin, 'Scientific Agriculture', *Nature*, 13 (1875), 101; cf. Dyke's comment that his work on evaporation 'did little to enhance Lawes' reputation as a scientist': Dyke *John Lawes of Rothamsted* (note 5), 45.

[40] J. Caird, 'General View of British Agriculture', *Journal of the Royal Agricultural Society of England*, 2nd series, 14 (1878), 286.

[41] Quoted in Sykes (note 4), 264.

[42] Ernle (note 37), 369.

[43] J. R. Fisher, 'Public Opinion and Agriculture 1875–1900', (PhD thesis, University of Hull, 1972), 82. Lawes's original replies may be found in c.3096, BPP xvii (1881), 950–53, questions 57646 and 57728.

[44] J. R. Kloppenburg, *First the Seed: The Political Economy of Plant Biotechnology, 1492–2000* (Cambridge, 1988), 59.

[45] Caird (note 40), 289.

[46] Fisher (note 43), 81–90.

had only just begun to take their places as definite branches of agricultural science';[47] according to Russell, 'in 1894 ... it could hardly be said that soil science existed in England ... every lecturer on agricultural chemistry included soil in his course along with fertilizers, feeding stuffs, animal nutrition, dairy chemistry, insecticides, and a variety of other subjects', but there was no English textbook on soil science, things seemed much more advanced in the USA, and 'curiously enough neither Lawes nor Gilbert seemed particularly interested in the soil'.[48] Animal nutrition work was also more advanced in Germany and the USA: 'the determinations of the food value and digestibility of the various cattle feeds depend almost wholly upon German and American data', according to an article written by Hall in 1904.[49]

It is important to recognize that Hall was engaged in fundraising for Rothamsted when he wrote this article. The Lawes Trust funds were only producing £2500 per year, whereas Lawes himself had been spending about £3000 per year on Rothamsted, and Hall wanted to expand its activities by taking on more people than Lawes had employed.[50] But he was not the first to compare research activity and expenditure in Britain unfavourably with other countries. Back in 1877, reviewing the Report of the Commissioners of Agriculture of the United States of America for the year 1875, *Nature* commented that

> The general interest in scientific agriculture is remarkably evinced in America by the large number of agricultural colleges. There are no fewer than thirty nine agricultural and mechanical colleges attended by 3,703 students and taught by 463 professors. When it is remembered that the total population of the States is only fractionally larger than our own, the fact of the existence of nearly 4,000 agricultural students is somewhat startling. In this country we have one agricultural college supported by less than 100 students. Yet we are the possessors of the most extensive colonies in the world, far exceeding in extent, even the vast area of the United States. It may well be difficult for English agriculturalists to compete with foreign rivals if the meagre number of agricultural students in England compared with America may be taken as in any degree a gauge by which interest in scientific progress may be measured.[51]

And not only agricultural students, but also experimental stations. In 1895 Herbert Cousins, one of the original members of the academic staff of Wye College, took the opportunity, when writing the preface to his translation of Professor Wolff's book on *Farm Foods*, to attack 'the paltry and inefficient way in which England has approached the problem of applying science, system, experiment and education to agriculture ', and the 'apathy of our own government towards the application of science of agriculture'. To support his case he argued that there were 291 experimental stations in other countries, including 67 in Germany, 54 in the USA and 53 in France in 1892.[52] His figures are roughly in line with those given by George Grantham, who states that the

[47] J. C. F. Fryer, 'Plant Protection', in *Agriculture in the Twentieth Century*, edited by A. D. Hall (Oxford, 1939), 291.

[48] E. J. Russell, 'Soil Science in England 1894–1938', in Hall (note 47), 163.

[49] A. D. Hall, 'Agricultural Research in England', offprint (with some alterations) from *Contemporary Review* (November 1904), 14.

[50] Russell (note 4), 234.

[51] Anon., 'Agriculture in the United States', *Nature*, 15 (19 April 1877), 525–26.

[52] Emil von Wolff, *Farm Foods: Or, the Rational Feeding of Farm Animals*, trans. H. H. Cousins (London, 1895), vii, viii.

number of publically funded agricultural research stations staffed by professional scientists increased from one in 1851 (at Mockern in Germany) to 90 in 1875, to 500 in 1990, spending about $2 million and employing 1500 professional scientists.[53] Agricultural science was not alone in suffering by comparison: 'In the middle decades of the [19th] century ... professional biology flourished in continental Europe at a level that it would not achieve in Britain or American until the last decades of the century'.[54]

These figures, for expenditure per station and number of scientists, are of the same order of magnitude as those given by Hall for Rothamsted, in that they suggest about three scientists and a budget of about £1000 per station. But some were clearly much bigger. Halle employed 15 people with PhDs, according to Hall, and Mockern had an income of £3150 per year, of which the Government contributed £2150. In the USA each state had a Federal Grant of £3000 for its experimental station, and there were 54 of them, together with agricultural colleges, and the federal USDA, which in 1905 spent £210 000 on specific investigations alone, in addition to the salaries of permanent officials.[55] In Britain, the Secretary of the Board of Agriculture, Sir Thomas Elliott, 'though a man of high ability and strong character, was not generally supposed in his later years to welcome novelties with enthusiasm', and in 1904–5 the Board spent no more than £425 on research.[56]

3. Failure before 1890: an explanation

It therefore seems clear that, in the opinion of most contemporary commentators, and in comparison with other developed countries, agricultural research in Britain would fail in a peer review exercise, certainly as far as most of the nineteenth century was concerned. How can this be explained?

In contrast to the position in Britain, agricultural research, advisory work and education in Germany developed earlier and more extensively. Thaer established his first agricultural academy at Celle near Hanover in 1802, and another in Prussia in 1806. By the 1930s similar academies existed in several German states.[57] There was at the time a controversy over the function of agricultural academies and the experimental stations which came after them: were they there to answer the farmers' questions or the chemists' questions? To investigate the laws of nature or the practice of agriculture? The controversy has been repeated in the recent historical literature on the topic. Finlay has argued that until the late 1850s the founders of the Mockern experimental station (generally recognized as being the first *state-supported* experimental station) were more concerned with the farmers' questions than with the chemists'. But he accepts that after 1857 more funds were allocated to the scientific section, and as Mockern was only founded in 1850 the question is only really concerned with the first few years of its existence.[58] Schling-Brodersen has set the Mockern station against the background of similar developments in other parts of Germany, pointing out that Liebig was an even more prominent and controversial figure in German agricultural science than in its British equivalent. Apparently he wanted the scientific work in agriculture to be

[53] Grantham (note 7), 192.

[54] P. J. Bowler, *The Fontana History of the Environmental Sciences* (London, 1992), 254–55.

[55] Hall (note 49), 21–22.

[56] H. E. Dale, 'Agriculture and the Civil Service', in Hall (note 47), 7.

[57] U. Schling-Brodersen, 'Liebig's Role in the Establishment of Agricultural Chemistry', *Ambix* 39 (1992), 21–31.

[58] M. R. Finlay, 'The German Agricultural Experiment Stations and the Beginnings of American Agricultural Research', *Agricultural History*, 62 (1988), 41–50.

dominated by the universities, in order to demonstrate the political and economic relevance of agricultural chemistry, and so promote the social status of chemistry itself. In practice, however, the experimental stations were out of his control and, in some cases, run by this opponents.[59] In summary, although some prominent and influential figures were antipathetic to the idea of agricultural research in state-run experimental stations, it was beginning to develop from the late 1850s onwards.

Grantham has suggested a model that explains the rapid expansion of agricultural research in Germany. He argues that the main problem for those investing in research is the uncertainty of the returns on their investment. Thus any factor that increases the expected marginal return on money invested in research increases the likelihood of the investment being made. Hence the importance of a scientifically literate bureaucracy and readily available scientific expertise: together, in the official mind, they produce a high expected marginal return from research. This, along with farm organizations that also favoured research, led to early funding of research by the state. 'What gives Mockern its significance is the degree of state support it received and the way that it spawned the first wave of research stations', argues Grantham. Scientists who worked there trained other scientists and encouraged them to take their expertise to further newly-established stations, and so the rapid expansion of the research effort was brought about. The crucial features of Grantham's model are therefore a scientifically-literate bureaucracy, cheap and plentiful scientists, farm organizations favouring research, state funding, and training of new generations of scientists by existing practitioners.[60]

The British experience can then be examined in the light of this model, in two periods: before and after *c.* 1890. In the earlier period there is little evidence for the existence of a scientifically literate bureaucracy, and the sort of scientist who would be paid 1200 marks in Germany would command an annual salary in Britain equivalent to 2000 marks, so the expected marginal return on research would be low.[61] Some British farmers adopted the methods advocated by the scientists, but one of the best known—John Prout of Sawbridgeworth in Hertfordshire—pointed out that other farmers were prevented from following his example by lack of security of tenure and restrictive clauses in their leases (Prout himself was an owner-occupier).[62] This is hardly incontrovertible evidence that British farmers were anti-science, but, equally, there is little evidence that they were enthusiastically pro-science. Perhaps they felt that before 1875 they did not need science; and after that they couldn't afford it. British governments were generally against public support for scientific research, and the Board of Agriculture was no exception. Even in 1902 Daniel Hall was told by Sir Thomas Elliott that British Agriculture was dead, and the Board's job was to bury it decently.[63] Thus there was little state funding, and the Royal Agricultural Society only supported a small experimental station at Woburn from 1876.[64] Whereas German scientists

[59] Schling-Brodersen (note 57), 26.

[60] Grantham (note 7), 196–98.

[61] Alter (note 6), 247–50. D. S. Landes, *Unbound Prometheus* (Cambridge, 1972), 187, makes the same point.

[62] C. S. Orwin, *The Future of Farming* (Oxford, 1930), 66.

[63] H. E. Dale, *Daniel Hall: Pioneer in Scientific Agriculture* (London, 1956), 56 n.1.

[64] Brigden (note 4), 203; although to be fair to the agricultural societies, the Bath and West of England Society's support for dairy research (see note 31) should be remembered. Conversely, although the Yorkshire Agricultural Society promoted some manuring experiments in the 1840s, it refused support for several scientific and educational projects, including a dairy school on the Bath and West model, between 1888 and 1896, according to Vance Hall, *A History of the Yorkshire Agricultural Society 1837–1987* (London, 1987), 84, 125.

encouraged young colleagues, Gilbert at Rothamsted accused one of his, Robert Warington, of 'trying to get known from my hard work', and was generally suspicious of young scientists.[65] And, perhaps, not only young ones. Eleanor Ormerod, consulting entomologist to the Royal Agricultural Society between 1882 and 1894 lived at St Albans, but seems never to have met Lawes and Gilbert or visited Rothamsted, even though it was only about an hour's walk away.[66] Most of the few practising agricultural scientists worked as consultants and so had no time for basic research. Consequently, in Britain before 1890, there were few research stations to build on the early example of Rothamsted.

However, when these conditions were changed, so was the outcome, and herein lies the answer to the second part of the question posed in my Introduction: why did agricultural science expand after 1890, and especially at the beginning of the twentieth century?

4. The post-1890 expansion

The scientific literacy of the bureaucracy was presumably improved when T. H. Middleton, Professor of Agriculture at Cambridge, moved to the Board of Agriculture in 1906 as Assistant Secretary in charge of education and research; Daniel (later Sir Daniel) Hall, Principal of Wye College and then Director of Rothamsted, went to the Development Commission in 1910. As the university departments of agriculture were established and expanded from 1889 onwards, more agricultural scientists became available.[67] It is more difficult to determine whether farmers' attitudes changed, although it is interesting to note that A. E. Humphries, a farmer and miller from Surrey and chairman of the Wheat Growers' Association, spoke approvingly of the work of Lawes and Gilbert in giving evidence to the Reay Committee in 1908, and argued that it was 'distinctly discreditable to a nation of our standing that we should expect such work as they have done to be done, as it has been done, on private resources'.[68] The report of the Reay Committee at least marked, if it did not actually produce, a change in Government thinking on support for agricultural research. It recommended increased expenditure on research without really saying where the money was to come from. It came, in the end, from the Development Fund, which was established in 1910 and controlled by the Development Commissioners, one of whom, as we have seen, was Hall.[69] One agricultural scientist, with the benefit of twenty years' hindsight, felt that the 1909/10 Development and Roads Improvement Act 'marked the beginning of a new epoch for agricultural entomology and phytopathology as for other sections of agricultural science.[70]

By 1914 research institutes were established at Imperial College (plant physiology), Cambridge (plant breeding, and also animal nutrition), Long Ashton (cider and fruit), East Malling/Wye (fruit), Rothamsted (soil and plant nutrition), Reading (dairying), Birmingham (helminthology), Manchester (entomology), Oxford (agricultural eco-

[65] Russell (note 4), 61–62.

[66] Dyke, *John Lawes of Rothamsted* (note 5), 31.

[67] Although some agricultural scientists came from a pure science background: Hall and Russell were both chemists.

[68] Board of Agriculture, *Report of the Departmental Committee on Agricultural Education in England and Wales*, 1908, Cd. 4206, (the Reay Committee), BPP 1908 xxi Minutes of Evidence, minute no. 13835.

[69] Olby (note 1), 521. See also T. DeJager, 'Pure Science and Practical Interests: The Origins of Agricultural Research Council, 1930–37', *Minerva*, 31 (1993), 131.

[70] Fryer (note 44), 292.

nomics), Kew (plant pathology), and the Royal Veterinary College (animal pathology)[71] Most of them, it is worth noting, were associated with university departments. But numbers of scientists involved were still small. Rothamsted, with 21 scientific staff, was the biggest, most of the rest had five to eight, and the total academic staff in all research institutes was 67.[72] The other part of the institutional framework was the learned society and journal. The expansion of agricultural colleges and peripatetic lecturers in the 1890s resulted in the production of much material that was too applied for the pure science journals and insufficiently popular for the agricultural societies' journals, so Hall, Wood, Biffen, and Middleton took the view that a journal 'devoted wholly to definitely scientific papers in agricultural subjects' was needed. Thus the Cambridge University Press began publishing the *Journal of Agricultural Science* in 1905.[73] A learned society covering the same range of interests, and run by and for scientists, on the other hand, never developed.[74]

5. Conclusions

British agricultural scientists, in the shape of Lawes and Gilbert, Johnston, and Daubeny, were active as early as the Germans and before the Americans, but their numbers did not expand as quickly. Neither (perhaps more arguably) did they achieve as much before 1890. The reason why is explained by Grantham's model for the rise of agricultural science in Germany, which seems to work well for Britain too, both in its neglect before 1890 and its observance afterwards. Therefore, in Grantham's terms, the Development Commission was important because it brought the scientifically literate into the bureaucracy. Olby's conclusion[75] about the importance of Hall is thus confirmed, and the influence hitherto attributed to Lawes and Gilbert is questioned. Nevertheless, agricultural science was beginning to expand before the establishment of the Development Commission, as the universities expanded,[76] and the Development Commission would have had no framework on which to hang its money if that had not happened.

This material also prompts, without answering, some further speculative questions: (1) Does the experience of Germany and the USA and Britain after 1890 suggest that scientific productivity increases when there is a critical mass of scientists? (2) Has too much of the investigation of agricultural science been done on a national basis? Should historians examine scientific problems and see how they were solved, rather than just

[71] Olby (note 1), 522.

[72] Board of Agriculture and Fisheries, *Annual Report of the Education Branch on the Distribution of Grants for Agricultural Education and Research, 1913–14* (Cd. 7450), 7, BPP, xi (1914), 717.

[73] 'Editorial', *Journal of Agricultural Science*, 1 (1905).

[74] It might be argued that the Royal Agricultural Society of England's interests ranged across agricultural science as a whole, but the papers in its *Journal*, where they touch on scientific matters, were almost invariably written by scientists for a readership of farmers and landowners, and this was also the group from which its leadership was (and still is) derived.

[75] Olby (note 1), 524.

[76] An adequate account of the reasons why the university agricultural departments expanded in the 1890s would require more space than is available here. P. Brassley, 'Developments in Agricultural Science, Research and Education', in *The Agrarian History of England and Wales*, VII (1850–1914), edited by E. J. T. Collins (Cambridge, in press), argues that several factors were involved, including greater availability of Government funding, general expansion of technical education prompted by fears of German competition, Victorian respect for science, attempts to combat the effects of depression in agriculture, and the efforts of a few pro-education agricultural journalists. See also Richards (note 24), and S. Richards, '"Masters of Arts and Bachelors of Barley": The Struggle for Agricultural Education in Mid-nineteenth-Century Britain', *History of Education*, 12 (1983), 161–75.

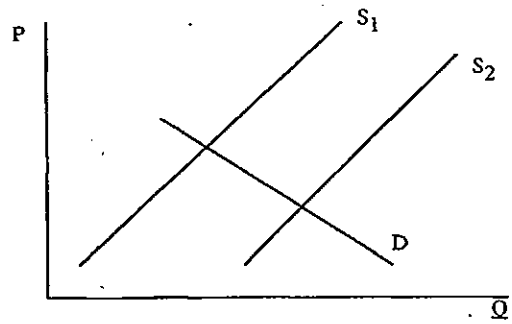

Figure 1. Effect of technical change upon the supply of a product. *P*, market price; *Q*, quantity demanded in or supplied to a market; S_1 and S_2, supply curves; and *D*, demand curve.

look at the activities of scientists in one country? and (3) How much of the failure of agricultural science in Britain is a result of the restricted market for agricultural products, in contrast to Germany, protected from imports from the USA, and the USA, with an expanding market for exports. The same question, the other way round, applies to the post-World War II period. Did science expand because farmers wanted, or were encouraged, to produce more, or did farmers produce more because science just happened to expand?

But most important is the confirmation of Olby's conclusion about the influence of Hall and the public money that he generated for agricultural research. The system of research he set up before World War I continued, with only a few modifications, until after World War II, and forms the foundation of the system we still have today. Equally, although Hall, the other early twentieth-century agricultural scientists, and the institutions within which they worked, might appear, at first sight, to have emerged fully formed from the cash-rich chrysalis of the Development Commission, it is important to recognize that they had been slowly developing, caterpillar-like, over the previous twenty (and in some cases sixty) years.

6. Appendix

The economist's conventional static analysis of a market relies on the demand curve, which relates the quantity demanded by the consumer to the price of the product, and the supply curve, which relates the quantity supplied by the producer to the price of the product. The market price of the product and the quantity supplied to the market is determined by the point at which the two curves intersect.[77] If price remains constant but another supply-influencing variable, such as the state of science or technology, changes, the supply curve will shift, usually to the right (from S_1 to S_2 in Figure 1), since no profit-maximizing producer would wish to adopt an innovation that reduced output for a given level of cost. Consequently, market price will fall and quantity produced will increase. Harvey has pointed out that the effect of a supply curve shift depends on the slope of the demand curve, which is determined by the price elasticity of demand for the product. If it is flat (price elastic demand, meaning that a 1% decrease in price will increase the quantity demanded by more than 1%) total revenue—price multiplied by quantity, which forms the consumers' expenditure on the product and the producers'

[77] The theory is explained in any economics text, such as J. Sloman, *Economics* (Hemel Hempstead, 1991), 62–67.

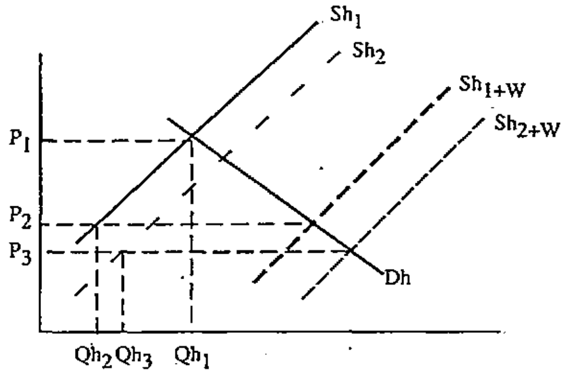

Figure 2. Effect of imports and technical change upon prices and quantities supplied. P_1, P_2 and P_3, market prices; Q_{h1}, Q_{h2} and Q_{h3}, quantities supplied to the market by British producers; S_{h1} and S_{h2}, British producers' supply curves, before and after technical change; W, imports from the world market; and D_h, home demand (i.e. from British customers).

receipts—will increase, and so farmers will have some incentive to increase output still further.[78]

From 1840, or earlier, to the mid-1870s this ought to have been happening. However, it does not mean that we can measure the benefits of science by simply assessing the extent of the output increase, because output depends on several factors, of which science/technology is only one. At its simplest, output can be increased by increasing the area devoted to a crop or an animal enterprise, but since this normally involves a reduction in the supply of an alternative product, total welfare is not necessarily increased. This is why both farmers and economic historians are most interested in *yield* or *productivity* increases. Productivity is the ratio of output to input, so a productivity increase is an increase in output per unit of input, brought about either by increasing the level of ouput while keeping input constant, or producing the same level of output for fewer inputs.

There are several ways in which productivity changes can be brough about. Good or bad weather conditions will affect yields from year to year, farmers may change their objectives in the face of different market conditions, from profit maximization when prices are high to survival when they are low, they may adopt already proven practices from other farmers and increase their use of manures and fertilizers or drainage, or they may adopt new kinds of technology, such as new varieties or new pesticides. Clearly the main impact of agricultural science is likely to be through the provision of new technologies, but this does not mean that the impact of science can be measured by the extent to which productivity increases, because the extent to which a new practice is adopted by a farmer depends on other, additional factors. Product prices are likely to be among the most important of these. Thus thousands of acres were underdrained when prices were high, but drainage virtually ceased when prices fell after the mid-1870s.[79]

From the mid-1870s onwards, as far as cereals were concerned, the supply curve was most affected by imports, which increased more or less constantly. Thus prices were reduced more than they would have been if the supply increase had simply been the

[78] D. R. Harvey, 'Beneficiaries in the Human Food Chain', in *Agricultural and Food Research—Who Benefits?*, edited by T. E. Wise (Centre for Agricultural Strategy, University of Reading, paper no. 23, 1991), 17–19.

[79] A. D. M. Phillips, *The Underdraining of Farmland in England in the Nineteenth Century* (Cambridge, 1989).

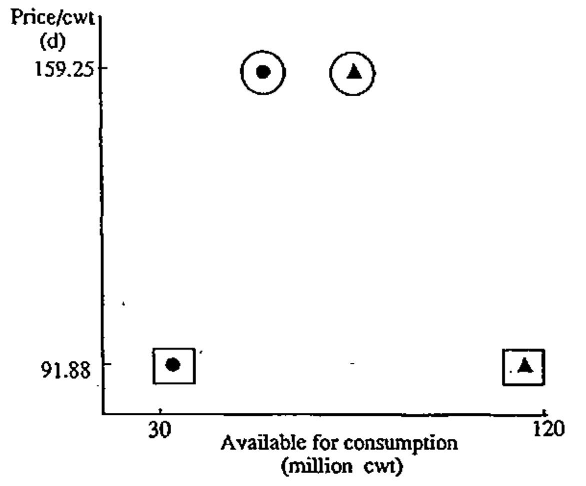

Figure 3. Prices, home production, and imports of wheat, 1852–60 and 1884–92. Home wheat production plotted against price: ⊙, 1852–60; and ⊡, 1884–90. Home wheat production *plus* imports plotted against price: ⊙, 1852–60; and ⊡, 1884–90.

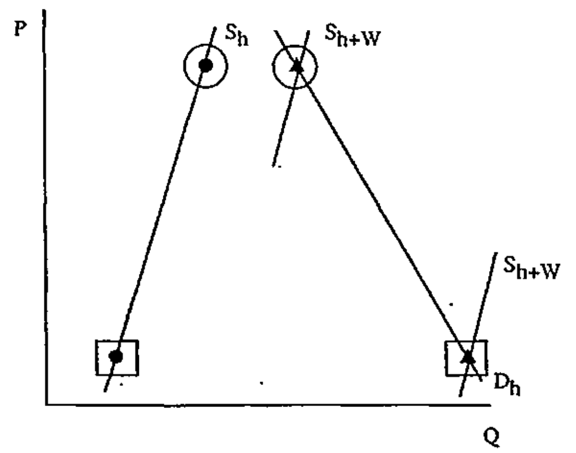

Figure 4. An explanation of the changes in prices and quantities supplied between 1852–60 and 1884–92, which does not involve technical change. For symbols, see Figures 1–3.

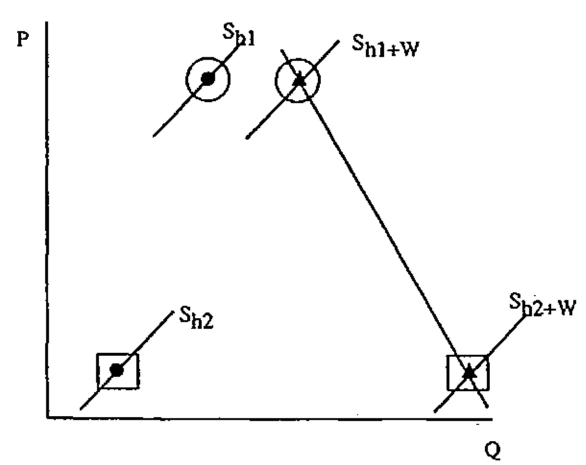

Figure 5. An explanation of the changes in prices and quantities supplied between 1852–60 and 1884–92, which assumes a technical change. For symbols, see Figures 1–3.

result of increased home output, and so this would reduce the incentive to expand production. And note that Palladino argues that farmers were aware of the possibility of increased output depressing prices.[80] This is explained in Figure 2, in which Dh represents home demand in Britain, and S_{h1} represents home supply from Britain before a science-based innovation. Under these conditions, market price is P_1 and Q_{h1} tons of output are supplied to the market by home producers. If the level of imports from the world market then rises, the supply curve for the British market shifts to $S_{h1} + W$, and price falls to P_2, with Q_{h2} tons of output sold to the market by home producers. In this case, output has changed while the state of technology has remained constant. Then a science-based technical change (not that all technical changes are science based) shifts the home supply curve to S_{h2}, so that the total supply curve shifts to $S_{h2} + W$, price falls to P_3, and the quantity sold to the market by home producers increases from Q_{h2} to Q_{h3}. In this case the technology change has produced an output change.

Figures 3–5 illustrate the same exercise, but using the real production and import statistics shown below:[81]

	Price per hundredweight (pence)	Available for consumption (million cwt)	
		Home production	Total
1852–53/59–60	159·2	57·377	77·669
1884–85/91–92	91·88	37·287	115·271

In Figure 3 the statistics for home production and imports are plotted, using points for home production and triangles for home production plus imports. Data for the 1850s are enclosed in circles, and those for the 1880s in squares. Figure 4 shows how the changes between the 1850s and 1880s can be explained without assuming technical change. In this case the home supply curve (S_h) does not shift, neither does the home demand curve (D_h), and only the total supply curve ($S_h + W$) shifts. Figure 5 shows how exactly the same figures can be explained, but this time assuming a technical change from S_{h1} in the 1850s to S_{h2} in the 1880s. There is no means of knowing, from the statistics alone, which is the correct explanation of the observed change. Indeed, there may even be a third explanation, involving a rightward shift of the demand curve.

Acknowledgements

I am extremely grateful to my colleagues Martyn Warren and Derek Shepherd for their comments on initial drafts of this paper, and to Barbara Sheaves for her help with the preparation of the diagrams. I am also grateful for the helpful and perceptive comments of an anonymous referee.

[80] Palladino, 'The Political Economy of Applied Research' (note 2), 467.

[81] Prices are taken from Ministry of Agriculture, Fisheries and Food, *A Century of Agricultural Statistics* (London, 1966), 81, and quantities from J. B. Lawes, 'Home Production, Imports, Consumption, and the Price of Wheat for 40 Harvest Years, 1852–3 to 1891–2', *Journal of the Royal Agricultural Society of England*, 3rd series, 4 (1893).

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'A Pioneer in Everything': Primrose McConnell, 1856-1931

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The nineteenth edition of Primrose McConnell's *The Agricultural Notebook* was published by Messrs. Blackwell in the summer of 1995[1]. The first edition, written by McConnell himself and published by Crosby Lockwood appeared in 1883[2]. Only Fream's *Elements of Agriculture*, first published in 1892 under the auspices of the Royal Agricultural Society of England, with its most recent edition, the seventeenth, now renamed *Fream's Principles of Food and Agriculture*, appearing in 1992, can claim as long a period in print as an agricultural textbook[3]. Fream has had his biographer[4], but apart from a note in recent editions of the *Notebook* to the effect that he was a tenant farmer of Ongar Park Hall, there has been no biography of McConnell. Yet many of the farmers, advisers, land agents and agricultural students who have kept successive editions of his work on their shelves over more than a century must have wondered who McConnell was, why he wrote his *Notebook*, what else he did in his lifetime, and how he came to be called 'Primrose'. This article attempts to answer those questions.

The name 'Primrose' has apparently been in McConnell's family for several generations, from the time when his ancestors were connected with the Primrose family estates near Edinburgh, and McConnell himself maintained the tradition in the naming of his second son, as did his daughter in the name of her second daughter[5]. At the time of Primrose McConnell's birth, on April 11th 1856, his parents, Archibald and Agnes, were farming Lessnessock Farm near Ochiltree in Ayrshire, about ten miles east of Ayr, but in 1862 Archibald McConnell moved a few miles further east to take the tenancy of Castle Mains Farm, New Cumnock[6]. The young Primrose was originally intended to become an engineer, and so, on leaving Ayr Academy, he was apprenticed to a Glasgow engineering firm. How long he remained is not known, but he did not complete his apprenticeship, and transferred to the University of Edinburgh to study agriculture[7]. When McConnell was there in the 1870s, the university did not award degrees in agriculture, but prepared its students for the diploma examinations of the Highland and Agricultural Society of Scotland. In 1878, at the age of 22, he obtained his diploma, and when Edinburgh instituted the degrees in agriculture in 1889 he returned to become the second student to obtain the B.Sc. By then he had also (in 1880) taken the Royal Agricultural Society of England's examination for membership[8]. For some time in the late 1870s and early 1880s he may have held an assistant manager's post on an estate in Staffordshire, and between 1880 and 1882 he was the professor of Agriculture in the Glasgow Veterinary College, but whether this was a full-time or part-time appointment in unknown[9].

In the summer of 1883 McConnell moved to Essex, and so was one of the first of what became a well-known migration of Scots farmers to what was then called 'derelict Essex'[10]. In the early 1880s, he subsequently wrote, 'reports and advertisements of vacant farms in the south of England appeared in the papers - notably in the *North British Agriculturalist* - land actually going begging for tenants; so we turned our eyes southward. First one or two came, and finding the taste good, sent back a satisfactory report to their friends. When these latter came, they in their turn sent for other friends, until now the country is overrun with us'[11]. With his father, he rented Ongar Park Hall Farm, near Epping, about twenty miles from London on stiff clay. There were 636 acres, about half of them arable when he first took the farm, but cereal prices were falling in the 1880s as cheap grain from the new world came on to the market, so he grassed down about 200 acres, and made his living from eighty dairy cows, sixty of which were in milk at any one time, and rearing sixty calves a year to two or three years old. He also fed sheep on grass and cake in the summer, until they were affected by scab, when he replaced them with more cattle. He described it as 'a dairy and mixed husbandry farm'; it was the policy with which most of the Scots immigrants were being successful[12].

Having reached the age of 27 and made a start in farming, McConnell went back to Scotland and married the Minister's daughter, Katherine Anderson, on January 10th 1884 at the Free Church Manse, New Cumnock. Later that year their daughter Anna was born. Archibald arrived three years later, to be followed in 1890 by their second son, Primrose. The family lived in a cottage on the farm until 1893, when Archibald McConnell senior returned to Scotland (he died in 1898) and they moved into the farmhouse[13].

By the beginning of the twentieth century McConnell was in his mid-forties and an established figure, not only as a working farmer but also as an educator[14] and writer (see below). His agricultural expertise had also taken him abroad. In the 1890s he crossed the Atlantic (not comfortably: he later told his granddaughter 'At first I was afraid I was going to die; then I was afraid I wasn't going to die') to visit the Sunbeam farms that Lord Brassey had set up for Red Indians in Saskatchewan, during which time he met some of the Indians who had fought Custer at the Little Big Horn. He also visited the United States, taking a close interest in the farm machinery, which he found to be rather more advanced than that to be found at home, and Holland and Switzerland, where his attention was caught most by the farm buildings[15]. And, on the recommendation of William Fream ('from personal knowledge'), he had just been elected a Fellow of the Geological Society of London[16].

In February 1904 McConnell, exasperated by his landlord's agents, gave notice of his desire to quit Ongar Park Hall. What began as a minor disagreement over valuations escalated into a major legal battle with his landlord, Major Capel Cure, and his agents, in which claim and counterclaim about permissible rotations, dilapidations, sales of hay, purchases of manures and feedingstuffs, ploughing of meadows, and maintenance of buildings were traded backwards and forwards between agents, solicitors, valuers, arbitrators, and, eventually, a judge in the Essex County Court. McConnell felt that he has had the better of the argument, but clearly resented the waste of time, energy, and money on legal costs[17]. His response was to write an 84 page report on the whole affair, containing every relevant letter and legal document, and have it privately printed. The reason for doing so, as stated at the beginning of the report, was that the case had so many unique features about it, and that many of his friends were interested in the details, especially of the valuations, 'that I consider it desirable to set these forth herein'[18]. It may have been as simple as that; it might also be that he had his reputation to consider. What would have been the effect on his career as a writer, lecturer, and generally accepted agricultural expert if the story that he had been taken to court by his landlord for what might be construed as bad husbandry went unchallenged? He had to demonstrate not only that he won the case, but also that the reason why it arose in the first place lay in the inability of a traditionally-minded landlord and his agents to cope with the implications of McConnell's modern methods of dealing with low prices for the traditional products of the district[19].

By the time the case ended McConnell had moved to a new farm. In the autumn of 1905 he bought North Wycke, 500 acres of the flat land between the Crouch and Blackwater estuaries, three miles from the sea. He took over the live and dead stock at valuation, and the labour force, some of whom remained with him for the rest of his life. He presumably managed to buy the farm out of the profits he had made at Ongar Park, but only just, for he admitted that 'Eighty cows and 10 horses (which is what he started with) are not sufficient stock for a 500 acre farm, I know, but I require some time to get up the stock, and I require more time to get up the money to pay for the same'[20]. The dairy herd was later increased to about 100 cows, initially Shorthorns and Ayrshires, but later with some Friesians, all housed in a purpose-built cowshed[21].

He remained at North Wycke for the rest of his life, gradually becoming less involved in the physical work of farming but remaining active as a writer[22]. His granddaughter remembers that he was always surrounded by piles of manuscripts and proofs. He brought out the eleventh edition of the *Notebook* in 1930, shortly after his wife's death, and in July 1931, at the age of 75, he too died. He was buried in the Congregational burial ground at Southminster[23]. North Wycke remained in the family until Anna Kelly died in 1943. It was sold shortly afterwards[24].

These, in brief, are the main details of McConnell's life as a farmer, and farming was clearly the foundation upon which all the many other aspects of his life, as writer, teacher, inventor, and public figure, were based. The *Agricultural Notebook*, first published in 1883 when he was still in his twenties and just beginning his career as a farmer, was the basis of his reputation as a writer and the reason why he is still remembered today. It began, he explained, when the author, as an agricultural student, '... oftentimes felt the great want of a book containing all the data connected with the subject he was studying... the great value of Molesworth's "Pocket-book of Engineering Formulae" (which he presumably discovered as an engineering apprentice) to engineers, and of similar books to those engaged in other professions, was so apparent to the author, that it occurred to him that a book compiled in the same style, and devoted to farming matters, could not fail to be useful as a ready means of reference for refreshing the memory'[25]. Since 45,000 copies of the eleven editions written by McConnell were sold he appears to have been right[26]. After his death the family discussed the continuation of the book, and concluded that no one author was competent over the range of material that McConnell, especially with the aid of his son, could cover. Accordingly, they suggested that the job should be given to an agricultural college[27].

In fact, the *Notebook* was not McConnell's first publication ('I began to write to the farm papers at the age of eighteen, when first learning to hold the plough'[28]), although it was his first book. Others followed: *The Elements of Farming*, a slim introduction to the subject published in 1896; *The Elements of Agricultural Geology* (1902), an account of his hobby; *The Diary of a Working Farmer* (1906); and *The Complete Farmer* (1908, with a second edition in 1911), a more substantial work. He also wrote sections of some of the multi-author multi-volume encyclopaedias which were popular at the beginning of the twentieth century[29], the article on Agriculture for the

Encyclopaedia Britannica[30], and articles for the major agricultural journals[31]. From 1905 he edited and wrote for his own magazine, *Farm Life*, initially of 12 pages, price 1d, in which the *Diary* was first published in weekly parts. Its aim was to provide news and practical information, all illustrated with photographs, country people being 'particularly susceptible to pictorial teaching', and to appeal to townspeople as well as those in the countryside[32]. He was also the dairy editor of the *Agricultural Gazette*[33].

As with his writing, McConnell's involvement with education was carried on in parallel with his farming. All of his appointments, with the possible exception of the Glasgow chair, were part time. After the Balliol lectureship (see above), the Essex Technical Laboratories at Chelmsford (the forerunner of Writtle College) were congratulated[34] on securing the services of 'one of the best known agricultural authorities in the country' as lecturer at their nine week winter school, and he was also an examiner at the Dairy Institute, Reading, at Cirencester, and at Wye College. In fact, much of public work was concerned with dairying. He was a council member of the British Dairy Farmers' Association, one of the founder members of the Eastern Counties Dairy Farmers' Association, and a regular attender at the Dairy Show in London[35]. Closer to home, he could be found proposing the toast at Agriculture at the local NFU annual dinner, or speaking at the dinner following the South East Essex Agricultural Society's annual ploughing match, or lecturing the Dengie Hundred Field Club on sugar beet cultivation, or the geology or prehistory of the area in the parish Room at Southminster. Probably his last lecture, in March 1931, was on the history of the Dengie Hundred, to the Congregational Church Guild at Southminster. His daughter Anna read his paper for him, but he was there to answer questions at the end[36].

If this long list of productions and achievements suggests a dour workaholic, it is misleading. Rather, it is evidence for his enormous energy and endless interest in the world around him. And it was no dilettante interest. As befitted an agricultural graduate, he believed in dealing professionally with the questions that puzzled him. Faced with a new plough, he would fit it with a dynamometer and use it himself for a day[37]. When he realised that he did not know when calves began to ruminate, he set his cowman to observe the calves, and he observed them himself too. After a while they compared notes, and agreed that the process began at about three weeks[38]. With the invention of a milking machine, he tried for several months, found that it resulted in decreased yields, went back to hand milking, and then, having considered his experiences, wrote an article for the *Agricultural Gazette* setting out his costs, yield changes, and probable explanations. But although he may have found against an individual machine, he was too wise to write off the whole idea: 'we do not know what mankind may accomplish in another generation. We may, therefore, see a successful milking machine, but it has not arrived yet'[39]. Bus loads of visitors would come to see his hundred cow cowshed[40]. He developed his own system of milk recording, for which he was awarded a gold medal, kept a Gerber fat testing machine in his own dairy, and invented an elevator and a hay sweep (and a fortnight before his death was taken to see it being pulled by a tractor)[41]. 'His conclusions on certain agricultural engineering subjects may not meet with the approval of our agricultural engineering friends, but they are quick to realise that the opinion of Mr Primrose McConnell carries, perhaps, more weight than that of any other man in the agricultural world', in the view of the *Hardware Man and Iron Workers Chronicle*[42].

And yet, despite his constant activity, he still found time to lay a Brownie trail or make a peep show for his granddaughter when she was a little girl, or talk to her for hours at a time about what she was learning at the East Anglian Institute of Agriculture (the name of Writtle College in the 1930s) when she was older. She described him as one of the first modern farmers: he operated a specialist enterprise on a large scale in response to the market forces of the time, and adopted whatever innovations passed his critical evaluation: Friesians, for example, did, and silage did not. It is a convincing argument. He was, as she says, 'a pioneer in everything'[43].

Acknowledgements

The author is most grateful to Miss Kathleen Kelly, Primrose McConnell's granddaughter, for agreeing to be interviewed for this article, to John and Mary Evered for making the interview possible, and to the editor of this *Journal* for realising the significance of Mr Evered's kind offer. For all her work in the Essex Record Office and the British Library at Colindale, and an enormous amount of other material, he is also indebted to Elizabeth Sellers of Chelmsford.

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1. R. J. SOFFE (ed.), *The Agricultural Notebook* (Blackwell, 1995).
2. PRIMROSE McCONNELL, *Notebook of Agricultural Facts and Figures for Farmers and Farm Students,* (Crosby Lockwood and Co., London, 1883). This is the title as it appears on the title page of the first eleven editions, although the title is given as *The Agricultural Notebook* on the front cover and *McConnell's Agricultural Notebook* on the spine. From the twelfth (1953) edition the title is standardised as *The Agricultural Notebook* wherever it appears. For the sake of brevity, it will henceforth be referred to as the *Notebook.*
3. W. FREAM, *Elements of Agriculture* (John Murray, London, 1892); C. R. W. Spedding (ed.), *Fream's Principles of Food and Agriculture* (17th edn., Blackwell, Oxford, 1992).
4. GWYN E. JONES, 'William Fream: agriculturist and educator', *Journal of the Royal Agricultural Society of England* (henceforth given as *JRASE*) vol 144 (1983) pp.30-45. There is a shorter biography at the beginning of the two most recent editions of *Fream's.*
5. There are two accounts of the connection. In one, from McConnell's granddaughter, Kathleen Kelly, (in an interview with the author, henceforth referred to as 'K. Kelly interview', at Birch, near Colchester, on March 30th 1995, for the arrangement of which my thanks are due to John and Mary Evered) the McConnell's were factors to the Earls of Rosebery, whose family surname was Primrose, at Dalmeny House, a little to the west of Edinburgh. The other version (in the *Burnham on Crouch and Dengie Hundred Advertiser,* Essex Record Office, T/A 823, (henceforth referred to as the *Advertiser*) of 11th July 1931) has the McConnell's as tenants to Viscountess Primrose at Oxenford, about ten miles south east of Edinburgh.
6. *Advertiser,* July 11th 1931; see also McConnell's marriage certificate in the General Register Office, Edinburgh. According to Miss Kelly, the young Primrose shared a pram from time to time with his future wife, the daughter of the Rev. George Anderson, free Church Minister of New Cumnock (K. Kelly interview).
7. *Advertiser,* 11th July 1931.
8. Obituary of Primrose McConnell, *University of Edinburgh Journal* vol iv No.3 (1931) pp.297-8.
9. The only reference to his job in Staffordshire is in the *Advertiser* obituary (11 July 1931), but since this is otherwise reliable there is no reason to discount it. The dates for his chair at Glasgow are given in J. R. Fisher, *Public Opinion and Agriculture, 1875-1900,* University of Hull Ph.D. thesis (1972) p.67. Unfortunately, Fisher gives no source for his statement, but on the title page of the first edition of the *Notebook* McConnell is described as 'Late Professor of Agriculture, Glasgow Veterinary College'.
10. C. S. ORWIN and E. H. WHETHAM, *History of British Agriculture, 1846-1914* (2nd edn., Newton Abbot, 1971) p.275; the phrase 'derelict Essex' is used in Primrose McConnell, *Report on the Valuations at Ongar Park Hall, Ongar, Essex,* (published by the author, no date stated but c. 1907, henceforth referred to as *Valuations*) p3.
11. PRIMROSE McCONNELL, 'Experiences of a Scotsman on the Essex Clays', *JRASE* 3rd series vol 2 (1891) p. 312; he later claimed that 'certain articles of mine then (1883) published in the *Ayr Advertiser* and the *North British Agriculturist* were afterwards blamed for starting the stream of north-country men towards Essex'. (*Valuations* p.3).

12. PRIMROSE McCONNELL, *The Diary of a Working Farmer* (London, 1906, henceforth referred to as *Diary*) p.90; the description is in the preface to Primrose McConnell, *The Elements of Farming* (Vinton's Handbooks of the Farm, London, 1896).
13. Marriage Certificate, General Register Office, Edinburgh; 1891 census enumerator's data for Ongar Park Cottage, Stanford Rivers parish, Essex, in PRO RG 12/1360, folio 55, No.13; *Advertiser* 11 July 1931.
14. He had taught agricultural science at balliol College, Oxford, from 1886 to 1893, and was Assistant Examiner in the Principles of Agriculture for the courses then run by the Science and Art department at South Kensington. See Fisher, *Public Opinion and Agriculture*, p.67; details of the assistant Examiner's job are mentioned on the title page of the 5th edition of the *Notebook.*
15. K. Kelly interview; obituary in the *Essex Weekly News*, 10 July 1931; C. BEALE and G. OWEN, *Writtle College: the first hundred years* (Writtle, 1993) p.9.
16. From a copy of the certificate of application provided by Mr John Thackray of the Geological Society of London.
17. The final result left him with all but about £104 of his final claim of £1,232, but Major Capel Cure was awarded only £396, out of a counter-claim of £1,388. These, at least are the total figures given in the report, but if the sums of which they are apparently composed are added together, McConnell's total claim appears to be £1,837, of which he was awarded £1,643, which was £194 less than his claim. (*Valuations* pp.82-3).
18. *Valuations*, p.3.
19. In this context it is interesting to remember that John Prout, who made money out of continuous cereals in this period, considered that he was only able to do so because he was an owner-occupier and did not have to worry about a landlord's claims for dilapidations. See John Prout, *Profitable Clay farming under a just system of Tenant Right* (Stanford, London, 1881) pp.96-100.
20. *Diary* pp.90, 92 and 96. The purchase price of North Wycke is unknown, but he estimated the value of Ongar Park at about £10 per acre, so if he paid the same for his new farm, which he might not have done, for it was not well equipped (see K. Kelly interview) it would have cost him about £5,000).
21. K. Kelly interview.
22. His daughter Anna married in 1910 and returned to live at North Wycke in 1928, when her husband, James Milroy Kelly, became farm manager there. His son Archibald was an invalid with tuberculosis from 1922, and died in 1935. His younger son, Primrose, fought through the first World War as an artillery officer, and was killed in 1918. The effect on his father can only be imagined, but it is worth remembering that McConnell had lost not only a son, but also a colleague in farming and writing. At the time of his death he was helping with the latest edition of the *Notebook*, and the 9th, 10th and 11th editions are dedicated to him. K. Kelly interview; *Essex Weekly News*, 4 November 1904 and 8 March 1935.
23, *Essex Chronicle* 17 July 1931.
24. K. Kelly interview.
25. Preface to the first edition of the *Notebook.*
26. Foreword to the 12th (1953) edition. McConnell's work also has its imitators for related professions, such as Bright's *Agricultural Surveyor and Estate Agent's Handbook*, also published by Crosby Lockwood, and J. C. Newsham's *The Horticultural Notebook* (Technical Press, London, 1937), the preface to which specifically acknowledged 'the usefulness to Agriculturists and all who are connected with Rural Economy of Mr McConnell's "Notebook..."'.
27. K. Kelly interview. In the early 1950s the copyright had passed to Farmer and Stockbreeder publications, who invited Dr Ian Moore, the Principal of Seale-Hayne College, to edit a new edition. The editors, and many of the contributors, have been drawn from the staff at Seale-Hayne (now part of the University of Plymouth) ever since then.
28. *Diary* p.95.
29. Including R. P. Wright's *The Standard Cyclopaedia of Modern Agriculture and Rural Economy* (1905-10) and C. E. Green and D. Young's *Encyclopaedia of Agriculture* (1907).
30. According to the title page of the 11th (1930) edition of the *Notebook*, which makes a statement to this effect.
31. Primrose McConnell, 'Experiences of a Scotsman on the Essex Clays', *JRASE* third series, vol. 2 (1891) pp.311-24; Primrose McConnell, 'Rotations', *JRASE*, vol. 69 (1908) pp. 17-31; Primrose McConnell, 'Milking Machines', *Journal of the Bath and West and Southern Counties Society*, 4th

32. Copies of *Farm Life* are held at the British Museum Newspaper Library at Colindale in London. It ceased publication in 1920, by which time McConnell's involvement with it appears to have ceased.
33. *Advertiser* 11 July 1931.
34. By the *Essex Weekly News* of 4 Nov 1904).
35. *Advertiser* 11 July 1931.
36. *Advertiser,* 25 Dec 1909, 28 Jan 1911, 20 Jan 1923, 27 Oct 1923, 7 March 1931.
37. *Diary*, p.7.
38. K. Kelly interview.
39. The article was subsequently reprinted in the *Journal* of the Bath and West Society; see note 31. By the 1911 edition of *The Complete Farmer* only five years later, he could write (p.414) 'we seem now to be within sight of a solution to the mechanical difficulties of the problem'.
40. K. Kelly interview.
41. *Advertiser*, 11 July 1931; the sweep rake is illustrated on p.320 and described on pp.385-6 of *The Complete Farmer* (2nd edn., 1911), where McConnell claims that 'This labour-saving implement is of American origin, and was first adapted to work in this country in 1894, by the author of this handbook. It took him two years of experiment and development to get it to handle an English crop satisfactorily, but it is now a recognised adjunct of the hayfield, and many thousands with many different modifications introduced by different makers are now in use in the South of England'.
42. Reported in the *Advertiser*, 7 March 1914.
43. K. Kelly interview.

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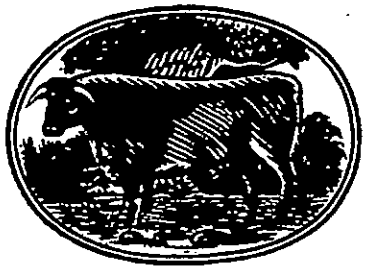

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Silage in Britain, 1880–1990: The Delayed Adoption of an Innovation*

By PAUL BRASSLEY

Abstract
Silage is now the most common way for grass to be conserved as winter fodder. It has become so only within the last twenty years, but this is the culmination of a process which has been going on since about 1880 in Britain. The technique was introduced into this country from continental Europe in the early 1880s, and generated much interest in the wet summers of that decade, to the point where official reports were written upon it and detailed statistics collected which make it possible to assess the extent of its penetration into general farming practice. Thereafter interest dwindled for twenty years, to be revived during and after the First World War, and especially during the Second World War. From the 1940s onwards it is possible to make estimates of national production, which demonstrate gradual adoption until the 1970s, when the rate of adoption increased dramatically. The technical and economic changes which produced these wanings and waxings of interest in silage are discussed, and the conclusions which can be drawn from this case study for the adoption of innovations in agriculture are considered. The most important point to emerge is the necessity for all components of a system to be in place before rapid adoption can occur.

'GOOD hay, sweet hay, hath no fellow' cried Nick Bottom, the weaver, in *A Midsummer Night's Dream*, but he was under the influence of the Queen of the Fairies at the time, and, presumably, he had never tried to make good sweet hay in a bad summer.[1] When, in the wet summers of the 1880s, the farming press began to carry stories about a technique called 'ensilage', which promised good winter fodder in the absence of sunshine, it was not surprising to find that it rapidly attracted the attention of opinion-formers in the agricultural industry. Prominent scientists conducted experiments upon it, and the Royal Agricultural Society and a government commission published reports which confirmed its usefulness. An ensilage society was formed. Thorold Rogers, MP and economic historian, wrote a long letter to *The Times* in 1882 (and followed it up with a book the following year) extolling the virtues of silage as it was made in the USA,[2] where it was rapidly becoming established.[3] Thus the widespread and rapid replacement of hay by silage in Britain, too, might have been expected.

In the event, the process took nearly a century. The rapid adoption of silage, to the point where its production is now ten times greater than that of hay, has taken place, but only in the last two decades. Despite the attention of agricultural scientists, and numerous official campaigns to popularize it, silage has only recently overtaken hay as the most popular method of fodder conservation. Ironically, perhaps, this recent expansion of silage, with its associated use of nitrogen fertilizer, has been blamed for the increasing rarity of

* I am most grateful to two anonymous referees and to my colleagues Martyn Warren, Derek Shepherd, John Halley, John Usher, and John Brockman for their comments on a previous draft of this paper, and to Barbara Sheaves for her help with its production.

[1] William Shakespeare, *A Midsummer Night's Dream*, act 4, scene 1, line 33, in S Wells and G Taylor, eds, *William Shakespeare: The Complete Works*, 1988, p 326.

[2] J E Thorold Rogers, *Ensilage in America: Its Prospects in English Agriculture*, 1883. The letter to *The Times* of 23 October 1882 is printed as an appendix to this book.

[3] According to John T Schlebecker, *Whereby We Thrive: A History of American Farming, 1607–1972*, Ames, Iowa, 1975, p 183, the first silo was built in the USA in 1873, by the 1890s most dairy farmers used silage, and by 1914 it was becoming popular in cattle feeding areas. I am grateful to Dr Douglas E Bowers, head of the Agricultural and Rural History Section in the United States Department of Agriculture, for providing me with this and many other references.

meadow flowers and partridges (*Perdix perdix*) and the disappearance of the corncrake (*Crex crex*) from mainland Britain.[4]

This paper seeks to describe the initial introduction of silage in the nineteenth century, trace its progress through the twentieth century, and explain the long delay between its initial introduction and eventual widespread adoption.

I

The system of ensilage 'might be summed up as the burying of grass in trenches', according to John Wrightson, professor of agriculture at the Downton Agricultural College, writing in 1890.[5] If ensilage is the process, the resultant product is now called silage, although it, too, was often called ensilage in the nineteenth century, and the trench or pit in which the grass was buried was called a silo. Cut grass continues to respire, converting sugars to carbon dioxide and water, and giving off heat in the process. When it is turned into hay by the action of sun and wind this process is arrested by drying, which also inhibits the formation of moulds. Artificial drying, either by forced draught ventilation as in barn hay drying, or in a high-temperature drier, has the same effect. When the dry matter content of the grass reaches about 85 per cent, its degradation ceases, but since grass in the field contains only about 25 per cent of dry matter this means that about 3.25 tonnes of water must be lost to produce one tonne of hay. Preservation by ensilage works on a different principle. The action of the enzymes which enable respiration to occur can also be prevented by changing the acidity of the ensiled material in the absence of oxygen. Bacteria present on the crop ferment the sugars it contains to lactic and other acids which, in effect, pickle the ensiled material as long as oxygen is excluded. If oxygen is available the whole heap will decompose like a pile of lawn mowings. The obvious advantage of the process is that the farm's winter fodder supply is no longer so dependent upon the dry weather required to make hay. Moreover, since drying is less important, the grass can be cut when it is younger and leafier and so has a higher feed content. On the other hand, achieving the conditions required to produce the lactic fermentation required to make good silage is no less, and possibly more, technically demanding than making good hay.[6]

Wrightson saw ensilage as a product of the 1880s, but the idea of preservation by burying in pits was much older than that.. The word 'silo' is apparently derived from *siros*, a Greek word for a pit used for storing corn, and many of the early references to storage in pits similarly refer to corn, rather than forage, storage. The Roman Columella, for example, refers to *siri*, pits in the ground used for corn storage, especially in the overseas provinces.[7] On the other hand, there seems to be some evidence for the ensilage of green fodder in Carthage in 1200 BC, and Cato, writing about AD 100, speaks of the Teutons storing green fodder in the ground and covering

[4] B H Green, 'The impact of agricultural management practices on the ecology of grasslands,' p 1.9, and T C E Wells, 'Responsible management for botanical diversity' pp 4.4–4.7, both papers presented to British Grassland Society meeting on *Environmentally Responsible Grassland Management*, Hurley, Berks, 1989; A Colston and J Best, 'Vanishing meadows', *Natural World*, No 32, 1991, pp 22–24; A Crofts and R G Jefferson, eds, *The Lowland Grassland Management Handbook*, 1994, esp p 5:8. I am grateful to Caroline Steel of The Wildlife Trusts for this reference. For the corncrake, see also John Arlidge, 'Crofters' care makes isles a haven for corncrakes,' *The Independent*, 10 August 1994, p 5, which reported that farmers in the Western Isles of Scotland were being paid up to £50 per hectare by various conservation bodies to delay harvesting hay meadows until 1 August in order to allow corncrake chicks to fledge before the grass was cut. Many of those on the island of Tiree were reported to use the money to pay for baling their silage.

[5] J Wrightson, 'The agricultural lessons of "the Eighties"', *JRASE*, 3rd ser, 1, 1890, p 285.

[6] P McDonald, *The Biochemistry of Silage*, Chichester, 1981, pp 11–12 and 42–59; H I Moore, *Grassland Husbandry*, 1946, pp 94–5; J S Brockman, 'Grassland', in R J Halley and R J Soffe, eds, *The Agricultural Notebook*, 18th ed, 1992, pp 198–200.

[7] McDonald, *Biochemistry of Silage*, p 10; K D White, *Roman Farming*, 1970, p 428; storage vessels for grain are referred to as silos in S Isager and J E Skydsgaard, *Ancient Greek Agriculture: An Introduction*, 1992, p 55.

it with dung. In the medieval period wilted grass was ensiled in Italy, in the eighteenth century in Sweden and Baltic Russia, and in early nineteenth century Germany beet tops and leaves were ensiled.[8] 'In so different a climate as that of the islands of the South Seas the natives avail themselves of the principle of the silo for the preservation of bread-fruits', wrote Martin J Sutton in 1895.[9] Clearly the principle was widely known from early times, but apart from prehistoric grain storage pits and isolated references in seventeenth-century manuals of husbandry, it does not seem to have made much impression on farming in Britain until the 1880s.[10]

The first mention of anything resembling silage in the nineteenth-century agricultural literature in Britain appeared in the *Transactions* of the Highland and Agricultural Society in 1843. James Johnston, a lecturer in chemistry at the University of Durham and a well-known writer on agriculture, published an article arguing for the importance of feeding moist materials to livestock, in the course of which he posed the question 'Is it possible to preserve these crops in their moist state? Can I cut them down and so preserve them undried, as to obtain from them, for my cattle, an amount of food more nearly equal to that which the fresh cut grass is capable of affording? A method has lately been tried in Germany, which, by the aid of a little salt, seems in a great measure to attain this object'. He then went on to translate the contents of an article in the *Transactions of the Baltic Association for the Advancement of Agriculture* for 1842 which described the preservation of grass by salting.[11] This is, of course, the same technique as that used in the making of sauerkraut, which preserves green material by producing a lactic acid fermentation, as the process of ensilage does, and which had been known in Germany for centuries.[12] The importance of Johnston's article appears only in hindsight: it seems to have been ignored for nearly forty years.

Johnston was probably correct in postulating a German, or, at least, a non-French, origin for the practice of ensilage of forage crops. Some English writers appear to assume that silage developed in France, perhaps as a result of the importance of Frenchmen in popularizing the idea in England,[13] but although the French had been experimenting with the storage of cereals in silos in the first half of the nineteenth century, they appear to have acquired the idea of storing forage from a French translation of a series of letters written to a German newspaper between 1862 and 1865. These were written by Herr Reihlen of Stuttgart, who, in 1861, attempting to avoid the waste of sugar beet leaves and tops, decided to preserve the leaves and tops from 400 acres of sugar beet in silos five or six feet deep. The experiment was successful, and Reihlen took it further. He had been to America, and on his return to Germany, experimented with growing maize. This was hardly a new crop in Europe, having been grown in Spain since the sixteenth century and in France, Italy and southern Germany since the seventeenth century. However, near Stuttgart, which is near the northern limit for the reliable production of grain maize, he found that his crop did not always ripen, and so took to preserving it in his silos, sometimes alone, and sometimes mixed with beet pulp. By 1870 his silos, ten feet deep and fifteen feet wide at

[8] McDonald, *Biochemistry of Silage*, p 9; it may be worth noting that G Barker, *Prehistoric Farming in Europe*, 1985, p 48 denies that silage was made in the prehistoric period.

[9] Martin J Sutton, *Permanent and Temporary Pastures*, 5th ed, 1895, p 122.

[10] H I Moore, 'The conservation of grass', *JRASE*, 133, 1972, p 29.

[11] James F W Johnston, 'On the feeding qualities of the natural and artificial grasses in different states of dryness', *Trans Highland and Agricultural Soc*, new ser, 9, 1843, pp 60–61.

[12] M Toussaint-Samat, trans A Bell, *A History of Food*, 1992, pp 693 and 775; Henry Woods, in his *Ensilage: Its Origin, History and Practice*, 1883, p 12, advances the same argument.

[13] H I Moore, *Silos and Silage*, 2nd ed, 1950, p 10; S J Watson and A M Smith, *Silage*, 1951, p 15; Woods, *Ensilage*, p 12.

the top, had a total length of three-fifths of a mile.[14] Reihlen's letters were translated by a M Vilmorin-Andrieux and published in the *Journal d'Agriculture Pratique* in 1870.[15] At about the same time Comte Roederer, in the Orne department of Normandy, began making silage of green maize mixed with cut straw and oat cavings, and a M Moreul ensiled unchopped but salted maize. Then in 1877 Auguste Goffart published his *Manuel de la Culture et de l'Ensilage des Mais et autres fourrages verts*, which described the process of ensilage in detail, and was influential not only in France, where it resulted in the decoration of its author by the national agricultural society, but also in America.[16] The story was taken to England by the Vicomte de Chezelles, who farmed in the Oise department, about thirty miles north-east of Paris, and visited the Royal Show at Reading in 1882, where he described his methods of making silage in pits using red clover, sainfoin, lucerne, meadow grass, winter and summer vetches, and maize.[17]

Whether Herr Reihlen thought of the idea of ensiling his sugar beet tops independently, or whether he adapted the ideas of others, is unclear. His influence upon French practice, and, consequently, upon the adoption of silage in Britain and America, seems undeniable.[18] But his was not the only influence. In 1870 Samuel Jonas of Chrishall Grange near Saffron Walden, a large (4200 acres of arable) and prominent farmer, wrote to the *Journal* of the Royal Agricultural Society with details of his system of enhancing the feeding value of cut chaff by mixing it with about one hundredweight of cut tares or green rye and one bushel of salt per ton of chaff: 'It is, if well managed, thus rendered by fermentation as sweet as well-made hay, and eaten by our flocks with great avidity', and had enabled him to feed both sheep and cattle during two winters in which the turnip crop had been a complete failure.[19] Subsequently, in 1874, John Wrightson, then professor of agriculture at the Royal Agricultural College, undertook a ten-week tour of the Austro-Hungarian Empire, and published a report of it on his return. 'In the management and preservation of fodder-crops, the Austrians and Hungarians are in advance of English agriculturists', he argued, and drew attention to the system of making 'sour-hay':

> It is done by digging long graves or trenches, 4 feet by 6 or 8 feet, in depth and breadth, and cramming the green grass or green Indian corn (maize) tightly down into them, covering the whole up with a foot of earth. The preservation is complete, and the wetter the fodder goes together the better. No salt is used, and the operation is as simple as it appears in the description... This sour-hay affords a capital winter fodder, and when cut out with hay-spades, it is found to be rich brown in colour and very palatable to stock. The making of sour-hay is very similar to the process of preserving 'pressling', or sugar-beet pulp, which is also stored in long graves until wanted for winter's use.[20]

[14] H M Jenkins, 'Report on the practice of ensilage, at home and abroad', *JRASE*, 2nd ser, 20, 1884, pp 129–37; E S Bunting, 'History of the maize crop in N W Europe', in E S Bunting, ed, *Production and Utilisation of the Maize Crop*, Ely, 1980, pp 3–13.

[15] Jenkins ('Practice of ensilage', p 136) points out that, ironically, it was a dry season which prompted French interest in ensilage, whereas 'the moving force with us has been a succession of *wet* seasons.'

[16] The first silo in the USA appears to have been built in 1873, at Spring Grove, Illinois, by Fred L Hatch, who had read a translation of Vilmorin-Andrieux's paper while a student at the University of Illinois. However, Goffart's book was perhaps more influential, because it was translated and published in 1879 by Mr J B Brown, president of the New York Plow Co, and mailed to hundreds of his customers in the USA as an advertisement for his firm. See Lyman Carrier, 'The history of the silo', *Jnl American Society of Agronomy*, nd, c 1920, p 181; United States Department of Agriculture, *Yearbook, 1899*, Washington, 1900, p 617; Anon, *The First Vertical Silo*, American Society of Agricultural Engineers, 1969. I am indebted to Dr Bowers for all of these sources.

[17] Jenkins, 'Practice of ensilage', pp 137 and 207; Moore, *Silos and Silage*, p 10; at about the same time, M J Sutton claimed to have been 'the medium of first placing ensilage obtained from France before agriculturalists at the Smithfield Cattle Show': see Sutton, *Permanent and Temporary Pastures*, 3rd ed, 1886, p 108.

[18] Although it is worth noting that Sutton (*Permanent and Temporary Pastures*, 5th ed, 1895, p 122) claimed that silage was made in Canada 'long before it became familiar to farmers in Great Britain'.

[19] S Jonas, 'On straw chaff', *JRASE*, 2nd ser, 6, 1870, pp 119–21; Jonas's career is outlined in R Brigden, *Victorian Farms*, Marlborough, 1986, pp 231–2.

[20] J Wrightson, 'Report on the agriculture of the Austro-Hungarian Empire', *JRASE*, 2nd ser, 10, 1874, p 351; according to Primrose McConnell, *The Agricultural Notebook*, 1st ed, 1883, p 120, 'Ensilage is a system of preserving hay or green fodder, originally introduced from Hungary.'

In July 1875 the farm bailiff on earl Cathcart's farm near Thirsk in north Yorkshire recorded in the farm diary: 'Finished leading Grass to make it into "pickeled" Hay', and in that year, or the one after, Mr Arthur Scott of Rotherfield Park, Alton, in Hampshire, began to experiment with ensilage of vetches, clover, ryegrass, oats and meadow grass, which were successful, and mangold leaves, cabbages, comfrey, and artichoke stalks, which were not.[21] There is no evidence to show whether or not Wrightson's article provoked these experiments, but if it did not the coincidence is interesting, if not remarkable.

A succession of poor haymaking seasons occurred between 1875 and 1884. Haytime was wet in 1878 and very wet in 1879, when Disraeli walked out at Hughenden 'asking his farmers whether the dove had left the ark yet.' 1881 was wet with a small hay crop. June and July were wet and cold in 1882, and meadow hay gave a heavy crop which was much damaged. In 1883 thunderstorms in late June were followed by a stormy July, and the following year the early hay crop was good in quality but poor in quantity, while the late crop was heavier but damaged by thunderstorms.[22] Against this background, interest in silage grew. In 1881 Lord Walsingham persuaded Henry Woods, his steward, to build a small experimental silo on the home farm at Merton, near Thetford. Woods was sceptical to begin with, but later recanted to the point of writing a sixty-three page pamphlet extolling the virtues of silage, in which he mentioned other successful experiments in Hampshire, Kent and Suffolk. A party of Norfolk farmers visiting Holland in 1882 were impressed by a Dutch farmer's demonstration of silage.[23] The agricultural press began to give their attention to the subject, and early in 1883 James Howard MP suggested to the Journal Committee of the Royal Agricultural Society that the society should commission an investigation into ensilage and its suitability for English conditions. Several practical farmers were invited to undertake the task; none, in the end, felt that he could spend the necessary time away from his farm. Eventually H M Jenkins, the secretary of the society and editor of its *Journal*, who had previously felt himself unfitted for the job because he already had some knowledge of maize silage and so believed that he might not have an open mind, agreed to do it. His report appeared in the April 1884 edition of the *Journal* and covered 120 pages.[24]

Jenkins began his investigation by sending out a list of twenty-three questions, about the type of silo ('What are the dimensions of your silo? How is it constructed?'), how it was filled ('When did you fill your silo? What crop or crops do you preserve? Are the crops pitted in a whole or chopped state?'), how the material in it was compressed, the costs of the whole process, and the results achieved. He also requested a sample of the silage so made, which he would pass on to Dr Voelcker, the society's consulting chemist, for analysis. The questionnaire was sent to thirty-six farms in Britain, fifteen of which were in Cheshire, Yorkshire, or further north, and six in East Anglia, three in the Midlands, and eight in the south of England, one in Scotland and three in Wales. It was also sent abroad, to five farms in France and one in Holland. Those in France included the farms of his friend M Lecouteux, editor of the *Journal*

[21] Jenkins, 'Practice of ensilage', pp 134 and 152.

[22] E L Jones, *Seasons and Prices: The Role of Weather in English Agricultural History*, 1964, pp 173–6; J M Stratton, *Agricultural Records, AD 220–1968*, 1969, pp 118–23. From 1875 to 1883 the rainfall in June, July and August was above the 1915–50 average in every year except 1876, and in 1879 it was 186 per cent of the average, according to H H Lamb, *Climate: Present, Past and Future*, ii, 1977, p 623.

[23] Woods, *Ensilage*, pp 28–9 and 37–9.

[24] Jenkins, 'Practice of ensilage', pp 126–246; N Goddard, *Harvests of Change: The Royal Agricultural Society of England, 1838–1988*, 1988, p 120.

d'Agriculture Pratique, and an honorary member of the Royal Agricultural Society, the Vicomte de Chezelles, who had had such an important role in introducing silage to Britain, and Comte Roederer, another pioneer. In the resultant article in the *Journal* he printed all the responses at length. Mr Hopkins, who farmed near Cardiff, built an uncovered silo, two-thirds below ground level, which was soaked by the autumn rains and flooded by the adjacent brook in winter, so that only a thin layer of silage in the middle was fit to eat, 'the remainder being fit only for manure.' Most of those who replied had covered silos in which the ensiled material was compressed by portable weights, and there was a roughly equal split between those who used chopped and those who used unchopped material. Many different crops were ensiled: vetches, oats, clover, ryegrass, meadow grass, rye, lucerne, maize, tares, trefoil, coarse grass from the orchard, sainfoin, prickly comfrey, beans, peas – in short, just about anything green was ensiled by one or another of Jenkins' correspondents. The range of weights was similarly wide: concrete blocks, bricks, loose earth, logs of wood, and one hundredweight iron blocks ('three men can lift 24 tons from the bottom on to the side in 3 hours, and can replace them in little more than an hour') were all employed. There were a few examples of 'silos with mechanical means of compression'. Mr C G Johnson of Croft, near Darlington, who had been trained as an engineer, built a brick tower, 28 feet high and 10 feet by 18 feet inside, with an ingenious system of beams and weights which allowed the weight of the silage to exert the pressure on itself. However, the grass still had to be thrown up to the top of the tower by men with pitchforks. On a smaller scale, Mr Stocks of Cleckheaton in Yorkshire developed small wooden portable silos, capable of holding about 25 tons, in which the top could be screwed down. Messrs Reynolds and Co, of Blackfriars Road, London, patented an appliance for compressing fodder in silos by the use of rollers and chains tightened by a screw apparatus. The respondents included a suburban dairy farmer, a sewage farm, and a veterinary surgeon who also had a farm, but the majority were landlords, gentry at least, two MPs, a colonel, two dukes (Hamilton and Sutherland), through their agents, of course, earl Fortescue, and lords Middleton, Tollemache, and Egerton, who had used an old ice-house at Tatton Park, Cheshire, as an experimental silo. The survey contains what is perhaps the first recorded example of pollution by silage effluent, in that the Rev C H Ford of Bishopton in Durham found that 'the ensilage liquor finds its way into the drains, and renders the well water unfit for use'; conversely, Mr Stobart of Pepper Arden near Northallerton had a tap at the bottom of each silo by means of which the 'juice is drawn off and used for feeding the pigs, who take it greedily.' Jenkins also gave details of two silage cutters and blowers, one French and the other by Messrs F and J S Bust of Winterton, Lincolnshire, 'to satisfy those who wish to build or otherwise make silos this summer that the assumed difficulty of filling silos above ground, especially with chopped material, is by no means insuperable.'[25]

After his exhaustive account of the experiences of a relatively small sample of silage producers, Jenkins set out his conclusions. He thought that it was unnecessary to have excessively thick walls for a silo, and that many barns, now less used with the declining output of corn, could easily be converted to silos. For new silos, brick, stone or concrete were the preferred materials. There were no great advantages in having the silo below ground rather than above, but decided advantages in having it on a slope so that it could be filled from

[25] Jenkins, 'Practice of ensilage', pp 142, 164–5, 197, 231.

the top and emptied from the bottom, and in having it roofed. The cost should be about £1 per ton capacity. Chopping of the ensiled material he thought desirable as 'it facilitates the expulsion of air from the silo', and treading was important: 'Englishmen employ horses and men, while Frenchmen add draught oxen to their list of treading machines.' He considered weighting necessary, though he thought that the two hundredweights per square foot he had seen employed in some places excessive. The practice of M de Chezelles, who covered his fodder with about a foot of earth, he thought as good as any other. The total cost of all the operations involved in the filling of the silo averaged about 20–25 shillings per acre, or 5 shillings per ton of silage. Maize was the best crop for silage, grass and clover would do well if cut earlier than for hay, and green oats and rye, possibly buckwheat, but *never* prickly comfrey. He was still waiting for the report of his learned colleague Dr Voelcker on the chemistry involved, but he recognized that lactic fermentation was involved in the production of good maize silage, and that crops cut early, chopped, and well trodden, would make better silage than old, unchopped, wet material, imperfectly trodden. The feeding value of good silage was as great as that of hay, and it was often less risky. Whether or not it should supplant hay depended on the circumstances of the individual farm. The capital costs could not be ignored, but it had a place in wet seasons, and on the clays where turnips were notoriously difficult and expensive to grow, for the suburban dairy farmer, and on southern and eastern arable farms for preserving catch crops of rye or winter vetches, cut in May. Overall, he regarded ensilage 'as a valuable addition to the resources of the English farmer, but not as a complete substitute for the old haymaking process.'[26]

The learned Dr Voelcker reported six months later, having analysed various samples of silage for water content, albuminous compounds (ie those containing nitrogen), soluble carbohydrates, crude fibre and ash, and some for their lactic and butyric acid content. He pointed out that the production of silage was a bacterial process, distinguished between sweet and sour silage, and recognized the importance of sorting out the scientific principles involved if silage making were to be rendered less haphazard, but he remained unclear about its value as an animal feed.[27] It seems reasonable to say that he added little to what had already been reported by Jenkins. The basic outlines of the ensilage process were clear; the details remained fuzzy. Nevertheless, the attention of the leading agriculturalists of the time was clearly drawn to it. Primrose McConnell, writing the first edition of his *Agricultural Notebook* in 1883, gave it only a paragraph, not, seemingly, based on personal experience ('cattle apparently relish and do well upon it'), but by 1892 the third edition of Fream's *Elements of Agriculture* devoted nearly as much space to silage as to hay. Fream reported that the process had only been practised 'on any extensive scale' within the last ten years, during which time the operation had been much simplified, to the point where silage might be made in stacks, as long as the cardinal principle of excluding air from the green herbage was observed, and concluded that it was 'not to be regarded merely as a substitute for haymaking'. On the other hand, the English translation of Wolff's *Farm Foods*, which provided evidence of extensive scientific work on silage in Germany, concluded that 'with moderately good weather it is more advantageous to make ordinary meadow fodder into hay',

[26] *Ibid*, pp 232–46.

[27] A Voelcker, 'On the chemistry of ensilage', *JRASE*, 2nd ser, 20, 1884, pp 482–504.

although it allowed a role for silage in wet seasons.[28]

The years following the publication of the Jenkins report in 1884 saw the spillage of much ink on silage. An ensilage society was established and published instructions on how to make silage.[29] The Private Ensilage Commission under the chairmanship of Lord Walsingham produced a preliminary report to the Agricultural Department in July 1885, to the effect that silage was a 'valuable auxiliary to farm practice', especially in bad weather, and increased the range of crops which might be grown, and most especially maize.[30] They questioned numerous witnesses, including Voelcker, the consulting chemist and Carruthers, the consulting botanist to the Royal Agricultural Society, the Vicomte de Chezelles, and Sir John Bennet Lawes of Rothamsted, who had published opinions antipathetical to silage.[31] The printed replies to their questions ran to over three hundred pages.[32] Their final report to the Agricultural Department, published in 1886, concluded that silage promised 'great advantages to the practical farmer',[33] in that it would insure against unfavourable seasons, improve the quantity and quality of dairy produce, increase stocking rates and increase the supply of manure.[34] It was also in 1885 that Sir Massey Lopes, a Devon landowner, and president of the Royal Agricultural Society, offered a prize of 100 guineas for the best silo in England and Wales. The competition attracted thirty-two competitors, including five members of the House of Lords and a baronet, and was the subject of a fifty-page report in the society's *Journal*. Again the main advantage of silage was seen to be its comparative independence of the weather.[35] From 1884 the official annual agricultural statistics began to print figures for the number of silos and their capacity. The first year's figures revealed the existence of 514 silos in England, 36 in Wales, and 60 in Scotland, with an average capacity of a little over 3000 cubic feet each, and the numbers grew in subsequent years.[36] In the words of John Wrightson, discussing the agricultural lessons of the decade, 'The system of ensilage belongs essentially to the "Eighties"...ensilage is favourably spoken of, and generally accepted, in almost every agricultural district.'[37] The agricultural statistics show that by 1889 silage was produced in every county of England and Wales and most Scottish counties. There were 178 silos in the West Riding of Yorkshire and 158 in Lancashire. Westmorland, Kent, Warwickshire and Dorset all produced more than 35 tons of silage for each thousand acres of mowing grass in the county. In contrast, some counties (Durham,

[28] McConnell, *Agricultural Notebook*, p 120; W Fream, *Elements of Agriculture*, 3rd ed, 1892, pp 227–31; E von Wolff, trans H H Cousins, *Farm Foods: or, The Rational Feeding of Farm Animals*, 1895, pp 157–75.

[29] H Kains-Jackson, 'Experiments in making ensilage during the wet season of 1888', *JRASE*, 2nd ser, 25, 1889, p 281 mentions a *Practical Guide to Making Ensilage in Stacks and Silos*, issued by the Ensilage Society and published by Eyre and Spottiswoode, price 6*d*.

[30] BPP, 1884–5, XX, *Return of the Evidence received by the Private Ensilage Commissioners: part 1, preliminary report and minutes of evidence*, p iii.

[31] Lawes first wrote to *The Times* and *The Agricultural Gazette* about silage in 1882, exhibiting no great enthusiasm for it, again in 1884 ('So long as the making of ensilage is confined to the wealthy, and to enthusiastic amateurs, no harm can be done...'), and in the season 1884–5 conducted a series of experiments on which he reported to *The Agricultural Gazette*: see G V Dyke, *John Bennet Lawes: The Record of his Genius*, Taunton, 1991, pp 239, 240, 248, 296, 326–7. These reports were subsequently reprinted, with minor alterations, as a pamphlet (Sir J B Lawes and J H Gilbert, *Experiments on Ensilage, conducted at Rothamsted, season 1884–5*, 1886), which concluded, *inter alia*, that silage was 'a very good food' for milking cows and fattening oxen, but that the output per acre would be less than that of roots, and that the area under cleaning crops would be reduced, so reducing the area suitable for growing grain crops (pp 55–8).

[32] BPP, 1884–5, LXXXIV, *Return of the Replies to Questions relating to Silos and Ensilage, put by the Agricultural Department, Privy Council Office, to persons who have silos in Great Britain; with their Observations thereon*, pp 295 *et seq*.

[33] Not that the commission was overloaded with practical farmers, although among its members were the agricultural writer Faunce de Laune, James Howard, who originally suggested the production of the Jenkins report, the silage enthusiasts Henry Kains-Jackson and Stanhope Tollemache, and Lords Drogheda and Egerton, landowners.

[34] BPP, 1886, XIX, *Final Report of the Private Ensilage Commissioners*, p 345.

[35] The Judges, 'The silo and silage-stack competition, 1885–6', *JRASE*, 2nd ser, 22, 1886, pp 259–311.

[36] See the references in Table 1 (note a).

[37] Wrightson, 'Agricultural lessons', pp 285–6.

Lincoln, Rutland, Suffolk, Oxford, Shropshire, and Somerset) produced less than 10 tons of silage per thousand acres of mowing grass.[38] Silage had clearly captured the attention of the agricultural establishment. The innovators had sorted out the technique. The way had been made straight for its adoption by those practical farmers to whom the Private Commission had recommended it; would they respond?

II

At first sight the nineteenth-century silage production figures are impressive, with the number of silos and their capacity quadrupling in the six years between 1884 and 1889. In addition, it should be remembered that these were only the figures for silage made in silos. From 1887 the official statistics listed the 'Number of persons who proposed to make ensilage in Stacks', and by 1889 their number (2851) was slightly greater than the number of silos (2825).[39] The implications of this for the output figures are unclear, because the comparative sizes of stacks and silos are not known, although it seems reasonable to assume that the average size of stacks would not exceed that of silos. But if silage production developed rapidly in percentage terms, in absolute terms it remained less important. Although there were nearly 3000 silos by 1889, their average size was small, at between 2600 and 2900 cubic feet, which means that they would hold about 45 or 50 tons of silage (which, if 4 tons of 20 per cent dry matter silage are equivalent to about 1 ton of hay, corresponds to 11 to 13 tons of hay, or the production of 8 acres of grass in a good year or 12 in a bad year). Alternatively, if it is assumed that a cow would eat 40 lbs per day, the average silo would feed 18 cows for a five-month winter period. As Table 1 and the graph derived from it (Fig 1) demonstrate, silage production in the nineteenth century probably never exceeded a figure of the order of 300,000 tons, even if it is assumed that as much silage was made in stacks as was made in silos,[40] compared with hay production which averaged nearly 4.5 million tons and the root crop which averaged nearly 25 million tons in the 1880s. Thus, if all the silage was fed to the dairy herd, which is unlikely, only enough silage was made to feed about 112,000 cows (using the same assumptions as above) which represents about 5 per cent of the dairy herd of 2.5 million cows in the late 1880s.[41]

The series of figures for silo capacity printed in the *Agricultural Statistics* ended suddenly after 1889, for reasons which are not stated, but it is possible to get some impression of the popularity of silage from the figures contained in the annual reports of the consulting chemists to the Royal Agricultural Society. Each year they gave figures for the number of samples sent to them for analysis, and from 1884 these figures included a reference to silage samples: 21 in 1884, 12 in 1885, 7 in 1886 and 10 in 1887. In 1888 the figures for silage and hay samples were stated together, and continued so to be until 1896. Each year between one and seven samples were analysed, except in 1894, when sixteen

[38] The sources of the statistics are given in Table 1 (note a). I am most grateful to Ms Kate Templeton for her help with the production of these figures.

[39] BPP, 1889, LXXXIII, *Agricultural Statistics*, pp 88–9.

[40] The weight of a cubic foot of silage depends upon its composition (ie whether it is made from grass, grass and legumes, cereals and legumes, maize, or arable by-products such as cereals), moisture content, and degree of compaction, which increases as the depth of the silo and the effective weight applied to it increases. Thus A Amos, 'The silage content of tower silos and silage clamps', *JRASE*, 84, 1923, pp 50–60, found that for silage made from oats and tares, material with a high dry-matter content (37.4 per cent) taken from the top of a silo weighed 20.7 lbs per cubic foot, whereas material with a lower dry-matter content (27.5 per cent) taken from 20 feet from the top of a silo weighed 56.7 lbs per cubic foot. Having considered various types of silage made in several different years, he concluded that for a fairly typical moisture content of about 30 per cent, for both tower silos and clamps, a figure of 40 lbs per cubic foot could be used for converting a volume of silage to a weight. The same figure was given for grass silage in McConnell, *Agricultural Notebook*, 12th ed, 1953, p 708, and it is the one used for the appropriate calculations in this paper. In his first edition McConnell equates 4 tons of silage with one of hay (p 120).

[41] MAFF, *A Century of Agricultural Statistics*, 1967, pp 118–23.

TABLE 1
Estimated silage production in Great Britain, 1884–1993

Year	*'000 tons*	*Year*	*'000 tons*	*Year*	*'000 tons*	*Year*	*'000 tons*
1884	33.245[a]	1950	1832[b]	1970	9359[g]	1982	33,506[g]
1885	59.163[a]	1951	1987[b]	1971	11,130[g]	1983	34,070[g]
1886	81.442[a]	1952	2009[b]	1972	13,370[g]	1984	34,972[g]
1887	129.695[a]	1953	2420[b]	1973	16,464[g]	1985	42,348[g]
1888	132.272[a]	1954	2729[b]	1974	17,465[g]	1986	45,864[g]
1889	144.000[a]	1955	2564[b]	1975	17,587[g]	1987	47,673[h]
		1956	3393[b]	1976	17,744[g]	1988	49,197[h]
1940	250[b]	1957	3860[b]	1977	20,730[g]	1989	46,348[h]
1941	540[c]	1960	4760[e]	1978	23,438[g]	1990	48,073[h]
1944	1000[d]	1962	4293[f]	1979	25,660[g]	1991	51,098[h]
1947	350[c]	1967	5600[e]	1980	28,707[g]	1993	52,868[h]
1948	725[c]	1969	8294[g]	1981	30,193[g]		

Sources: [a] BPP, 1884, LXXXV p 210; 1884–5, LXXXIV, pp 82–3; 1886, LXX, pp 80–81; 1887, LXXXVIII pp 306–7; 1888, CVI, pp 90–91; 1889, LXXXIII, pp 88–9, *Agricultural Statistics*. This source gives the total capacity of silos in Great Britain, and this figure is converted to a tonnage by assuming that a cubic foot of silage weighed 40 lbs. The rationale for this assumption is explained in footnote 40.

[b] BPP, 1958/9, VIII, p 321, *Report of the Committee on Grassland Utilisation*, chairman Sir Sydney Caine, Cmnd 547, November 1958; the figures for 1940 and 1957 are also reported in H I Moore, *Grass and Grasslands*, 1966, p 108. Moore was a member of the committee.

[c] E Rea, 'Silage for self-sufficiency', *JRASE*, 110, 1949, p 29. Rea gives the tonnage for 1948, and then mentions that this was 'more than double that of 1947 and one-third more than the wartime peak production of 1941', and the figures for 1947 and 1941 are therefore estimated from this.

[d] H I Moore, *Ploughing for Pasture*, 1944, p 28. Note the conflict between this figure and Rea's remark about the wartime peak of production.

[e] W R Catt, 'Commercial harvesters now', in J K Nelson and E R Dinnis, eds, *Machinery for Silage*, British Grassland Society Occasional Symposium No. 17, Maidenhead, 1985, p 33. Catt's figures are given in dry matter terms for England and Wales for various years between 1960 and 1982. They have been converted to the ones given here by comparing them with the figures given by Marks and Britton (see g) and calculating that an approximate multiplier to reconcile the overlapping figures is 7. Thus they cannot be regarded as anything more than a rough approximation.

[f] This is also a rough approximation, from the remark made in H W Gardner, *A Survey of the Agriculture of Hertfordshire*, Royal Agriculture Society of England, County Agricultural Surveys, No 5, 1967, p 59, that the silage acreage in that county in 1962 was one-sixth of the acreage devoted to hay. Taking the same proportion to apply at a national level, which is clearly unlikely, and assuming that one ton of hay is equivalent to three of silage, this converts the national hay output of 8,587,000 tons (see g below) to 4,293,000 tons of silage.

[g] H F Marks, ed D K Britton, *A Hundred Years of British Food and Farming: A Statistical Survey*, 1989, p 197. This contains the complete list for the years 1969–86 of the estimates of silage production made by the Ministry of Agriculture, Fisheries and Food and printed in their annual series *Output and Utilisation of Farm Produce in the United Kingdom*.

[h] Ministry of Agriculture, Fisheries and Food, Statistics Press Release 64/94, 30 March 1994, Table 7, p UK3.

samples were analysed. From 1897 onwards the annual reports indicated that the consulting chemist continued to offer his analytical services to farmers, but no more silage or hay samples were sent to him.[42] There is a clear impression of dwindling interest in silage, although it was revived to some small extent by the example of Mr George Jacques of Tivetshall in Norfolk, who built a tower silo for oats and tares in 1910.[43] But tower silos were expensive, and even at the height of the silage boom in the 1880s not all had been convinced: a speaker at the Cartmel Show in the Furness district of Lancashire made his audience laugh by suggesting that 'if they got a few more dry seasons, silos and ensilage would die a natural death and there would not even be a *post mortem*.'[44] At the other end of the country a survey of the agriculture of Sussex simply declared that 'Before the First World War there was no silage made in Sussex', while admitting that 'a very few old farmers could remember the attempts at silage making between 1880 and 1890'. By the first decade of the twentieth century a textbook writer explained the lack of interest: 'the root

[42] J A Voelcker, 'Annual report of the consulting chemist', *JRASE*, 2nd ser, XXI, 1885, p 337. Subsequent annual volumes contain similar reports, except for the volumes for 1890 and 1895. The 1891 volume contains 2 reports.

[43] H I Moore, *Grass and Grasslands*, 1966, p 108.

[44] A Mutch, 'Rural society in Lancashire 1840–1914', Unpublished Manchester University PhD thesis, 1980, p 271.

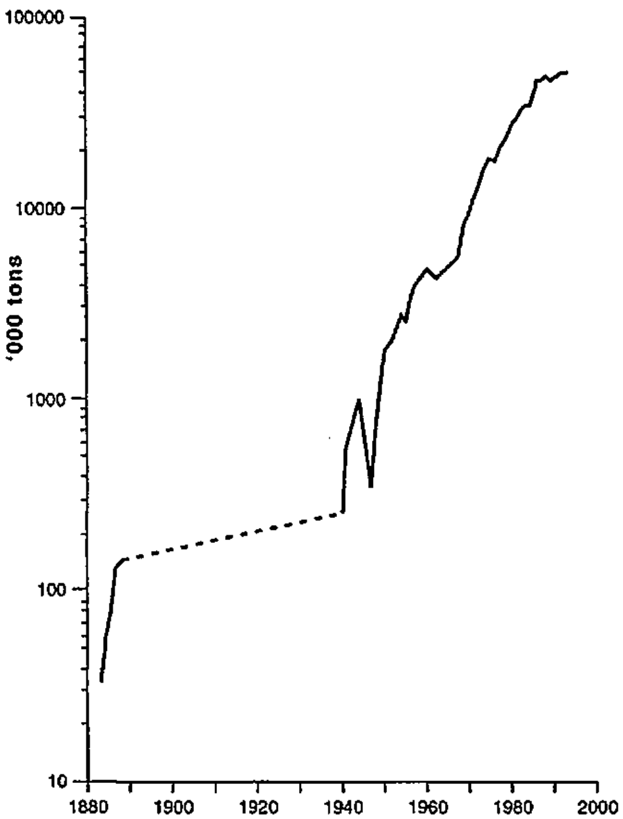

FIGURE 1
Silage production in Great Britain, 1884–1993.

crop is of such cultural and feeding importance, and as a rule a comparatively certain crop, that succulent winter feed is generally obtainable, and it is not often that conditions are such that a reasonable quality of hay crop cannot be secured.'[45]

It was as an alternative to roots that silage was taken up again in Sussex at the end of the First World War, as some younger farmers began to take an interest in American methods using large wooden silos. At Wappingthorn Farm, near Steyning, two wooden silos were roofed and joined to make a fortified gateway into the steading. In 1918 the Food Production Department of the Board of Agriculture had provided advice, working drawings, and priority certificates for materials to farmers wishing to erect brick or concrete tower silos. It was estimated that a one hundred ton silo, thirty feet high and fifteen feet in diameter, could be built for about £310 in concrete or £340 in brick. The Cheshire County Council erected a tower silo at their farm institute at Reaseheath, and a few of the larger farmers in the county also invested in them. In Hertfordshire, too, silage was popular in the period between 1918 and 1923,[46] and in his revision of Ernle's *English Farming Past and Present*, completed in 1936, Sir Daniel Hall observed that in about 1920

> there was a considerable recourse to silage made either in the wooden silos imported from America or round silos of reinforced concrete; a mixture of oats, tares, and beans being the crop most favoured for preservation as a succulent fodder for the winter feeding of milch cows. But even silage making involves a good deal of labour and today the silos are little used except for an excess of grass in a wet season.[47]

As far as the majority of farmers was concerned, Hall was quite correct, but some persisted with it. There was a temporary revival of interest in the 1930s in Northumberland, where several large concrete and brick silos, each costing several hundred pounds, were erected for arable silage to replace increasingly-expensive turnips. A J Hosier, who became well-known for his practice of bail-milking dairy cows, used silage as part of his normal fodder conservation programme from the early 1930s.[48] The real enthusiasts seem to have been the scientists. Amos and Woodman, who worked at Cambridge, wrote several papers in the *Journal of Agricultural Science*

[45] R H B Jesse, *A Survey of the Agriculture of Sussex*, Royal Agricultural Society of England, County Agricultural Surveys, No 2, 1960, p 125; R P Wright, ed, *The Standard Cyclopaedia of Modern Agriculture*, V, nd, *c* 1910, p 59.

[46] Jesse, *Agriculture of Sussex*, p 125; J Weller, *History of the Farmstead*, 1982, p 198; Anon, 'Supply of silos by the Food Production Department', *Jnl Board of Agriculture*, 25, 1918, pp 149–52; W B Mercer, *A Survey of the Agriculture of Cheshire*, Royal Agricultural Society of England, County Agricultural Surveys, No 4, 1963, p 81; H W Gardner, *A Survey of the Agriculture of Hertfordshire*, Royal Agricultural Society of England, County Agricultural Surveys, No 5, 1967, p 58.

[47] Lord Ernle, *English Farming Past and Present*, 6th ed, 1961, p 453.

[48] H C Pawson, *Cockle Park Farm*, 1960, p 174; A J Hosier and F H Hosier, *Hosier's Farming System*, 1951, p 133.

in the 1920s in which they attempted to find out what was going on in the ensilage process, and what determined the nutritive value of silage, while articles in the *Journal* of the Royal Agricultural Society were more concerned with the practicalities of making silage and the comparative costs of silage and roots.[49] In the 1930s S J Watson, who at that time worked at the ICI research farm at Jeallott's Hill, published several papers and eventually a book on silage making.[50] But most farmers remained unenthusiastic.

'Twenty pounds of grass silage produces a gallon of milk and takes the place of 3.5 lbs of imported concentrated food. Thus every six tons of silage made has liberated one ton of shipping space' wrote Dr Ian Moore in a British Council pamphlet in 1944, so explaining official enthusiasm for silage in the Second World War.[51] The foreword to the Ministry of Agriculture's 1944 edition of their bulletin on *Ensilage* made the same argument and concluded 'Indeed, the making of silage is not now merely desirable; it has become a duty!' The use of molasses and acids as additives was better understood as a result of Watson's work at Jeallott's Hill, and cheaper silos, of wire mesh lined with sisal paper or made of concrete slabs erected on the farm, were available. The summer of 1941 produced a bumper maize crop, some of which was ensiled, pea pods were found to produce excellent silage, and there was even research at Jeallott's Hill on the ensilage of bracken ('unlikely to prove profitable' was the conclusion).[52] 'Make silage, make sure' was the ministry's slogan. As the figures in Table 1 indicate, silage production increased significantly, although whether it doubled or quadrupled depends on whether Rea's post-war estimate of half a million tons, or Moore's figure of a million tons, given in what was clearly a work of wartime exhortation if not propaganda, is seen as the more credible. George Henderson, who farmed a small but intensive holding on the eastern slopes of the Cotswolds near Enstone in Oxfordshire, felt that 'The silage campaign has not received the support it deserves. We have learned to value silage so much that we no longer look upon it as a mere wartime expedient, but as something well worth incorporating into our general farming practice for the future.'[53]

Post-war policy maintained the emphasis on 'dollar-saving by greater self-sufficiency', and so silage remained in official favour. In 1947 the Minister of Agriculture launched a four-year plan or expansion programme which envisaged the expansion of silage production from 725,000 tons to 2 million tons and dried grass production from 100,000 to half a million tons, both at the expense of hay output, which, it was envisaged, would fall from 7 to 4 or 5 million tons, all by 1952.[54] Officers of the County Agricultural Executive Committees – the War Ag, still operating in the post-war years – encouraged farmers to make silage in pits, and showed them how to match the size of pit

[49] See, for example, T B Wood and H E Woodman, 'The digestibility of oat and tare silage', *J Ag Science*, 11, 1921, pp 304–9; A Amos and H E Woodman, 'A study of the process of making clamp silage', *J Ag Science*, 15, 1925, pp 444–54; H E Woodman, 'The nutritive value of stack silage', *J Ag Science*, 15, 1925, pp 327–33; A W Oldershaw, 'Crops for ensilage', *JRASE*, 84, 1923, pp 39–49; H W Kersey and C S Orwin, 'The comparative cost of mangolds and silage', *JRASE*, 86, 1925, pp 48–58.

[50] See, for example, S J Watson, 'The conservation of grassland herbage', *JRASE*, 95, 1934, pp 103–16; *idem*, 'The chemical composition of grass silage', *J Ag Science*, 27, 1937, pp 1–42; *idem*, *Silage and Crop Preservation*, 1938.

[51] H I Moore, *Ploughing for Pasture*, 1944, p 28.

[52] H E Woodman and Arthur Amos, *Ensilage*, Ministry of Agriculture and Fisheries, Bulletin No 37, 6th ed, July 1944. The first edition of this work, which was published in 1926, was based on a series of articles in the *Journal* of the Ministry written by Amos and Woodman, who, as footnote 48 indicates, were among the leading research workers on silage at that time: Jesse, *Agriculture of Sussex*, p 125; Watson, *Silage and Crop Preservation*, p 140; F H Garner, 'Recent developments in silage making', *JRASE*, 103, 1942, p 164; W Godden, 'The feeding of livestock', *JRASE*, 106, 1945, p 48.

[53] George Henderson, *The Farming Ladder*, 1944, p 154.

[54] Eric Rea, 'Silage for self-sufficiency', *JRASE*, 110, 1949, pp 28–9.

to the output of their grassland.[55] Helped by the example of such expert farmers as Rex Paterson, who invented and popularized the use of the buckrake, and extension techniques such as the silage competitions run by the National Agricultural Advisory Service for several years in Hertfordshire, output did indeed increase, and the 2 million ton target appears to have been met by 1952, although the quality of the product was not always high.[56] It was comfortably exceeded by 1957 (Table 1), although still agricultural scientists such as Professor M McG Cooper could complain that 'there are surprisingly few farmers making silage in Britain, many less than one would expect having regard to the publicity that has been given to this form of grass conservation and the surplus of grass that is available for this purpose.'[57] Silage was also one of the techniques popularized by the BBC radio programme *The Archers*, which was first produced in 1950 as an imaginative attempt to change the ways of small farmers in the Midlands who were not responding to the advice they were receiving from the Ministry of Agriculture and the county committees.[58] In fact, silage was made on 34,300 holdings in England in 1957, which represented 14.4 per cent of all holdings. The percentage was less in Wales and very much less in Northern Ireland. Dairy farmers were more likely to be silage makers: in a survey of 944 herds in England and Wales carried out by the Milk Marketing Board nearly half of those in the Midlands made silage in 1957, although the comparable figure for east and south-east England was only 26 per cent and for Wales 18 per cent. Over England and Wales as a whole the proportion of surveyed farms producing silage increased from 25.5 per cent in 1955 to 35.7 per cent in 1958.[59] By this time a grant scheme had been introduced, to run, initially, for three years, under the terms of which farms could qualify for grants of up to £250 for roofed silos or £125 for unroofed silos. The precise amount payable on any one farm depended upon the work done: excavation was grant-aided at 3*s* 6*d* per cubic yard, drainage at 2*s* 6*d* per yard run, roofs at 27*s* 6*d* per superficial yard covered, and so on. Nearly 18,000 proposals, involving grant expenditure of £2,762,348 (an average of £155 per farm) had been approved by the end of June 1958.[60]

The Caine Committee on Grassland Utilisation was established in 1957 'to consider methods of further stimulating the better production and use of grass... with a view to reducing the cost of production of livestock and livestock products and securing economies in imports of feedingstuffs...', and its 1958 report endorsed the advantages of silage. Indeed, a minority report by four members of the committee suggested that a subsidy of 15 shillings per ton of silage of adequate quality should be paid to any farmer, for a maximum period of four years per farmer, until national silage output had reached 10 million tons. The justification for their suggestion, apart from the perceived advantages of silage, was that a similar scheme operated since 1955 in Northern Ireland had resulted in the trebling of production there. Moreover, they felt, farmers had been slow to adopt silage because of the risk of

[55] The capital cost of towers was thought to be too great for them to be given equal emphasis. I am grateful to Mr Victor Burke, of Rattery, Devon, who was employed by a War Ag in 1947–8, for this information.

[56] Gardner, *Agriculture of Hertfordshire*, p 57; Rex Paterson, *How We Make Silage*, 1950; Q Seddon, *The Silent Revolution*, 1989, p 27.

[57] M McG Cooper, *Competitive Farming*, 1956, p 35. Cooper was professor of agriculture first at Wye College and then at the University of Newcastle upon Tyne.

[58] The programme's objectives were 10 per cent education, 15 per cent information, and the rest entertainment. I am grateful to Godfrey Baseley, the first producer of *The Archers*, for this information. See also S Laing, 'Images of the rural in popular culture', in B Short, ed, *The English Rural Community: Image and Analysis*, 1992, p 145.

[59] BPP, 1958/9, VIII, *Report of the Committee on Grassland Utilisation* (the Caine Committee), p 321. The figures are given on pp 55–6 in the original pagination of the report.

[60] Anon, *The Farmer and Stockbreeder Grassland Handbook*, 1957, pp 265–9; BPP, 1958/9, VIII, p 36.

turning from purchased feedstuffs, where the return was immediate, to a system which required greater forward planning. The majority of the committee disagreed: 'the failure on the part of many farmers to make silage where there is a clear case for them to do so cannot be attributed to the costs involved in the process but simply to apathy.' No tonnage subsidy was forthcoming, although the recommendations included the continuation of the silo subsidy and further research on silage (there were, after all, three academics on the committee).[61]

Another, less official, initiative took place in the Teign valley in Devon in 1960, where the Nuffield Foundation sponsored the setting up of three machinery groups for making silage, in Longdown, Dunsford and Bridford parishes. The report on the project found that there was 'a general trend towards silage as an alternative to hay', especially since the introduction of the forage harvester, although it was still 'far from being generally accepted in the Teign Valley.' This was not just due to traditional conservatism, but was a logical response to steep land, poor access and difficult farm layouts. The advantages of silage were greater for bigger farms.[62] At this point Devon was one of the counties in which silage appears to have been more popular than it was in the country as a whole. A survey of 27 Devon farms found that 14.7 acres in every hundred were devoted to silage, compared with 22.6 for hay, in 1960. If this pattern had been reproduced nationally it would have implied a level of silage production of something like 16 million tons, which was probably three or four times what it actually was then.[63] Cheshire was another county in which silage was relatively popular in the early 1960s, with between 30,000 and 40,000 acres out of the 120,000 mown acres being devoted to it. The response to the national silage campaign was said to be 'more marked in Cheshire than in any other part of the country because here the cows are thickest on the ground, the need for semi-concentrated fodder the greatest'.[64] In Warwickshire at the same time, Clyde Higgs found that 'The amount of silage made increases every season but all too slowly', although he explained the rapid decline in the root acreage by its substitution by silage, while in Sussex the use of the buckrake in silage making was said to be common in 1960.[65] In Hertfordshire in 1962 six acres were cut for hay for every one cut for silage, and it was 'not now increasing in favour' despite all the recent labour-saving innovations in silage making.[66] Writing in 1969, Harwood Long found that 'Silage has not made as much progress in the Yorkshire dales as one might have expected in an area of such high rainfall', although the West Riding contained more forage harvesters than any other county in England.[67]

All these examples tend to confirm Coppock's judgement that by the early 1970s, 'While silage-making has been increasing in popularity in the post-war period, the number of farmers making silage and the amount made are still small', and that it was more commonly made in midland and southern than in eastern England.[68] Nevertheless, by 1969 the popularity of silage was sufficient to persuade

[61] BPP, 1958/9, VIII, pp 48–62.

[62] J Bradley, *Co-operation: A Report on an Experiment in setting up co-operative Groups for the Purpose of making grass Silage*, University of Bristol, Report no 125, Newton Abbot, 1961, pp 1 and 38–9. I am most grateful to Mr Geoffrey Hearnden of Bridford for providing this reference for me and discussing the project.

[63] V H Beynon, *Grassland Management: An Economic Study in Devon*, University of Exeter, Department of Economics (Agricultural Economics) Report No 138, 1963, p 6.

[64] Mercer, *Agriculture of Cheshire*, pp 81–2.

[65] C Higgs, 'The agriculture of Warwickshire', *JRASE*, 123, 1962, pp 73–4; Jesse, *Agriculture of Sussex*, pp 125–6.

[66] Gardner, *Agriculture of Hertfordshire*, p 59.

[67] W Harwood Long, *A Survey of the Agriculture of Yorkshire*, Royal Agricultural Society of England, County Agricultural Surveys, No 6, 1969, p 140.

[68] J T Coppock, *An Agricultural Atlas of England and Wales*, 1976, p 117.

the statistical branch of the Ministry of Agriculture that it should report silage production tonnages in addition to the production of hay in the annual figures for output and utilization of farm produce.[69] Silage production was beginning to take off. It is interesting to compare two editions of Cooper and Morris's textbook *Grass Farming*: in the third edition, published in 1973, they complained that 'Since 1940, when the drive for more silage got under way, farmers have been adept in finding good reasons why they should not make the stuff'. In the fifth edition, published ten years later, they continued to explain why silage had been unpopular but observed that after the 1960s 'there was a growing feeling that silage was the more sensible product because of the fickleness of the British weather and by 1980, in terms of conserved dry matter, silage was just as popular as hay.'[70] Production rocketed, from less than 10 million tons per year in 1970, to nearly 30 million tons in 1980, to over 50 million tons in the early 1990s. At the same time, hay production fell. It had peaked at 9,692,000 tons in 1971 (a similar tonnage to that of silage for that year) and thereafter fell steadily to less than 4 million tons in 1989.[71] After a century, the technology introduced in the 1880s had become the dominant system of fodder conservation. Why did it take so long?

III

In consternation, last summer [1888], the farmers throughout England, Scotland and Ireland saw the forage crops of the year washed and rotting on the meadows, or uncut passing their maturity and becoming rather vegetable wire than succulent herbage. A scramble was then made, partly in despair, partly in hope, to save the deteriorated hay-harvest by the new-fangled process of ensilage.[72]

Clearly, that wet season provided the initial impetus for many farmers to begin silage making ('but I have not seen or heard of any that continued the experiment', wrote Primrose McConnell, three years later.[73]). A fine summer had the opposite effect, as in 1955, 'the best in memory for haymaking...scores of farmers have swung back to hay in preference to silage. Many, indeed, have asserted that the progress of silage making has been retarded ten years by the glorious weather of July and August.'[74] The adoption of silage was also delayed, and for a longer time, by other problems: 'ensilage I shall never touch again', McConnell told his diary in 1905:

I was a member of the Ensilage Society when the craze for that sort of thing was on, and I made a stack of grass ensilage once, but only once, and never more. A stack of hay was put on the top for pressure, but it heated tremendously for all that. It boiled all the albuminoid ratio out of itself, and the outside rotted for a couple of feet inwards. But that was not all; when the stack was opened the smell was perceptible at a village three miles away, when the wind lay in the proper direction, while the man who cut it out and handled it was debarred from all the beershops in the neighbourhood till he could 'sweeten' himself. It put the milk off the cows, tainted it after it was produced, and had eventually to be given to a lot of young beasts. Farmers are blamed for not being progressive, but how could you progress in a case like this, with a smell as bad as ten motor cars?[75]

Thus it appears that the adoption of silage was delayed by labour and quality problems. But would these, by themselves, have been sufficient to cause the length of delay observed in the case of silage?

The best recent summary of adoption theory as it applies to agriculture is by Hill and Ray, who list five factors which affect

[69] H F Marks, ed D K Britton, *A Hundred Years of British Food and Farming: A Statistical Survey*, 1989, p 197.
[70] M McG Cooper and D W Morris, *Grass Farming*, Ipswich, 3rd ed, 1973, p 159 and 5th ed, 1983, p 169.
[71] Marks and Britton, *British Food and Farming*, p 197; see Table 1.
[72] Kains-Jackson, 'Experiments in making ensilage', p 281.
[73] P McConnell, 'Experiences of a Scotsman on the Essex clays', *JRASE*, 3rd ser, 2, 1891, p 321.
[74] H I Moore, 'Silage on the farm: experience and experiment', *JRASE*, 116, 1955, p 60.
[75] P McConnell, *The Diary of a Working Farmer: being the True History of a Year's Farming in Essex*, 1906, p 207.

the rate of diffusion of new technology: information, uncertainty, capital requirements, management demands, and factor pricing. Thus delayed adoption might be explained by a lack of information about the technique, high risks of failure in using it, and its having high capital requirements and demanding skilled management by the farmer, while increasing the demand for expensive inputs or only saving cheap ones. They also point out that the sociological characteristics of innovators or early adopters are likely to be different from those of laggards: the former are likely to have high levels of social status, wealth and education and to operate large or specialized businesses; the latter are not.[76] However, before deciding whether or not this model can explain the initially delayed and subsequently rapid adoption of silage, it is necessary to analyse in more detail the changes which occurred and the explanations advanced by contemporaries. First, we shall examine the problems of silage making and the advantages of alternative winter feeds. These, presumably, were the considerations which were dominant from the late nineteenth century until the early 1970s. Thereafter, the problems with alternative feeds began to increase in importance, while the difficulties of silage making began to be solved. These processes are discussed in the next two sections.

IV

Silage making in the nineteenth century was heavy work, compared to haymaking, because of the extra moisture that had to be moved by the muscles of men and horses. 'I do not for a moment believe that when a farmer can turn his grass into hay in three genial days he will consent to cart nearly four times the weight of freshly-cut grass to the silo', wrote Martin J Sutton in 1886, and commentators were still agreed on 'the heavy nature of the work' in the 1950s and '60s.[77] Having made silage, it was also heavy work to feed it: 'The tough job was cutting it out in the winter – we did this with an old hay knife, and loaded it on to a trailer,' on Arthur Court's dairy farm on the Wiltshire/Somerset border in the 1950s.[78] Moreover, as McConnell's remarks indicate, farmers, farmworkers, and their wives often disliked its smell.[79] There were also problems with labour management, since silage making clashed with root hoeing.[80] It should therefore follow that the cost of silage was high in comparison to that of alternative feeds. Jenkins, in his report for the Royal Agricultural Society in 1884, estimated the cost of filling a silo at five shillings per ton, but, since he gave no comparable cost for haymaking or roots, this figure is of little use for comparative purposes.[81] In the early twentieth century it was suggested that silage involved more labour and horse work than haymaking, and that it was more economical for large than small farms,[82] but the first attempt to make a direct comparison of the cost of silage with other feeds used mangolds as the alternative and concluded that the cost of producing a ton of silage was three times that of a ton of mangolds, although its feeding value was only twice that of mangolds. However, it was admitted that producing a tilth for sowing corn after late-folded roots could be difficult, and that

[76] B Hill and D Ray, *Economics for Agriculture: Food, Farming and the Rural Economy*, 1987, pp 284–93.

[77] Martin J Sutton, *Permanent and Temporary Pastures*, 1886, p 109. W H Jordan, director of the New York Agricultural Experiment Station, made the same point in *The Feeding of Animals*, New York, 1903, p 219, as did Jesse, *Agriculture of Sussex* p 125; Moore, *Silos and Silage*, p 13; Bradley, *Co-operation*, p 38; Cooper and Morris, *Grass Farming*, 3rd ed, 1973, p 159.

[78] Arthur Court, *Seedtime to Harvest: A Farmer's Life*, Bradford on Avon, 1987, p 78; in the 1880s Clare Sewell Read, 'Suggestions for stock-feeding in the winter of 1893–4', *JRASE*, 3rd ser, 4, 1893, p 469, passed all his silage through the chaff-cutter with straw, and then added shredded roots and cake to it before feeding: an early version of complete-diet feeding perhaps?

[79] Moore, *Silos and Silage*, p 13; Higgs, 'Agriculture of Warwickshire', p 73; Cooper and Morris, *Grass Farming*, 5th ed, 1983, p 169.

[80] Moore, *Silos and Silage*, p 13.

[81] Jenkins, 'Practice of ensilage', p 238.

[82] Wright, *Cyclopedia of Modern Agriculture*, p 60.

silage could have a place where a low average rainfall 'renders the root crop uncertain'.[83]

By the end of the Second World War investigators were more concerned with comparing silage costs with those of dried grass and concentrates, as silage was seen as a source of protein. In the late 1940s, with a production cost of about £1 15*s* 0*d* per ton, it was much cheaper than dried grass and about as expensive as hay, although with its higher protein content it was a better replacer of concentrates than hay. In the winter of 1953–4 it was calculated that the cost of food per gallon of milk from silage was less than half of that from cake. Data from a sample of Devon farms in 1961 suggested that it was slightly cheaper to make silage than hay, and by 1971, with increased mechanization, the man-hours required for hay and silage making were roughly the same.[84]

The capital requirements of silage were also high, especially for those who employed some of the more complex weighting arrangements and the steam-powered cutters and blowers described in Jenkins' report. They were also variable: the Royal Agricultural Society's silage competition in 1885–6 showed the cost of silos varying between £15 and £542, at which point they were clearly beyond the reach of the small farmer.[85] It was, perhaps, no accident that the competitors included five peers and a baronet. Hence the comment by Lawes indicating that it was those with capital who first adopted silage.[86] The chopper-blowers and tower silos of the 1920s were also expensive at a time when farming profits were restricted, and even in the early 1960s comments were still being made about the high capital costs of silage.[87] Consequently, it was said at the beginning of the twentieth century, 'Ensilage making is more economical for large than small farms', and one of the conclusions of the silage co-operative project in the Teign valley in Devon in 1960 was that the large farmers (meaning those with more than 75 acres) would benefit more than the small.[88]

The quotation from McConnell's diary draws attention to the quality problem for silage, and McConnell was not alone in finding it difficult to make quality silage: 'the reeking smell of butyric acid was the chief reminder of the silage of that period' [the 1880s] in Sussex, and even in the late 1950s there were still quality problems. Skill is required to make good silage, and not all farmers (or their advisers) possessed it.[89] At least part of the success of silage in the USA resulted from the fact that the crop most commonly ensiled there, as in France, was maize, which is much easier to make into silage than grass.[90] And at least part of the failure of silage in Britain in the late nineteenth and early twentieth centuries must have resulted, paradoxically, from the success of George Fry's advocacy of sweet ensilage.[91] This process involved late cutting, wilting, and allowing air into the silo to raise the temperature to a high level, and produced a brown, sweet-tasting, very palatable silage in which, unfortunately, the results of oxidation reduced the nutritional content to little better than

[83] Kersey and Orwin, 'Cost of mangolds and silage', pp 53–5; Halley and Soffe, *Agricultural Notebook*, p 374.

[84] Watson and Smith, *Silage* p 138; Moore, 'Silage on the farm', p 62; Beynon, *Grassland Management*, p 10; John Nix, *Farm Management Pocketbook*, 4th ed, Wye, 1971, p 71.

[85] The Judges, 'The silo', p 306; even Clare Sewell Read ('Suggestions for stock feeding', p 469) felt that he could not afford a silo, and so made silage in a stack.

[86] see footnote 24 above.

[87] Watson and Smith, *Silage*, p 17; Jesse, *Agriculture of Sussex*, p 125; Moore, 'Silage on the farm', p 60.

[88] Wright, *Cyclopedia of Modern Agriculture*, p 60; Bradley, *Co-operation*, pp 38–9: I am grateful to Geoffrey Hearnden of Bridford, one of the farmers involved in this experiment, for supplying me with this reference, and for pointing out that it is easier to make silage in large quantities than in small. The same point is made in Mercer, *Agriculture of Cheshire*, p 83.

[89] Jesse, *Agriculture of Sussex*, p 125; Seddon, *The Silent Revolution*, pp 28–31.

[90] Moore, *Grass and Grasslands*, p 108; Watson and Smith, *Silage*, p 16; by 1944, according to C Culpin, *Farm Machinery*, 2nd ed, 1944, p 221, there were a million silos in the USA.

[91] G Fry, *Sweet Ensilage*, 1885.

maintenance quality. It 'put back the making of good silage in this country for a generation', according to one commentator, and for fifty years according to another.[92] Even in 1957 the Committee on Grassland Utilisation felt doubtful of the ability of many farmers to make good silage, and thought that tripodding or barn drying of hay were equally worthy of encouragement.[93]

It was not only its drawbacks but also the advantages of alternative winter feeds which slowed the adoption of silage. Its feeding value was no better than that of good hay, which, with the machinery available up to the 1960s, might be made more quickly in a period of good weather.[94] Roots yielded a greater weight of fodder per acre than silage and were also a cleaning crop, which was important when there were no herbicides and weeding was carried out by hoe, moved either by horse or human power.[95] They also had a high water content: Franklin explained how, in about 1890 (in south Northamptonshire), before his father changed from roots to silage 'he found he had to dig a well and erect a windmill to pump a plentiful supply of water to his covered yards and cowhouses, and even today [1953] many farmers cannot change from roots to silage for lack of a plentiful water supply.'[96] Dried grass was the best way of preserving the nutrients in young herbage. Mr Fuller of Neston Park, near Bath, demonstrated a drier at the Bath and West Show at Cardiff in 1884, but the process met with no great success until the 1930s, when Imperial Chemical Industries used it in conjunction with their experiments at Jeallott's Hill in Berkshire on high-output grass production with the aid of fertilizers. The first driers were fuelled by coke or coal, although by the early 1950s oil, which gave better temperature control and lower labour costs, was becoming more popular, and there were several types of drier available, including some mobile ones.[97] But from the inter-war period onwards, one of the main reasons why silage was not needed was that home produced foods were looked upon as providing only bulk and maintenance, while the production ration came from cheap imported concentrates – cereals and oilcakes – 'easy to handle and store, simple to ratio, and obtainable not by the sweat of men's labours, but merely by lifting the telephone!' Animal feed imports rose from 6.1 million tons in 1924–9 to 8.4 million tons in 1935–9, representing about a quarter of the total animal feed supply when measured in starch and protein equivalent terms. Bobby Boutflour, an agricultural adviser employed by Wiltshire County Council, toured the county telling farmers that they could get an extra gallon of milk for every four pounds of cake they fed. He became Principal of the Royal Agricultural College after the Second World War, and the college herd averaged two thousand gallons per cow, with some of them eating up to thirty pounds of concentrates per day. Concentrates were in short supply during the war years and shortly afterwards, but became available again in the 1950s, and by the 1960s were cheap enough to be used as part of the maintenance ration in the barley beef system. By the early 1970s British farmers were buying over two pounds of dairy cake for every gallon of milk produced, in addition to any home-produced cereals they might have fed. High

[92] McDonald, *Biochemistry of Silage*, p 11; T B Franklin, *British Grasslands*, 1953, p 162; Watson and Smith, *Silage*, p 15.
[93] BPP, 1958/9, VIII, pp 53, 57.
[94] Mercer, *Agriculture of Cheshire*, p 83.
[95] Lawes and Gilbert, *Experiments on Ensilage*, p 55; Kersey and Orwin, 'Cost of mangolds and silage', p 53.
[96] Franklin, *British Grasslands*, p 162.
[97] S G Kendall, *Farming Memoirs of a West Country Yeoman*, 1944, p 170; Franklin, *British Grasslands*, p 161; E H Whetham, *The Agrarian History of England and Wales, VIII, 1914–1939*, 1978, p 277; E T Halnan and F H Garner, *The Principles and Practice of Feeding Farm Animals*, 1944, p 134; J A Hanley, ed, *Progressive Farming*, 1949, pp 80–81.

summer stocking rates, less conserved grass, and bought-in cake made money.[98]

V

Therefore, if silage were to be widely adopted, the problems associated with it had to be overcome, or the advantages of the alternative winter feeds reduced, or both.

Perhaps the first of the alternatives to meet difficulties was the root crop, which was reduced in area as the cereal acreage was reduced from the mid-1870s.[99] As land was grassed down, roots no longer had their place as the cleaning crop in the four-course rotation. In the inter-war years basic wage rates for agricultural workers were twice what they had been in 1914,[100] and there were fewer of them available for the labour-intensive task of root hoeing as the number of farm workers steadily declined (Fig 2).[101] Later, from the 1960s onwards, the use of herbicides increased, which further eroded the necessity of the root break.[102] Consequently, as Figure 3

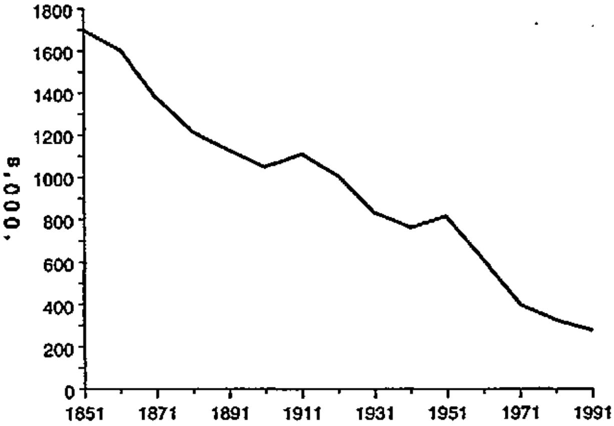

FIGURE 2
Number of farmworkers in Great Britain, 1851–1991.

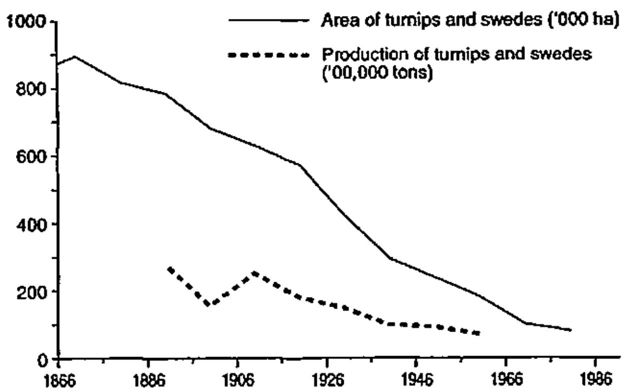

FIGURE 3
Area and production of turnips and swedes in Great Britain, 1866–1986.

demonstrates, the acreage and output of roots fell more or less steadily from its peak in 1870 to the present day.[103]

Hay production was remarkably stable from the 1880s to the beginning of the 1980s (Fig 4).[104] But even in a good season it could be wasteful of nutrients. Moore summarized the case against it: it was cut when nearing maturity so that it would make more quickly, and consequently its

[98] Watson and Smith, *Silage*, p 17; Cooper and Morris, *Grass Farming*, 5th ed, 1983, p 169; Whetham, *Agrarian History*, p 289; Court, *Seedtime to Harvest*, p 28; Moore, 'Silage on the farm', p 61; Seddon, *The Silent Revolution*, p 36; F Raymond, G Shepperson and R Waltham, *Forage Conservation and Feeding*, Ipswich, 1975, p 16. Between 1954 and 1972 the price of compound feeds (measured in constant prices) decreased by roughly one-third, according to Marks and Britton, *British Food and Farming*, Table 25.12, p 251.

[99] Marks and Britton, *British Food and Farming*, pp 158–62.

[100] *Ibid*, p 142.

[101] Numbers of farm workers are taken from Marks and Britton, *British Food and Farming*, p 138. The decrease in the number of farm workers was seen, at the time, as a reason for the adoption of silage in the 1920s: 'Ensilage not only compares favourably with root-growing in labour costs, but...facilitates the destruction of weeds, partly because these are smothered under the dense foliage and subsequently cut and ensiled before their seeds are shed, and partly because the crop is cleared from the field in early summer, and the land consequently can be broken up in hot weather by steam or tractor and the perennial weeds quickly destroyed' (H Hunter, ed, *Bailliere's Encyclopaedia of Scientific Agriculture*, 1931, p 284). Moore, 'Silage on the farm', p 60, makes the same point.

[102] H Kornberg, *Royal Commission on Environmental Pollution. Seventh Report: Agriculture and Pollution*, Cmnd 7644, 1979, p 10. The figures given are for sales of pesticides by UK manufacturers for home and export use, all at 1976 values, and they show an increase in herbicide sales from about £10 million in 1958 to about £80 million in 1976. However, no figures are quoted for consumption within the UK only (the problems of finding such data are discussed on p 9 of the report), although it is stated that roughly half of all pesticides were sold at home in 1976. The MAFF *Annual Review of Agriculture* gives no separate figures for expenditure on pesticides before 1983 (prior to that they were included with veterinary and electricity costs and rates) and no separate figures for herbicides at all.

[103] Marks and Britton, *British Food and Farming*, p 198; MAFF, *A Century of Agricultural Statistics*, pp 118–19.

[104] Figures for the years up to 1945 are for Great Britain, and are taken from MAFF, *A Century of Agricultural Statistics*, pp 120–21. From 1946 the figures are for UK production and are taken from Marks and Britton, *British Food and Farming*, p 197.

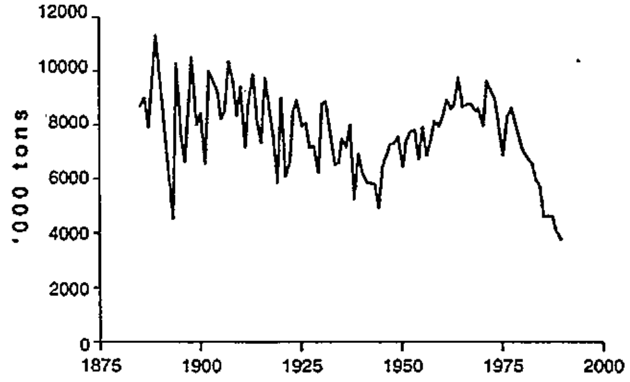

FIGURE 4
Hay production in Great Britain, 1885–1989.

fibre content was increased and its protein content reduced; in hot dry weather, especially when it was tossed about by machinery, there was a risk of loss of the leafier parts of the crop; the anxiety to get it in safely often led to premature carting, so that it was liable to heat in the stack, reducing the digestibility of the protein; in short, even good hay would have a lower energy and protein content than good silage.[105] In a wet season the problems were greater still, despite the advent of tripods, barn driers, balers, conditioners, tedders, and all the other ways in which scientists, machinery manufacturers, and farmers attempted to increase the quality and decrease the handling problems of hay.[106] Paradoxically, the problem was made worse by the increasing use of nitrogen fertilizers on grass. Even in 1905 Primrose McConnell had had problems with a heavy hay crop:

> The extra crop takes a lot of expense in manure and other etceteras to grow it; it is 50 per cent more difficult to cut, because it is certain to be tangled; it has all to be turned, and cocked, and shaken out and 'made' in a way quite unnecessary with a light crop, and then before you get it into the stack the weather breaks, and you get loads on loads of it spoiled...my advice to all whom it may concern is to grow moderate crops; if they do they will have fewer lines of care on their foreheads, they will have more coin chinking in their pockets, and they will prolong their lives.[107]

Despite these considerations, the use of nitrogen, which could treble the yield of a cut, increased by about six times between the late 1940s and the late 1970s, and by then about two-thirds of the total used was applied to the grass crop.[108] In addition, from the mid-1960s the new tetraploid ryegrasses were available, and they were more palatable and digestible because they had a bigger leaf. Consequently they needed more wilting before they would make hay.[109] Thus haymaking remained a problem. Perhaps only big balers really solved the problem of mechanizing it, and even they did not solve the handling problem at feeding time.

The quality and handling problems of hay were solved to some extent by dried grass, but at a significant cost in terms of capital and fuel. Thus it remained a big farmer's or a specialist's product: in 1962, for example, there were only 1100 grass driers in England and Wales.[110] The price of fuel oil, after allowing for inflation, more than doubled between 1970 and 1980, and so increased the variable cost of dried grass to the point where it was too expensive to compete with alternative feeds.[111]

At about the same time, especially in

[105] Moore, *Silos and Silage*, pp 12–13.

[106] Seddon, *The Silent Revolution*, pp 25–7 contains a vivid account of the problems of haymaking; F E Alder *et al*, *The Farmer and Stockbreeder Grassland Handbook*, 1957, pp 106–39 is a good account of the state of the haymaker's art in the late 1950s.

[107] McConnell, *Diary of a Working Farmer*, p 217.

[108] Kornberg, *Royal Commission on Environmental Pollution*, pp 13–15; I am grateful to Dr John Brockman for pointing out the extent of the yield response.

[109] Tetraploid ryegrasses first appeared on the NIAB recommended list in 1964: see National Institute of Agricultural Botany, *Varieties of Ryegrass*, Farmers Leaflet No 16, Cambridge, 1964, pp 4–7. I am very grateful to my colleague David Barnard for this point, and to him and Dr John Kirk for discussing the effects of tetraploid ryegrasses.

[110] MAFF, *Agricultural Statistics, United Kingdom*, 1962, p 22.

[111] These figures are taken from the indices of prices of medium fuel oil or gas oil fuel given in the annual volumes of the *Annual Abstract of Statistics* for the years 1964 to 1983, deflated by the Retail Price Index series (1985 = 100) given in A Burrell, B Hill and J Medland, *Agrifacts*, 1990, p 148. At its lowest, in 1970, the oil price index in real terms stood at 510.2; by 1974 it was 836.1; in 1980, 1179.3; and in 1983, 1492.3. In current price terms (ie not adjusting for inflation) the changes were much greater, nearly trebling between 1970 and 1975, and increasing by 13 times between 1970 and 1983.

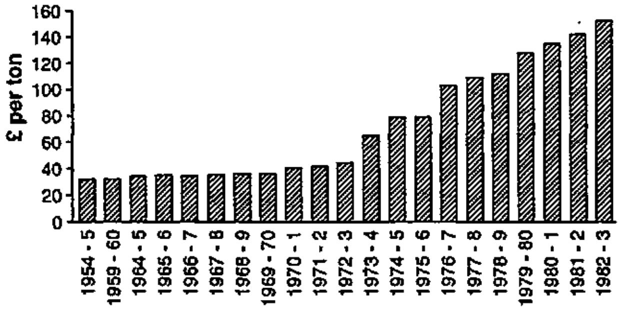

FIGURE 5
Prices of dairy compound feeds, 1954–83.

the years 1973 and 1974, the price of concentrate feeds began to rise (Fig 5) as world prices of cereals and protein feeds rose. For years, in the 1950s and '60s, farmers had been used to buying cake at between £30 and £40 per ton. Now, suddenly, it seemed, the price had doubled. The advantages of getting more than a maintenance ration from bulk feeds were increased.[112] But roots were no longer grown on a large enough scale, there were difficulties in making good hay reliably and cheaply, and dried grass was too expensive. If the quality and handling problems of silage could be overcome, there was a part for it to play.

The first successful attempts to improve the quality of silage were made in the inter-war period, with the introduction of additives. Good silage is made when bacterial action rapidly produces lactic acid, and for this fermentable carbohydrates are required. Thus mature herbage, well chopped, will ferment well, but being mature will have a lower digestibility and protein content than young green grass, which, unfortunately, will contain less fermentable carbohydrates.[113] Professor A I Virtanen, who worked for the Finnish Butter Export Association, introduced the idea of adding a mixture of hydrochloric and sulphuric acids to the grass as it was being packed into the silo in order to increase its acidity rapidly. Farmers in Finland and other Scandinavian countries attended week-long courses to learn how to make silage using this method, which was known as the AIV process after its inventor, and it was successful enough to attract the attention of S J Watson and other scientists working at the ICI experimental farm at Jeallott's Hill in Berkshire in the 1930s.[114] In the USA phosphoric acid was used in a similar process. In Britain, however, the most popular additive until the early 1960s was molasses, which had the advantage that no harm came from excessive application, no damage was done to clothing, containers, or machinery, and the diluted solution could simply be spread on to the crop with a watering can. It produced indirect acidification, in that it was simply a source of fermentable carbohydrate.[115] There was also a combination of these methods, known as the Defu process, which used a mixture of hydrochloric and phosphoric acids and molasses.[116] From the 1950s onwards sodium metabisulphate was added to the list of additives, and by 1980 there was a wide range, under various trade names (eg Sylade, Kylage Extra, Add F and Silage Shield).[117]

[112] Raymond, Shepperson and Waltham, *Forage Conservation and Feeding*, pp 16–17; the reasons for the increases in world prices in the early 1970s are discussed in S Harris, *The World Commodity Scene and the Common Agricultural Policy*, Wye, 1975. The prices charted in Figure 5 are for dairy compound feeds, listed in the 1971, 1975, 1983 and 1989 editions of Federation of United Kingdom Milk Marketing Boards, *UK Dairy Facts and Figures*. In constant price terms, compound feed prices in 1973 and 1974 increased to levels not experienced since the mid-1950s, although by 1982 they had again fallen to their 1972 level. See Table 25.12 in Marks and Britton, *British Food and Farming*, p 251.

[113] H I Moore, *The Science and Practice of Grassland Farming*, 1949, p 112.

[114] Watson, *Silage and Crop Preservation*, pp 131–2; Cooper and Morris, *Grass Farming*, 5th ed, 1983, p 169.

[115] Moore, *Science and Practice of Grass Farming*, pp 112–13.

[116] Charles Crowther, 'The feeding of livestock', *JRASE*, 96, 1935, p 332.

[117] Moore, 'Silage on the farm' p 65; Culpin, *Farm Machinery*, 10th ed, 1981, p 180; the various categories of additive are classified and described in Halley and Soffe, *Agricultural Notebook*, pp 199–200; this also describes a system (known as the Liscombe Star System) for deciding whether or not an additive is needed under various circumstances of grass variety, growth stage, nitrogen level, weather, degree of wilting and chopping: it is clear from this that even with good weather Victorian silage makers would have made better silage if additives had been available.

The other problem to be tackled in the late 1930s was the high capital requirement for building silos. Cheaper concrete silos became available, some costing as little as £15, and the wire mesh and sisal paper silo introduced in 1938 was even cheaper, with a capital cost of £10 for a 40 ton capacity silo.[118] Nevertheless, the problem of getting the grass into the silo remained, and so the advantage still lay with the farmer – usually the big farmer – who could afford green crop loaders and silage cutters and blowers. The biggest contribution towards solving this handling problem was made by the Hampshire farmer, Rex Paterson, in the late 1940s. It was the invention of the buckrake, 'quite one of the most brilliant creations of his fertile brain', according to another Hampshire farmer, John Cherrington.[119] Something like the buckrake had been used by the Hosiers before the war. It was called the haysweep, and mounted on the front of a tractor or an old motor car.[120] Paterson's contribution was to design a more manoeuvreable device, mounted on the hydraulic three-point lift of the cheap (just over £300 for several years after the war) little grey Ferguson tractor. With a buckrake a heap of grass could be collected, then lifted hydraulically and rapidly driven to a clamp made at the side of the field, where the tractor, in the act of depositing the load, also compacted the clamp. Paterson had light land on which he could outwinter his stock, and so the grass was fed back on the land from which it was cut.[121] Quite how many buckrakes there were in the 1950s is uncertain, because until 1968 they were counted along with hay sweeps in the machinery censuses, and, of course, not all of them were used in silage making, but their numbers were quite clearly significant, as Table 2 demonstrates. The buckrake was not really suitable for long-distance transport of grass, and it was the introduction of the forage harvester which allowed the mechanization of farmstead-based silage making. Forage harvesters were first introduced from the USA during the 1940s, and by the mid-1950s domestically-produced machines such as the Hayter Silorator were available. By 1962 it could be said that forage harvesters were replacing buckrakes in Warwickshire and increasing the popularity of silage in Devon.[122] The rate at which they were adopted can be seen from Table 3, which also shows that in recent years the simpler, cheaper, flail types have gradually been replaced by the larger, more complex machines. Sales of self-propelled forage harvesters, the largest

TABLE 2
Number of buckrakes in the United Kingdom

Year	*Number*	
1954	115,130	('hay and silage sweeps, and buckrakes')
1958	102,100	('hay and silage sweeps, buckrakes and hay loaders')
1961	88,400	('hay and silage sweeps, buckrakes and hay loaders')
1968	56,870	
1973	55,310	
1981	46,091	
1985	45,200	

Source: MAFF, *Agricultural Statistics, UK*, annual, various editions.

[118] Halnan and Garner, *Principles and Practice of Feeding Farm Animals*, p 136; according to Moore ('The conservation of grass', p 30) the wire mesh silos were difficult to fill, sometimes collapsed, and could only be regarded as a wartime expedient.

[119] John Cherrington, *On the Smell of an Oily Rag: My Fifty Years in Farming*, 1979, p 132; Cherrington was not the only enthusiast: it was 'one of the most valuable developments in modern grassland farming', according to M McG Cooper, *Competitive Farming*, 1956, p 29, and 'The greatest innovation in connection with silage making' for Jesse, *Agriculture of Sussex*, p 125.

[120] Hosier and Hosier, *Hosier's Farming System*, p 134. In fact, Hosier's hay-sweep was a simpler version of the horse-drawn sweep rake which Primrose McConnell claimed to have introduced from the United States of America in the 1890s: see P McConnell, *The Complete Farmer*, 1911, p 385.

[121] Cherrington, *On the Smell of an Oily Rag*, p 132; Cooper, *Competitive Farming*, p 29; Paterson, *How We Make Silage*.

[122] Culpin, *Farm Machinery*, 2nd ed, 1944, p 226, and 5th ed, 1957, p 283; Moore, *Science and Practice of Grassland Farming*, p 117; Bradley, *Cooperation*, p 38; Higgs, 'Agriculture of Warwickshire', p 76.

TABLE 3
Number of forage harvesters in England and Wales

Type	*1959*	*1962*	*1968*	*1971*	*1976*	*1983*	*1987*
Loader wagons					5570	8308	8390
Simple flail					12,190	8064	6160
Double chop					9740	.9898	8370
Metered chop					4940	11,904	13,050
Total	7920	15,260	21,950	23,690	32,440	38,174	35,970

Source: as for Table 2.

and most expensive of all, more than doubled between 1985 and 1992.[123]

Another major development which began in the 1960s was the increase in the size of dairy herds. The average herd size increased from 15 cows in 1942 to 20 in 1960, and then increased by at least one or two in most years to reach 41 in 1974 and 64 when milk quotas were introduced in 1984. Perhaps because these bigger herds could no longer fit into existing cowsheds, and perhaps also because farm improvement grants were available for the purpose, there was at the same time a trend to replace cowsheds by parlours and loose housing or cow cubicles. In 1964 less than 13 per cent of all dairy herds were milked through parlours; in 1974 the figure was nearly 40 per cent, and by 1982 two-thirds of all herds were parlour-milked.[124] Both loose housing and cubicles lent themselves to the self-feeding of silage, which overcame the handling problem. Self-feeding appears to have developed in the early 1950s, but it does not seem to have been widely adopted until the early 1960s.[125] An alternative, high capital approach was the tower silo coupled with a mechanized feeding system, but the numbers of these remained small: there were 1560 tower silos in 1971, and 930 mechanical unloading systems for tower silos in 1973.[126]

Tower silage was usually high quality material because it was well chopped and the tower was almost airtight. Silage made in clamps in the 1950s often had a high proportion (between 15 and 60 per cent was quoted by one author) of waste material in it.[127] At the same time that self-feeding of clamps was being developed there was another important innovation which had a major impact on the quality of the silage in the clamp: the use of polythene sheeting. It enabled the air to be kept out of a clamp, so promoting the lactic acid fermentation which produced high-quality material with little waste. By the early 1960s it was being used in New Zealand to make vacuum silage, in which polythene sheets were joined together to make, in effect, an airtight bag of grass, which was then evacuated by vacuum pump.[128] A simpler system was developed in Britain by Richard Waltham, a Dorset dairy farmer, also in the early 1960s. It involved stacking the grass rapidly in a wedge shape (hence the name of the system, the *Dorset Wedge*), then covering it overnight with a polythene sheet to prevent

[123] I am grateful to my colleague Derek Shepherd, and to Chris Evans of the Agricultural Engineers' Association Ltd for obtaining these figures.

[124] Federation of United Kingdom Milk Marketing Boards, *UK Dairy Facts and Figures* (annual), various editions.

[125] Cooper and Morris (*Grass Farming*, 5th ed, 1983, p 169) credit Rex Paterson with the invention of self-feed soon after 1950. It was discussed as an experimental method in Frank Henderson, *Making Mechanised Farming Pay*, Ipswich, 1954, and as a method under trial in 1955 in Moore, 'Silage on the farm', p 66. Arthur Court (*Seedtime to Harvest*, p 78), who was perhaps more typical of the ordinary farmer, mentions its adoption in 'about 1960', and Mercer, *Agriculture of Cheshire*, p 83 suggests its rapid adoption during the years 1960–63.

[126] Data from MAFF, *UK Agricultural Statistics*, 1974; for an illustration of the mechanisms see Weller, *History of the Farmstead*, pp 59 and 198.

[127] C P van Zeller, 'Vacuum compression silage', *Agriculture*, 72, 1965, pp 219–21.

[128] *Ibid*, p 220.

warm air rising out of the grass and being replaced by oxygen-rich cold air. Clearly the system depended on cheap polythene sheet, and by 1963 this was common enough for ICI to make a promotional film about *Farming with Polythene Sheeting*. By the late 1960s this was the system which both fertilizer companies (and ICI made both fertilizers and polythene) and Ministry of Agriculture advisers were promoting.[129]

By the beginning of the 1970s, therefore, most of the techniques which were needed for the average farmer to consider the adoption of silage were available. Perhaps the final technical change, which allowed the very small producer, with the aid of a contractor, to rely on silage, was the development of big-bale silage, first using plastic bags and subsequently wrapped bales, which are more resistant to damage. By the early 1990s big-bale silage accounted for 20 per cent of the total silage output.[130]

VI

Silage provides a case study of the adoption of a technical innovation in the late nineteenth and twentieth centuries. One interesting historiographical point to emerge from it is concerned with evidence. Much of the material from contemporary textbooks and journals is about the advantages of silage and the reasons why it should be adopted; most of the statistical evidence is about the extent to which it was *not* adopted until recently. In other words, the evidence generated by opinion-formers is at odds with the evidence of the activities of the majority. While this may not be surprising, it is not unimportant, because the ease of access to late-nineteenth and twentieth-century journals make them a tempting source. Yet the story of silage suggests that the picture which emerges from a reading of the contemporary literature may be different from that which appears from an examination of those sources which allow some measurement of the extent to which innovations were adopted. The same point might well apply to other technical changes, such as the adoption of inorganic fertilizers, pesticides, machinery, buildings, new breeds of livestock and new varieties of crops. The British agriculture of the textbook and journal appears to be technically dynamic in the period between 1850 and 1950; on the majority of farms it was less so.[131]

Hill and Ray's list of factors which prevent the adoption of an innovation – lack of information, uncertainty, management problems, high capital requirements and use of expensive inputs – has been shown to be largely applicable in the case of silage, except, perhaps, as far as information is concerned. With all the attention given to silage at agricultural shows and demonstrations, in advertisements, press articles, radio and television programmes, and by advisers, it would be difficult to argue that farmers were unaware of the technique. Even in the 1880s there was somebody making silage in each English and Welsh county. But awareness by itself was not enough to provoke adoption, and the slow uptake of silage provides a good illustration of the other factors on Hill and Ray's list. Quality problems produced uncertainty, as the difficulties caused by sweet ensilage demonstrate. In the USA, where easily-ensiled maize was a more common crop, the spread of silage was much more rapid. Later, the solution of the quality problem by the use of additives and polythene preceded the eventual rapid adoption of silage in Britain. The difficulties of making a quality product might

[129] Seddon, *The Silent Revolution*, pp 29–32; Anon, 'Polythene sheeting', *Agriculture*, 70, 1963, p 43; I am most grateful to my colleagues John Brockman and John Usher for making me aware, from their own personal experience, of the importance of polythene sheeting.

[130] P L Redman, 'Big bale silage', *JRASE*, 144, 1983, pp 113–18; Culpin, *Farm Machinery*, 12th ed, 1992, p 192.

[131] This point is discussed in greater detail in the sections written by the author of this article for E J T Collins, ed, *The Agrarian History of England and Wales, VII, 1850–1914*, forthcoming.

also be seen as a management problem. Farmers understood the problem of haymaking: it was simply a matter of dehydration. The complex biochemistry of silage was more difficult to grasp. The high capital requirements of silage presumably explain why its nineteenth-century adopters were mainly landowners and the bigger farmers; when farms and dairy herds increased in size, and polythene-covered clamps offered a relatively cheap method of producing a palatable product, the rate of adoption was rapid. With the advent of wrapped big bales made by a contractor or a neighbour, even those operating on a very small scale could go over to silage. Changing factor prices – of labour, concentrates, fertilizers and machinery – also had an effect on the process. When labour was cheap, roots were an important component of animal rations. When concentrate prices were low there was little incentive to maximize home-produced protein. Then, gradually, increasing fertilizer applications gave heavier grass crops over which to spread the costs of changing to silage making. Eventually, in the 1970s and '80s, more plentiful machinery and scarcer labour gave the advantage to a fodder conservation process which had, finally, been mechanized. Once farmers had encountered problems with alternative winter feeds, and had learned how to make good silage, reliably, and had the necessary machinery, and had found an easy way to feed it, its adoption was rapid. But until all those parts of the system were in place most of them resisted all the blandishments of enthusiasts, politicians, scientists and advisers for nearly a century.[132]

[132] There are perhaps some interesting comparisons to be made between the delayed adoption of silage and the pattern of adoption of fertilizers in Britain and high-yielding rice varieties in south-east Asia. Inorganic nitrogenous fertilizers were available in the nineteenth century, but their use expanded most rapidly after the 1950s, when shorter-strawed cereal varieties became available, which were capable of withstanding high nitrogen applications without lodging, and output expansion did not, thanks to price support, produce falling prices. Similarly van der Eng explains that the delay in the adoption of high-yielding rice varieties was the result of several inter-dependent factors: see P van der Eng, 'Development of seed-fertilizer technology in Indonesian rice agriculture', *Ag Hist*, 68, 1994, pp 20–53.

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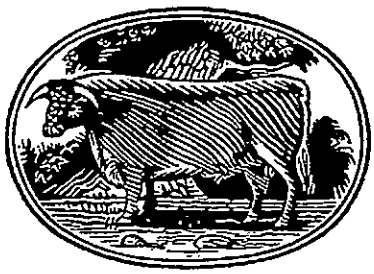

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The British Agricultural History Society

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producing vanners and omnibus horses as sidelines on their farms, had just cause for concern.[65] How far the profits of these people were affected by the growing volume of imports at a time of generalized depression in the agricultural industry is a matter beyond the scope of the present essay. For the breeder of pedigree heavy horses, on the other hand, there were apparent benefits to be gained since a buoyant American export trade to Britain in crossbred working animals would theoretically be dependent upon a steady supply of quality breeding stock.[66] At the time it seemed reasonable to assume that this stock would be obtained from Britain, and as many of those American importers who had closed their businesses after 1893 returned to trade in the early 1900s, British producers were optimistic. But their optimism was unfounded. The fact that 90 per cent of the 'bus horses in London in the late 1890s were cross-bred Percherons imported from the United States, speaks volumes for the transatlantic success of that breed, besides which, the potential for extensive British sales withered on the altar of greed. Having fared relatively well during the years of depression, breeders could not resist the temptation of demanding excessive prices from overseas traders. There was little point in a would-be importer even considering the matter, complained a *Livestock Journal* editorial, 'when he is not offered a two year old Shire at less than £200'.[67]

Small wonder, then, that although British exports to America advanced in the first decade of the twentieth century, the focus of transatlantic attention concentrated increasingly on the Percheron which could be obtained at reasonable prices, and probably more consistent quality. Even so, the Shire and Clydesdale horses which had previously made the arduous and stressful crossing of the Atlantic had played out a significant role in the agricultural and urban development of North America. While the actual effect of pedigree blood from the British Isles on the draught and conformational qualities of the horses cultivating the plains of the mid-West cannot realistically be quantified, it is probable that, at the local level at least, these animals had a greater influence than the mere counting of heads would suggest. As importers advertised the qualities of their stallions and stimulated local interest, the genetic material of individual sires would soon become widely spread as farmers used them to upgrade their own stock. And yet, foresighted breeders and farmers in the first decade of the present century could not have failed to notice the fading relevance of all these efforts. The inexorable spread of mechanisation on the land and in the city meant that ultimately horse power was doomed. But for many, the horse was more than a mere tool; it was a potent symbol of strength and self-reliance, an icon of the pioneering past not to be lightly cast aside. People hoped against hope that the heavy horse would remain the focal point of the farm with the tractor as an adjunct, and that attention to breed improvement would tip the balance in its favour. But despite intensive Canadian experimentation to improve horse efficiency, and the innumerable demonstrations of equine strength by way of pulling contests (carefully measured by dynamometers pioneered at Iowa State University and sophisticated by Professor E. A. Hardy of Saskatchewan), the future of the draught horse looked increasingly bleak.[68] So bleak indeed that by the later 1920s, horses were disappearing from the farmscape to be despatched to the meat packers at the rate of half a million a year.[69]

[65] *Livestock J.*, 28 Sept. 1894; 25 Oct. 1895.

[66] *Ibid.*, 13 July 1900.

[67] *Ibid.*, 3 Nov. 1899.

[68] T. C. Barker in F. M. L. Thompson (ed.), *Horses in European economic history. A preliminary canter* (1983), pp. 105–107.

[69] Howard, *The horse in America*, p. 229.

Output and technical change in twentieth-century British agriculture*

by Paul Brassley

Abstract

Previous estimates of British agricultural output in the twentieth century have covered the period before the Second World War, or after it, but not both. This paper reconciles the differences between previous estimates and goes on to calculate changes in the volume of output between 1867 and 1985. As a result, it is suggested that output grew more rapidly between 1945 and 1965 than during any period before or since. Some of the reasons for this rapid growth are then examined, and it is suggested that the rapid adoption of pre-existing technology was of greater significance than the technical innovations of the period.

Many of the histories of British agriculture in the twentieth century imply, by their starting or finishing dates, that there was a discontinuity at the beginning or end of the Second World War. Thus Miss Whetham's volume in *The Agrarian History of England and Wales* ends in 1939, Dr Perren's study of *Agriculture in Depression* in 1940, and Dr Brown's account in 1947.[1] The latter two also accept, as does Dr Thirsk[2] that the years between 1900 and 1939 represent a continuation of the period beginning in the 1870s, when high levels of imports produced low levels of domestic prices. This was the age of 'dog and stick' (i.e. low input-low output) farming, with increased emphasis on milk production, except for a brief period during and shortly after the First World War. Holderness goes so far as to assert that 'Farming in 1940 was not significantly different in structure and practice from farming in 1840'.[3] In contrast, the period after the Second World War is perceived as one in which government support ('subsidy' and 'feather bedding' are alternative terms which have been used) together with extra science and technology produced dramatic increases in output with a little less land, much less labour, and much more capital. In Joan Thirsk's terminology, the period between 1939/47 and 1985 is a period of mainstream agriculture. Historians of post-war agriculture have been concerned to explain how and why the output increases and technical changes of these years came about. Thus Seddon concentrates on the technology, Blaxter and Robertson on the science behind it,

* I would like to thank Derek Shepherd, Andrew Errington, and two anonymous referees for their comments on previous drafts of this paper, and Barbara Sheaves for her assistance with the preparation of the diagram.

[1] E. H. Whetham, *The Agrarian History of England and Wales*, VIII, *1914–1939* (1978); R. Perren, *Agriculture in depression, 1870–1940* (1995); J. Brown, *Agriculture in England. A survey of farming, 1870–1947* (1987).

[2] J. Thirsk, *Alternative Agriculture. A history, from the Black Death to the present day* (1997).

[3] B. A. Holderness, 'Apropos the third Agricultural Revolution: how productive was British agriculture in the long boom, 1954–1973', in P. Mathias and J. A. Davis (eds), *Agriculture and Industrialization: from the eighteenth century to the present day* (1996), p. 69

and Collins and Holderness on productivity changes.[4] The post-war period is generally seen as a coherent whole, at least until the middle of the 1980s, when concerns over the cost of supporting agriculture, and its environmental effects, led to the first restrictions on output.

The following paper does not seek to argue that these approaches are fundamentally wrong, but that the pre-war / post-war dichotomy might be an over-simplification. This view is based upon a new attempt to produce a coherent dataset for the output of British agriculture over the period 1867–1985, details of which are given below. The consequent speculations about the reasons for the observed changes concentrate on the history of technical innovation and adoption, although the effects of labour and developments in government policy towards agriculture are not ignored.

I

Since the beginning of the twentieth century, the output of British agriculture has increased, but not uniformly. Although the outputs of wheat, sugar beet, oilseed rape, milk, eggs, beef, pigmeat, and poultrymeat have all increased significantly, the quantity of sheepmeat produced has only increased a little and that of oats and root crops has decreased markedly.[5] To some extent, therefore, greater quantities of some products have been secured at the expense of smaller quantities of others. To measure overall output changes in physical units – tons or litres etc. – is therefore difficult and potentially misleading. This is not a new problem. It has been faced by all those attempting to measure productivity, and several approaches to overcoming it have been suggested. Campbell and Overton, for example, converted grain and potato outputs into energy equivalents.[6] Another solution is to measure all outputs in monetary rather than physical units. Not only does this render them all susceptible to addition, it also reflects the different values placed by society on various commodities. This is the approach adopted in National Product calculations, and consequently estimates of gross output, in current prices, are available for several industries, agriculture included, back to 1939. In addition, Ojala's well-known estimates of inputs and outputs cover the period from the initiation of the annual agricultural census, on which they are based, in 1866 (see Table A1). Although Ojala's figures are not directly comparable with the Ministry of Agriculture, Fisheries and Food's Departmental Net Income Calculation (DNIC), it is possible to adjust them to fit, and this has been done in the appendix to this paper.

Perhaps the main problem involved in using monetary units is their inconstancy. In order to make meaningful comparisons between different time periods, it is necessary to take account of the changing value of money. This too has been done in the appendix (Table A4). The

[4] Q. Seddon, *The silent revolution. Farming and the countryside into the twenty-first century* (1989); K. Blaxter and N. Robertson, *From dearth to plenty. The modern revolution in food production* (1995); E. J. T. Collins, 'Agricultural Revolution in a modern industrial state' (paper presented to the Economic History Society Conference at Canterbury, 1983); Holderness, 'Apropos the third Agricultural Revolution'.

[5] P. Brassley, *Agricultural economics and the CAP: an introduction* (1997), p. 38

[6] M. Overton and B. M. S. Campbell, 'Statistics of production and productivity in English agriculture 1086–1871', in B. J. P. van Bavel and E. Thoen (eds), *Land productivity and agro-systems in the North Sea area, Middle Ages-twentieth century: elements for comparison* (Turnhout, 1999), pp. 199–202.

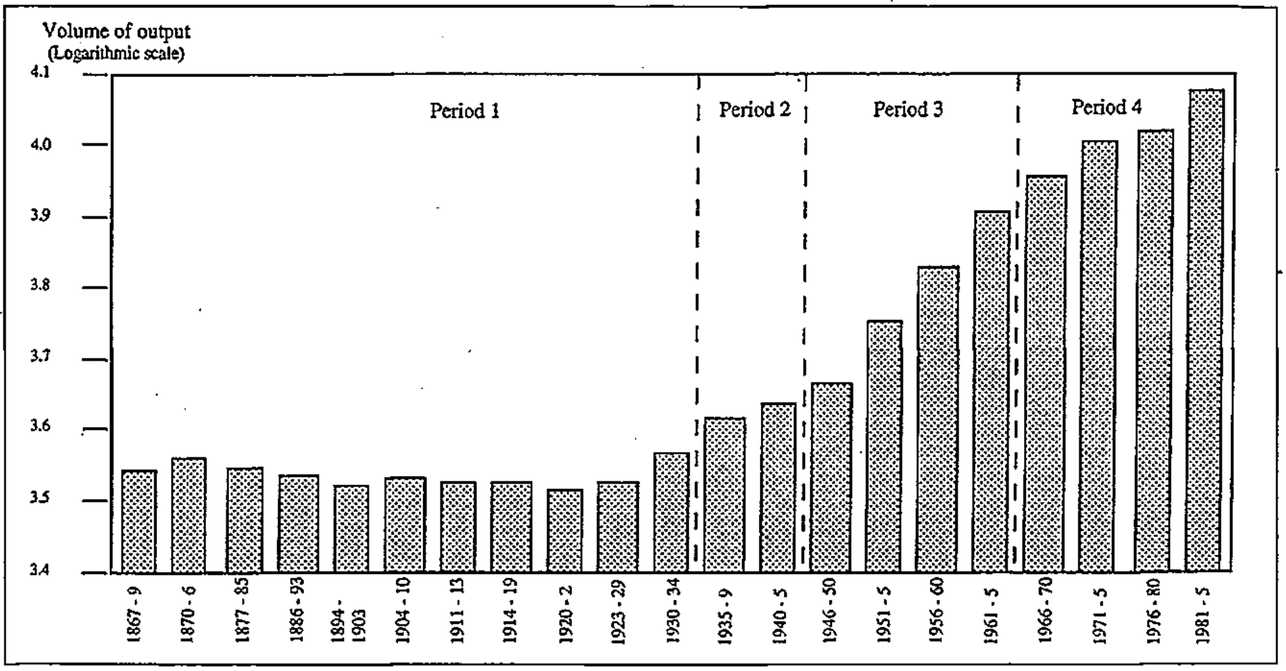

FIGURE 1. Changes in the volume of agricultural output in Britain, 1867–1985.
Source: See Table A4 below.

resulting figures, presented graphically in Figure 1, reveal an interesting pattern. Between 1867 and 1922, the output of British agriculture, in constant 1986 prices, was generally between £6 billion and £8 billion. Between 1924 and 1934 it fluctuated, but was always below £6 billion. Between 1935 and 1960 it rose from £6 billion to £12 billion, and thereafter remained between £12 billion and £14 billion. Thus it might be argued that there was a nineteenth-century plateau of production at the £6–8 billion level, and a late-twentieth century plateau at the £12–14 billion level. They are separated by a period of gradual decline in output, followed by a period of rapid increase in the two and a half decades between 1935 and 1960. However, a problem still remains. High levels of gross output may be produced either by high volumes of output or by high prices. Equally, volume increases may be masked if they occur at the same time as real farm price decreases. Consequently, it is also useful to calculate the volume of output, which can be done simply by deflating the gross output figures by the corresponding agricultural price indices. This in effect means that the physical output in any one period of time is multiplied by a constant price, so that the effects of increasing or decreasing prices are removed.[7]

The effect of this calculation, compared with the gross output figures, is to reduce the size of the change between 1940 and 1960, and to emphasize the continued expansion of output after 1965 (see Table A4). Nevertheless, as Table 1 demonstrates, the most rapid annual rate of output growth took place between 1946 and 1965. It therefore seems logical to divide the late nineteenth and twentieth centuries into four periods (as in Figure 1). In the first, up to the 1930s, prices declined but output was maintained as UK agriculture switched from arable to

[7] This is essentially the same as the method used by Turner for the 1867–1914 period, although the order of the calculations is different. See the discussion relating to Table A4 in the appendix, and M. Turner, 'Output and prices in UK Agriculture, 1867–1914, and the Great Agricultural Depression reconsidered', *AgHR* 40 (1992), pp. 38–51.

TABLE 1. Annual rates of growth in the volume of agricultural output

	% per annum
1870–1935	0.01
1935–1945	0.5
(1935–1965)	(2.3)
1946–1965	2.8
(1946–1985)	(2.3)
1966–1985	1.4

Source: for output volume figures, see table A4; the calculation of annual rates uses the method described in R. Floud, *An introduction to quantitative methods for historians* (2nd edn, 1979), pp. 94–5.

pastoral products. This was Turner's conclusion for the period up to 1914, and it seems to hold equally good for the post-World War I period.[8] The second period is the ten years or so between the mid-1930s and the mid-1940s. The gradual increase in output stimulated by government subsidies to wheat production and the success in the later 1930s of the Milk Marketing Board is often swamped by the drama of the war years. Overall, however, the input changes of this period (such as labour, fertilizer use and land reclamation) were more noticeable than the changes in the volume of output. Gross output certainly increased, but largely as a result of high wartime prices. It was in the third period, between 1946 and 1965, when prices were, initially at least, higher still (see Table A4) that the volume of output rose most rapidly as both arable and livestock sectors expanded.[9] In the final period, between 1965 and 1985, output still expanded, but at a reduced rate, as labour left agriculture rapidly, and much of the extra cereal production was fed to intensive livestock (pigs and poultry) and dairy cows.

II

A detailed explanation of the reason for these changes in the volume of output, and their timing, would take more space than is available here. Nevertheless it is possible to suggest some of the contributory factors. Those which appear to be especially important are changes in land use, changes in labour inputs, technical innovation and adoption, and agricultural policy, particularly its impact on farm prices and incomes.

Any change in the output of an individual crop can be attributed to a change either in the area devoted to the crop, or in the output per unit area. In any examination of the first of these, the cropped area, it makes sense to begin with the cereals, since these exhibited the greatest fluctuations in this period. As Table 2 demonstrates, the total cereal acreage fell between 1870 and 1930, before rising rapidly up to 1965 and rising further still until 1985. Within this

8 Turner, 'Output and prices', p. 51

9 The annual growth rates shown in Table 1 may be compared with the annual rates calculated for various periods between 1520 and 1850 by Overton, the greatest of which was 1.18 per cent for the period 1800–30. Mark Overton, *Agricultural Revolution in England. The transformation of the agrarian economy, 1500–1850* (1996), p. 85.

TABLE 2. Crop areas in Great Britain and the UK
('000 hectares)

	Wheat	Barley	Oats	total cereals	Potatoes	Sugar Beet	Fruit & Veg.	Fodder Crops	Temp Grass	Perm Grass	Rough Grazing
1870	1417	960	1118	3402	238	–	n.a.	1020	1825	4890	n.a.
1885	1003	913	1190	3251	222	–	233 [a]	959	1885	6214	n.a.
1910	732	700	1223	2811	219	2	265 [a]	812	1707	7066	n.a.
1930	567	456	1068	2291	277	141	266	556	1721	7389 [b]	n.a.
1940s	1403	723	1490	3547	563	169	383	451	1620	5547	8683
1965	1025	2183	410	3656	300	184	263	158	2430	4912	7216
1985	1902	1965	133	4015	191	205	236	74	1700	5019	5019

Notes: [a] author's estimates; [b] 1929 figure.
Sources: H. F. Marks (ed. D. K. Britton), *A hundred years of British food and farming: a statistical survey* (1989), pp. 130, 158, 173–4, 179–80, 183, 187.

overall trend, though, there are considerable differences between wheat, the acreage of which increased most dramatically between 1965 and 1985, barley, which expanded most rapidly between the Second World War and the 1960s, and oats, the acreage of which remained virtually untouched by the price changes of the late nineteenth century, only to fall away rapidly and continuously after the 1940s as the farm horse disappeared. Thus some of the extra wheat and barley appeared because land was no longer needed for oats, but this is not a complete explanation, because the total cereals area roughly doubled from its low point in the inter-war years by 1985. The other main crop which took up more land was sugar beet, the area of which expanded most rapidly in the first half of the twentieth century. To some extent the extra area used by these expanding crops in the post-war years was made available by declining acreages of potatoes, fruit and vegetables, and, especially, fodder crops, the area of which declined steadily from the 1870s onwards. But these shrinkages provided only about one third of the extra land needed for the expanding crops. The bulk of the extra cropland came from the conversion and reclamation of permanent grass and rough grazing. The permanent grass area, having expanded considerably at the end of the nineteenth century as the cereal and roots acreages fell, was attacked enthusiastically at the beginning of the Second World War. Speaking in 1942, William Davies, one of the leading figures in the Plough-Up campaign, claimed that over four million acres (1.62m hectares) of the sixteen million acres identified by the pre-war Grassland Survey of England and Wales had been ploughed up.[10] This figure roughly agrees with the change in the permanent grass area between 1929 and 1942 shown in Table 2. After the war the permanent grass area declined a little further, but not in the dramatic fashion of the war years. The area of rough grazing also decreased between 1942 and 1965, and between 1965 and 1985 (Table 2). What happened before 1942 is less clear as a result of difficulties in definition and enumeration

[10] W. Davies, 'Taking the plough round the farm', a talk broadcast on the Home Service of the BBC on Thursday 12 Mar. 1942, subsequently printed in a collection of *Farming Today broadcasts* published by Littlebury & Co., Worcester (?1943), p. 17.

TABLE 3. Numbers of Agricultural Workers (excluding farmers) in Great Britain

	('000)		('000)
1867–69	1450	1935–39	738
1870–76	1385	1940–45	815
1877–85	1221	1946–50	865
1886–93	1124	1951–55	777
1894–03	1047	1956–60	678
1904–10	1075	1961–65	567
1911–13	1103	1966–70	432
1914–19	1050	1971–75	377
1920–22	996	1976–80	341
1923–19	907	1981–85	314
1930–34	825		

Source: Marks (ed. Britton), *A hundred years*, p. 138. The Marks and Britton figures before 1923 are taken from the decennial censuses. The figure for 1867–69 is calculated from the average rate of decline over the decade; those for 1870–1922 from the census years that fall in the year groups, with the exceptions of the 1904–10 period, for which the figure is the average of the 1901 and 1911 figures, and the 1914–19 period, for which the figure is the average of the 1911 and 1921 figures. For the years after 1923 annual estimates from the agricultural census are available, and these are reported for each year by Marks and Britton, and have been averaged for each year group here. The figure used here for 1914–19 may be compared with Dewey's estimate, which is slightly lower, but measured in man-units, in which young males and all females are rated as less than one unit (P. Dewey, *British Agriculture in the First World War* (1989), pp. 44–5, 248–9).

in the agricultural returns.[11] What is certain is that the change in the permanent grass area between 1930 and 1985 (2.37m ha.) was more than enough to provide for the net increase in the area of the major crops in the same period (1.19m ha.), although it should be noted that much of the expanding urban area in this period was on land which would have been classified as arable, and much of the expanding forestry area on rough grazing.[12]

To some extent, therefore, the increasing volume of agricultural output in the second half of the twentieth century can be attributed to the more intensive use of land. Rough grazing was converted to permanent grass, and permanent grass to temporary grass or arable. But this will not explain all the changes, for while the process was being reversed (i.e. cropland was being converted to permanent grass) between 1870 and 1930, the volume of output was more or less maintained. And it was not maintained by simply substituting labour for land, because the move to pastoral farming saved labour (see Table 3). Conversely, the period of most rapid output increase, in the 1940s and '50s, was the only one in which the tendency to leave the land was reversed. Apart from the impact of the Womens' Land Army and prisoners of war during

[11] These problems are discussed at length in Ministry of Agriculture, Fisheries and Food, *A century of agricultural statistics, 1866–1966* (1968), pp. 10–11, and P. Allanson and A. Moxey, 'Agricultural land use change in England and Wales, 1892–1992', *J. of Environmental Planning and Management* 39 (1996), pp. 243–54.

[12] A. G. Champion, 'Competition for agricultural land', in A. Edwards and A. Rogers (eds) *Agricultural Resources* (1974), pp. 213–44.

TABLE 4. Crop yields, Great Britain (to 1914) / UK (tonnes per hectare)

	Wheat	*Barley*	*Oats*	*Potatoes*	*Sugar Beet*
1885–9	2.06	1.96	1.66	14.7	
1910–14	2.17	1.96	1.71	15.8	
1930–34	2.23	2.02	1.97	16.5	20.2
1942–46	2.56	2.37	2.16	17.8	26.4
1965–69	3.93	3.61	3.22	25.4	37.4
1985	6.33	4.95	4.59	35.8	38.3

Source: Marks (ed. Britton), *A hundred years*, pp. 164, 175, 180.

the war itself, returning servicemen appear to have had some effect in the five years after the Second World War when labour numbers reached a peak. Thus, as pointed out above, output can be changed by using more or less land, but also by producing more or less from any given acre of land. Other things being equal, more labour applied to a given acreage will tend to increase the output, or yield per acre, and less to decrease it. But other things were clearly not equal, for both total volumes of output and arable yields remained reasonably constant while agriculture was becoming more pastoral and labour was leaving the land between 1870 and 1930. Equally, yields increased as labour decreased after 1960 (see Table 4). Something else was affecting output and yields. Technical change is the usual suspect, and it is to the impact of technology that the discussion must now turn.

III

The range of technical changes in twentieth-century agriculture, in the UK alone, is large. There have been new techniques for accomplishing existing activities, such as silage-making for grassland conservation and artificial insemination of animals. New crops, such as maize, oilseed rape, peas for freezing, and sugar beet, have become an important part of the industry's ouput. Although there have been no new animal enterprises (*pace* venison and ostrich meat, sheep and goats' milk and angora goats and llamas), the output of milk, pigmeat, and poultrymeat have increased significantly. In order to produce these new or increased outputs there have been new inputs, such as the change from Shorthorn to Friesian cows, underdrainage, artificial fertilizers, purchased feedingstuffs, pesticides, new varieties of crops, and the mechanization of many field and farmyard operations. This is not necessarily a complete list, but it includes most of the major changes, and it is interesting to note that many of them were originally developed before 1935, although they became widely used after 1950 or later.

This observation emphasizes the importance of distinguishing between innovation and adoption when assessing technical change. This is not to say that one is more important than the other: without innovation there is nothing to adopt; without adoption the innovation is ineffective. They work together like the blades of the scissors, but, unlike the scissors, they do not necessarily work at the same time. Some innovations have been adopted rapidly, and others much more slowly, but of all the changes listed above probably only one (peas for freezing) was totally

TABLE 5. Sugar Beet in the UK

	Area ('000 ha)	*Output ('000 tonnes)*	*Yield (tonnes per ha)*
1912	2		
1925	23	497	21.6
Pre-war	135	2785	20.6
1946–8	168	3996	24.0
1959–61	175	6320	36.4
1983–85	200	8076	40.8

Source: Marks (ed. Britton), *A hundred years*, pp. 179–81.

unknown before the beginning of the First World War. Equally, few of them had been adopted on a significant scale before the Second World War. The best-known exception to this generalization was sugar beet, which could have been introduced in the nineteenth century: in the event, the first factory in England was not built until 1911, and met considerable indifference from the surrounding farmers. Following the introduction of a subsidy in 1924 the cultivated area and output increased nearly sixfold between 1925 and 1939 (See Table 5).[13] By 1960 sugar beet yields and output were approaching modern levels, but most of the modern technical developments – monogerm seed, precision drills, herbicides and harvesters – had still to be adopted. The significant point about these post-1960 developments is that they were all labour-saving rather than output-increasing.

Some new cereal varieties were also widely adopted in the inter-war period. By 1926 17 per cent of the wheat samples received by the National Institute of Agricultural Botany at Cambridge for germination testing were of Yeoman, a variety which had not been introduced until 1916.[14] Similarly, by 1939, 78 per cent of the barley samples received were of the varieties Spratt-Archer (first selected in 1908 and not grown in England on a field scale until 1920), Plumage-Archer (first produced in 1905) and Plumage (1902). The Ministry of Agriculture calculated that the average yield for the period 1922–9 was between 6 and 7 per cent higher than the average yield for the period 1912–19, which one respected (but not impartial) authority attributed largely to varietal change.[15] More detailed calculations, which attempt to distinguish between the yield increases due to varietal change and those caused by other factors such as the use of fertilizers and pesticides, reductions in harvest losses, and improvements in the standard of husbandry, are available for the period between 1947 and 1975. These suggest that 'other factors' had their major impact before the late 1960s. Between 1947 and 1967 new wheat varieties increased the national average wheat yield by 0.63 tonnes per hectare, or 26 per cent, whereas the increase due to other factors was 0.87 tonnes per hectare, or 36 per cent of the 1947 yield. In contrast, in the following decade, new varieties increased yields by a further 24 per cent, whereas other factors

[13] A. Douet, 'Some aspects of sugar beet production in England, 1945–85', *Rural Hist.* 7 (1996), pp. 221, 222.

[14] R. Biffen and F. L. Engledow, *Wheat-breeding investigations at the Plant Breeding Institute, Cambridge* (1926), pp. 61–2.

[15] H. Hunter, *The Barley crop* (1926), p. 32; E. S. Beaven, *Barley* (1947), pp. 103–5.

TABLE 6. New drainage in the UK ('000 hectares per year)

1941	6.1
1940–68 average	28.4
1968	58.7
1970s	100.0
1980s	55.0
1990s	10.0

Sources: B. D. Trafford, 'Field drainage', *JRASE* 131 (1970), pp. 132–3; B. D. Trafford, 'Recent progress in field drainage: Part 1', *JRASE* 138 (1977) p. 28; R. J. Parkinson, 'Field drainage' in R. J. Halley and R. J. Soffe (eds), *The Agricultural Notebook* (18th edn, 1988), p. 57; R. J. Parkinson, 'Soil management' in R. J. Soffe (ed.), *The Agricultural Notebook* (19th edn, 1995), p. 100.

had no effect. The story is similar for barley, although varietal change had a greater impact in the first post-war decade. The most prominent among the new varieties were Procter (a barley) and Capelle Desprez and Maris Huntsman (both winter wheats).[16]

Sugar beet was thus adopted between the wars, and cereal varieties at a greater or lesser rate over the whole century. There were other innovations which were adopted on a significant scale after 1960. There is no unequivocal test of 'adoption on a significant scale', but inspection of the available statistics reveals some clear trends. Bowers has pointed out that although the Ministry of Agriculture was successful in promoting arterial drainage schemes in the inter-war period, farmers and landowners did not follow them up with drainage schemes for individual fields.[17] Given the state of inter-war farm prices and profits, this should not be surprising. Table 6 reveals a peak in drainage activity in the 1960s and '70s which is quite clearly associated with the availability of drainage grants, which covered 65 per cent of the cost in the mid-1970s, but only 15 per cent by 1985 and after.[18]

The other principal post-1960 introductions were pesticides, silage, maize, and oilseed rape. Pesticide usage is not easy to measure using official statistics, for these do not seem to be available before about 1970. Estimates of pesticide output, which include both products used in the UK and those exported, show a much more rapid expansion after 1960 than before.[19] It might be argued that this represented relatively rapid adoption, because although sulphuric acid and copper sulphate had been used for weed control in cereals, on a small scale, since

[16] V. Silvey, 'The contribution of new varieties to increasing cereal yield in England and Wales', *J. of the National Institute of Agricultural Botany* 14 (1978), pp. 367–84; for a similar study on potato varieties, see P. M. Harris, 'Agronomic research and potato production practice', in R. G. Hurd, P. V. Biscoe and C. Dennis (eds), *Opportunities for increasing crop yield* (1980), pp. 205–17.

[17] J. Bowers, 'Inter-war land drainage and policy in England and Wales', *AgHR* 46 (1998), pp. 64–80.

[18] R. J. Parkinson, 'Field drainage', in R. J. Halley and R. J. Soffe (eds), *The Agricultural Notebook* (18th edn, 1988), pp. 56–7; R. J. Parkinson, 'Soil management', in R. J. Soffe (ed.), *The Agricultural Notebook* (19th edn, 1995), p. 100.

[19] D. Grigg, *English agriculture: an historical perspective* (1989), p. 75; Blaxter and Robertson, *From dearth to plenty*, ch. 6; K. Cowling, D. Metcalf and A. J. Rayner, *Resource structure of agriculture: an economic analysis* (1970), p. 138.

TABLE 7. Estimates of silage output in Britain

	('000 tonnes)
1884–6	58
1887–9	135
1940	240
1947	350
1950–4	2,195
1955–7	3,272
1962	4,293
1969	8,294
1970–4	13,558
1975–9	21,032
1980–4	32,290
1985–9	46,286

Source: P. Brassley, 'Silage in Britain, 1880–1990: the delayed adoption of an innovation', *AgHR* 44 (1996), pp. 63–87.

the beginning of the twentieth century, it was not until the early 1940s that the first modern selective herbicides, MCPA and 2,4-D and the insecticide DDT, were developed.[20] The subsequent expansion of scientific work on pesticides was dramatic: it was claimed that more than 10,000 scientific papers were published on herbicides alone between 1953 and 1958, although it took longer for the technology to be adopted at farm level.[21] Silage took much longer still. It was first introduced in the 1880s but not widely adopted for nearly 100 years despite the efforts of its official advocates (Table 7).[22] Adoption of silage required changes to the whole farming system, which was why it took time. But as farmers learned to make better grass silage, they transferred the knowledge and machinery to maize, and in addition, by the mid-1990s, maize qualified for Arable Area Payments of up to £320 per hectare. Thus Table 8 seems to indicate rapid expansion of the maize area from the 1980s onwards. Yet the first Board of Agriculture and Fisheries leaflet on maize appeared in 1902, and claimed that maize had then been grown in England for 20 years, and definitely since 1886, although there were also claims that it had been grown earlier, in the 1860s, back to Cobbett's time, and even in the eighteenth century.[23] In 1901 trials were being conducted at the South-Eastern Agricultural College (now Wye College, University of London), and there were further trials in the 1920s and 1940s. Nevertheless, until the late 1950s only about a thousand hectares were grown each

[20] G. E. Blackman, 'Weed control in cereals by chemical methods', *Agriculture* 53 (1946), pp. 16–22; H. W. Miles, 'DDT and the Farmer', *Agriculture* 53 (1946), pp. 217–9.

[21] E. J. Russell, 'Weeds. The ancient enemy', *Agriculture* 65 (1958), p. 8.

[22] P. Brassley, 'Silage in Britain, 1880–1990. The delayed adoption of an innovation', *AgHR* 44 (1996), pp. 63–87.

[23] Board of Agriculture and Fisheries, *Cultivation of Maize for Fodder* (Leaflet No. 73, 1902) subsequently published in Board of Agriculture and Fisheries, *Leaflets (Nos. 1 to 100)* (1913).

TABLE 8. Estimate of the maize area in England and Wales

	('000 ha)
late 1950s	5.0
1960–61	1.0
1975–9	28.6
1980–84	17.4
1985–89	23.0
1990–94	59.2
1995	106.0

Source: E. Bunting, 'Maize in Europe', in E. Bunting *et al* (eds), *Forage Maize* (1977); MAFF, *UK Agricultural Statistics* (various editions).

TABLE 9. Estimates of the oilseed rape area and output in Great Britain

	Area ('000 ha)	*Output ('000 tonnes)*
1969	5	9[a]
1970–74	11	20[a]
1975–79	56	131[a]
1980–84	176	541
1985	295	891

Note: [a] author's estimates
Source: Marks (ed. Britton), *A hundred years*, p. 172.

year.[24] Similarly, rape has been grown as a forage crop since at least the nineteenth century, and there are references to rapeseed oil in seventeenth-century Northumberland. In the twentieth century it was grown for seed in Europe and North America, but not in Britain until the late 1960s. It was then that there was a search for a combinable arable break crop as all-cereal rotations became popular, and oilseed rape proved ideal, avoiding land-damaging winter cultivations and adding little to fixed costs. The other crucial factor was the decision of United Oilseeds to handle the crop. In effect, they created a market for it; the resultant increase in output is shown in Table 9.[25]

Thus those innovations which were only adopted on a significant scale after 1960, with the possible exception of underdrainage, were not necessarily output-increasing. Pesticides have

[24] J. Darby, 'On green or fodder crops not commonly grown which have been found serviceable for stock feeding', *J. Royal Agricultural Society of England (JRASE)*, 2nd ser., 18 (1882), pp. 138–141; J. Long, 'British dairy farming', *JRASE*, 2nd ser., 23 (1887), pp. 125–34; A. Pell, 'William Cobbett', *JRASE* 63 (1902), pp. 1–26; E. Bunting, 'Maize in Europe', in E. Bunting *et al* (eds), *Forage Maize* (1978). I am grateful to Rob Dixon for these references. The maize area figures are complicated by the fact that maize might be grown for grain or silage, although most is now grown for silage.

[25] P. Brassley, 'Northumberland and Durham', in J. Thirsk (ed.) *The Agrarian History of England and Wales*, V (i), *1640–1750* (1984), p. 56; Thirsk, *Alternative Agriculture*, p. 231.

TABLE 10. Number of first inseminations in England and Wales

	('000)
1944–5	16
1954–5	1497
1960–1	2006
1972–3	2528
1985–6	1930

Source: Milk Marketing Board, *Dairy Facts and Figures* (published annually), various editions.

obviously had some yield effects, but herbicides in particular were labour-saving, to an extent which may not be easy to measure but which is put in context by Primrose McConnell's estimate (in 1919) that 'From a third to a half of the field labour on a farm is devoted to the destruction of growing weeds'.[26] Silage, maize and oilseed rape cannot be simply characterized as either output-increasing or labour-saving: they could do both, and affected the whole system of farming. The yield of conserved fodder may have been increased by the move from silage to hay, but at the same time silage also proved easier to mechanize than the hay harvest. On the other hand, the innovations of the 1920s and '30s, especially the new varieties, tended to increase output, but their impact was limited. New crop varieties had a much bigger effect on output after the war. But it was between these two periods, from the late 1930s to the late 1960s, that the most dramatic developments occurred.

Again, the technical changes of the 1935–65 period may be divided into the output-increasing and the labour-saving. Among the former were varietal change (as discussed above), fertilizers, feedingstuffs, Friesian cows and artificial insemination (AI). Among the latter were combine harvesters, tractors, and milking machines. And, once again, most of them had been invented for some time before they were widely adopted. The only exception to this generalisation is artificial insemination, which expanded from virtually nothing in 1942 to 80 per cent of its maximum level by 1960 (see Table 10). Building on scientific work in the 1930s in Russia, Denmark, and the USA, as well as in Britain, the first two trial centres, at Cambridge and Reading, were established in late 1942 and early 1943. The Artificial Insemination (Cattle) (England and Wales) Regulations of 1943 brought the whole process under government control and by 1945 eight centres were in operation, with eight more proposed.[27] The use of artificial fertilizers expanded during the nineteenth century, but although the half million tonnes used in the 1860s had increased by nearly a million in the late 1930s, the big increase came in the following twenty years (see Table 11). In those two decades the use of artificials increased fourfold, to within sight of the peak reached in 1985. Much of the increase was in the use of nitrogenous fertilizer, which has a more direct effect on yield than the other two principal

[26] P. McConnell, *Notebook of agricultural facts and figures for farmers and farm students* (9th edn, 1919), p. 278

[27] S. Bartlett and J. Mackintosh, 'The artificial insemination of cattle', *JRASE* 105 (1944), pp. 175–189; Anon., 'Artificial insemination of cattle', *Agriculture* 51 (1945), pp. 529–532.

TABLE 11. Fertilizer use in the UK

	(million tonnes)
1867–9	0.51
1904–10	1.05
1935–9	1.41
1950–1	4.15
1960–1	6.27
1970–1	6.95
1980–1	6.51
1985	7.09

Sources: 1967–1939 figures from E. M. Ojala, *Agriculture and economic progress* (1952), p. 212; subsequent figures from Marks (ed. Britton), *A hundred years*, pp. 254–5, calculated by dividing the expenditure totals in table 27.1 by the current price index in table 27.4. Rough and ready though this method is, it gives a figure (1.04 million tons) comparable with Ojala's for the late 1930s, and one (6.94) comparable with Marks and Britton's table 27.3 figure for total fertilizer use in 1985, assuming that tons of nutrient are converted to tons of product weight using a conversion factor of 30% N for N fertilizers, 40% P for P fertilizers, and 50% K for K fertilizers (estimated from J. Nix, *Farm Management Pocketbook* (5th edn, 1972), p. 121.

TABLE 12. UK Feedingstuffs use

	(million tonnes)
1904–10	6.1
1935–9	8.8
1959–62	13.4
1967–9	13.7
1985	16.3

Source: Ojala, *Agriculture and economic progress*, p. 212; Marks (ed. Britton), *A hundred years*, pp. 246–7. The 1959–62 figure is estimated from data for expenditure on purchased feeds in that period, deflated by the RPI.

nutrients, phosphate and potash.[28] Similarly, if not so dramatically, the use of purchased feedingstuffs, the other principal ingredient of Thompson's Second Agricultural Revolution in the nineteenth century, increased by fifty per cent between 1935 and 1962 (Table 12), despite the fact that they were rationed for pigs and poultry between 1939 and 1953.[29] And to consume at least part of these extra feedingstuffs there was a new breed of dairy cow: the Friesian. There have been importations of Dutch cattle since the eighteenth century, and there was probably some Dutch blood in the dominant breed in 1900, the Shorthorn, which accounted for 64 per cent of the national herd in 1908. Then, just at the beginning of the First World War, the first

[28] E. M. Crowther, 'Fertilizers in the agricultural expansion programme', *Agriculture* 54 (1948), pp. 491–500. It should be pointed out that the development of shorter-strawed varieties was necessary to allow the use of extra nitrogen on cereals without increasing the danger of lodging.

[29] F. M. L. Thompson, 'The second Agricultural Revolution, 1815–80', *EcHR*, 2nd ser., 21 (1968), pp. 62–77; V. H. Beynon, 'Bacon production from some home-grown foods', *Agriculture* 60 (1953), p. 208.

TABLE 13. Percentage of Friesian cows in the dairy herd (England and Wales)

1955	40.6
1965	64.2
1973–4	81.0
1985–6	85.8

Source: Milk Marketing Board, *Dairy facts and figures 1959*, p. 32; and subsequent editions for 1966, 1976, and 1986.

modern Friesians were imported. But again, they did not achieve their present dominance until after the Second World War (see Table 13).[30]

If the replacement of Shorthorns by Friesians increased milk yields, which it undoubtedly did, the labour required to extract the extra milk was reduced by the replacement of hand-milking by milking machines. Again, these were a nineteenth-century invention adopted in the 1940s and '50s. There were 237 patents for milking machines between 1860 and 1915, most of them of dubious worth. But the Struthers and Weir pulsator of 1892 and the Gillies teat cup of 1902 solved the major technical problems, so that by the late 1920s, according to Professor Collins, effective milking machines were available.[31] Nevertheless, ninety per cent of herds were still hand-milked in 1939. Between 1944 and 1961 the machine-milked proportion rose from ten to eighty five per cent. The delay in adoption was caused by cheap labour, high capital costs of machinery, small herds, and the association with the change from cowshed to parlour milking. As Collins points out, the eventual rapid uptake was 'part of a broader pattern of change affecting output, organisation, and the farm production function'.[32]

This broader pattern of change was also apparent in other aspects of farm mechanisation. It was eventually a labour-saving development, but not always initially. Roland Dudley of Linkenholt in Hampshire, who farmed a thousand acres of Hampshire cereal land, claimed in 1942 that '... on that same farm on which I employed three men and a boy just before the war I was employing thirty people as a result of mechanisation and today I haven't got enough cottages'. Geoffrey Tawell, a Bedfordshire market gardener, agreed with him: '... up-to-date equipment ... increases your gross output and so you become an employer of more labour rather than less'.[33] Mechanisation also contributed indirectly to output increases because not only human labour, but horse labour too, was saved. As horse numbers fell, so did the quantity of hay, oats and beans that had to be fed to them rather than to meat and milk producers. As Table 14 demonstrates, horse numbers were decreasing from the beginning of the twentieth

[30] Board of Agriculture and Fisheries, *The Agricultural Output of Great Britain* (Cd. 6277, 1912) (in BPP 1912–13, X, p. 529) table 11 p. 57; G. E. Mingay, *British Friesians. An epic of progress* (1982), pp. 34, 47.

[31] E. J. T. Collins, 'The uptake of the milking machine in England and Wales', in *Vom 'Fleissigen' zum 'Produktiven' Bauern. Aspekte zum Wandel der Europaischen Landwirtschaft des 19./20. Jahrhunderts* (Ostfolden: Scripta Mercaturae Verlag, 1996), pp. 2–7. I am most grateful to Professor Collins and John Creasey for providing a copy of this paper.

[32] *Ibid.*, p. 13.

[33] 'Machinery on the farm', a talk broadcast on the Home Service of the BBC on 3 Dec. 1942, in *Farming Today broadcasts*, p. 76.

TABLE 14. Tractors and Horses in Great Britain

	Horses *('000)*	*Tractors* *('000)*
1909	1132	0.05
1921	962	20
1940	642	66
1946	545	204
1950	347	332
1960	54	476
1971		477
1980		481
1985		491

Source: C. Cawood, *Vintage tractors* (1980), p. 3; Marks (ed. Britton), *A hundred years*, p. 146.

century, although before 1940 some at least of the decrease reflected the fall in the arable acreage. Once again, it was during the 1940–60 period that the replacement of the horse by the tractor was at its most dramatic. And once again, the tractor was a nineteenth-century invention. There were tractors in the USA in the 1890s, the first British tractor was produced in 1902, and enough Fordsons were imported in the First World War to bring the numbers up to 7,000 by 1918. But, as Table 14 shows, adoption was at first slow, hampered by capital cost and steel wheels (for there were no rubber tractor tyres before the 1930s). Then a combination of wartime labour shortages and the major technical changes of weight transfer and live power take-off embodied in the Ferguson TE20 of 1948 made a difference: numbers increased sevenfold between 1940 and 1961. It should also be remembered that tractors increased in power and capability, and their drivers in expertise.[34] In 1942 it appeared to one speaker that '... farmers of the last generation had the knack of horsemanship ... It will take a few more generations of mechanical power before farmers have the same instinct for tractors and tractor implements'.[35] Presumably the implication of comments such as this is that Table 14 understates the increase in effective tractor power after 1960.

Combine harvesters, too, like the reaper-binders which preceded them, were an American invention which were adopted much more quickly in the United States than in Britain. There were combines in the USA by the 1840s, and two thirds of the Californian wheat crop was said to be combined in the 1880s. Internal combustion engines were added after the First World War, and by 1926 over 5000 combines in Kansas cut 30 per cent of the crop.[36] The first combines in Britain were imported only in 1928, and they were soon followed by home-produced competitors: Clayton and Shuttleworth, long-established as threshing machine manufacturers in

[34] C. Cawood, *Vintage tractors* (1980); K. Cowling *et al*, *Resource structure of agriculture*, pp. 96–9.

[35] S. J. Wright, 'More power to the land', a talk broadcast on the Home Service of the BBC on 12 Feb. 1942 in *Farming Today broadcasts*, p. 80.

[36] P. Fearon, 'Mechanisation and risk. Kansas wheat growers, 1915–1930', *Rural Hist.* 6 (1995), p. 232.

TABLE 15. Changes in cereal harvesting machinery in the United Kingdom, 1942–80

	Binders ('000)	*Combines ('000)*	*Balers ('000)*
1942	102	1	nd
1946	119	3	nd
1950	120	10	16
1960	75	48	58
1971		57	70
1980		47	74

Source: Marks (ed. Britton), *A hundred years*, p. 146; MAFF, *Agricultural Statistics 1954/5: England and Wales Agricultural Censuses and Production* (1956), p. 89; *Agricultural Statistics 1960/1: England and Wales Agricultural Censuses and Production* (1962), p. 102; *Agricultural Statistics England and Wales 1976–7: Agricultural Censuses and Production* (1980), pp. 138–9.

Lincoln, exhibited a 'combined harvester and thresher' with a 12 foot cut at the Manchester Royal Show in 1930. In 1936 Allis-Chalmers had a small (5 foot cut) combine, powered by the tractor power take-off, which was said by the judges at the Bristol Royal Show in 1936 to be 'a distinct advance towards a combine suited to British conditions', on sale for £230.[37] Nevertheless, by 1939 there were only one hundred machines in the country. Their adoption was delayed by lower labour costs, smaller fields and farm sizes, the need for driers, the absence of balers to deal with the straw, and the capital cost involved. Consequently it came a little later than that of the tractor, and it was in the 1950s that it occurred most rapidly (Table 15).

IV

This is not a complete survey of the technical changes which have affected British agriculture in the twentieth century, but simply a selection of some of those which are judged to be both important and capable of quantification. There are obviously others which may be one or the other but not both. The intensification of pig and poultry production has clearly had a major impact on the output of eggs, pigmeat, and poultrymeat, but it is not easy to find figures which illustrate the change from hens running around the orchard and pigs in sties to battery cages and sow stalls over a long period of time. It might also be suggested that the identification of some quantifiable development as a technical change, which, in theoretical terms, produces a shift in the supply curve, as opposed to an increase or decrease in the use of inputs which produces a movement up or down along the supply curve, is, to some extent, a matter of judgement. The example of fertilizer use illustrates this admirably. It is not difficult to identify the introduction of artificial fertilizers in the nineteenth century as a technical change, but the impact of a few thousand tons of guano then may not have had as much effect on total agricultural output as the rapid increase in the use of ammonium sulphate in the 1940s and

[37] R. Borlase Matthews, 'Report on new implements at the Manchester Show, 1930', *JRASE* 91 (1930), pp. 247–8; T. Close, 'Report on new implements at the Bristol Show, 1936', *JRASE* 97 (1936), pp. 405–6.

'50s. Yet that was existing technology, which farmers were employing in response to increased wartime demand and guaranteed prices.

Clearly this brings the argument back to the question of innovation and adoption. The futility of trying to decide which of these is the more important has already been discussed. On the other hand, the desirability of identifying the factors which promote either or both of them is obvious. There is a long list of potential influences: output price changes; input price changes and relative movements of different input prices; the impact of inflation on the *perception* of cost and price changes; state control of farm rents and the increase in owner-occupation which allowed farmers to retain a bigger proportion of their profits; state promotion of agricultural research and extension services; changes in the business objectives of farmers from survival to profit maximisation as they came to assume that government support would continue; successful implementation of agricultural policy (especially the 1947 Agriculture Act); a patriotic response to a perceived national need; and a combination of several of these. They could all be important. It would require at least one (and probably more than one) further paper of the length of the present one to place them in order of precedence. However, it seems clear that the greatest expansion in output took place when prices, in real terms, had returned almost to nineteenth-century levels, which was also the point at which state propaganda and policy was encouraging output maximisation at almost any cost (see Table A4).[38] The preamble to the 1947 Agriculture Act declared the purpose of British agriculture to be the production of 'such part of the nation's food and other agricultural produce as in the national interest it is desirable to produce in the United Kingdom', and in the 1940s and '50s that seemed to mean as much as possible.[39] Consequently, not only was money made available for research, and for a National Agricultural Advisory Service to put the fruits of the research into the hands and minds of the farmers, but something also encouraged farmers to believe that attempts to increase output would not be met by a return to pre-war low price conditions, as they had been after the First World War. The 1947 Act is an obvious candidate.[40]

Several conclusions thus emerge from this examination of the relationship between price, output, and technical change. First, the output figures suggest that the development of British agriculture in the late nineteenth and twentieth centuries should be considered in four periods: from the 1860s to the 1930s; from between 1930–35 to 1945; from 1945 to 1965; and the twenty

[38] Although it should be noted that the figures in Table A4 would obviously not support the contention that the volume of output was directly and closely related to the price level over the whole period 1867–1985.

[39] Agriculture Act, 1947, section 1(1), quoted in P. Self and H. J. Storing, *The state and the farmer* (1962), p. 23; Lord Williams of Barnburgh, *Digging for Britain* (1965), pp. 152–63.

[40] *The Economist* in 1950 called the 1947 Act 'the comprehensive measure of support British Agriculture has always wanted', and Lord Williams devoted an appendix of his autobiography to demonstrating the great increase in output between 1939 and 1959 (Williams, *Digging for Britain*, pp. 179 and 191–5). Tony Harman, who farmed in Buckinghamshire between 1931 and the 1980s felt that '... we made no *real* [his italics] progress until after the war ... when the war ended and farmers weren't immediately dropped ... but continued to be supported by the government, my confidence increased still further.' (T. Harman, *Seventy summers* (1986), pp. 186–7, 203). The impact of agricultural policy on producer expectations and consequent investment is discussed, in a different context, in A. Buckwell, 'Economic signals, farmers' response and environmental change', *J. Rural Studies*, 5 (1989), pp. 149–160. I am most grateful to Matt Lobley for this reference.

[41] Turner, 'Output and prices', p. 51.

years after 1965. Secondly, before 1935 the volume of output appears to vary little, as Turner suggested was the case before 1914.[41] There were only a few examples of technical adoption, and they did not change output very much one way or the other. In contrast, after 1965 both prices and labour inputs fell, but the impact of technology ensured that output continued to expand by increasing both land and labour productivities, probably at the expense of capital productivity. The crucial periods were the intervening years. The volume of output did not increase all that much in the Second World War, because the emphasis had to be placed on maximising self-sufficiency. Thus the changes in land use were dramatic, but the resultant increases in arable output were balanced by restrictions in livestock output needed to minimize the use of purchased feedstuffs. Once these restrictions were removed, from the late 1940s to the early 1960s, high prices, increasing labour, and the rapid adoption of what was mostly *existing* technology all combined to raise the volume of output more rapidly than ever before or since. This emphasis on adoption certainly attracted academic attention at the time.[42] Scientific breakthroughs and innovations, which have also attracted their share of academic interest,[43] could have had little influence on output in the absence of adopting producers. Thus, having identified the importance of the 1945–65 period, and made a case for the output increases depending on existing technology, the obvious next stage of research should be on the reasons for adoption. Given the prevalence of theories of technical change that claim the predominant influence of input prices,[44] the suggestion made here of the significance of high output prices is interesting. Detailed work on relative input price changes and other factors affecting labour and capital use is beyond the scope of the present paper,[45] but it would clearly be worthwhile. Further work is also needed to explain which of the other factors listed in the previous paragraph led farmers to become adopters. Whatever the reason for them, the dramatic output increases perhaps explain why farmers became so popular during the 1940s and '50s: extra output was required and farmers produced it. In other times and places it might have been called a Great Leap Forward.

Appendix
Calculation of gross output, prices and volume of output

This appendix explains the way in which gross output and price data have been brought together to form consistent series covering the period 1867–1985. First, a gross output series in current prices is constructed, then a retail price index (RPI) is produced and used to convert the gross output series to constant (1986) price terms. An agricultural price index (API) is also constructed, and deflated by the same RPI. Since no consistent data sets covering the whole of this period have been found, each of these series have been constructed from several sources. The deflated agricultural price index is then used to convert the gross output figures to a volume of output series.

[42] G. E. Jones, 'The diffusion of agricultural innovations', *J. Agricultural Economics* 15 (1963), pp. 387–409; E. H. Whetham, 'The mechanisation of British farming, 1910–1945', *J. Agricultural Economics*, 21 (1970), pp. 317–31. See also E. M. Rogers, *Diffusion of innovations* (1962).

[43] See, for example, Blaxter and Robertson, *From dearth to plenty*.

[44] These are summarized in B. M. Koppel (ed.), *Induced innovation theory and international agricultural development: a reassessment* (1995).

[45] Discussed to some extent in Holderness, 'Apropos the third Agricultural Revolution'

(i) Gross Output for UK Agriculture, 1867–1985.

Turner has discussed output and prices in UK agriculture, but only for the period 1867–1914. He concludes, after discussing previous estimates by Ojala, Dewey and Bellerby, that 'there are no reasonable estimates which we can use, but ... we should face up to the fact that a completely fresh approach to the problem of estimating output will be no guarantee of better results'.[1] Nevertheless, since the differences that he identifies between the various estimates are usually of the order of three or four per cent, and always less than ten per cent, it might be argued that for the purposes of the present study they are nugatory. The estimates used here are those produced by Ojala, adjusted to render them compatible with the Ministry of Agriculture, Fisheries and Food's Departmental Net Income Calculation (DNIC).[2] Once these two series can be put together, they produce a consistent data set covering the period from 1867 to the present day (although this study ends at 1985).

Although some of the categories used by Ojala and the DNIC are different (e.g. Ojala's 'horses' become 'other livestock' in the DNIC), their totals are the same except for Sundry Output, which is the annual value of own-account capital formation, such as the construction of glasshouses, silos, or pig and poultry houses. This is included in the DNIC but not in Ojala, so Ojala's figures need to be adjusted thus:

Ojala total output + sundry output = DNIC gross output.

Tasker uses Feinstein and Pollard's estimate of fixed capital formation.[3] Since these two sources use different year groupings, the Feinstein and Pollard figures are converted by assuming that the figure for each year is the same as the average for the group of years, and then adding the appropriate years for the Ojala year groupings. In addition, Ojala (p. 215) takes account of the impact of government subsidies on the gross output figures for 1930–4 and 1935–9 by adding £5 million and £10 million respectively. Having done this, he then concluded (pp. 207, 210) that the figures produced by MAFF for the 1935–9 period were better than his, and so in his final gross output estimate he used a figure of £279m. Adjusting this as above for sundry output (£4m) and subsidies (£10m) gives a gross output of £293m for 1935–9, which is in reasonable agreement with the figures reported by Britton and Marks for 1938 (£300m) and 1939 (£342m).[4]

Turner compares various output estimates for 1909–13, and Ojala's modified estimates are of the same order of magnitude.[5] There are certainly differences between Ojala and other estimators, but they are reasonably consistent, and, given the need for compatibility with the later MAFF DNIC figures to produce a data set covering the whole period under discussion, and the greater importance of relative changes as opposed to absolute levels of output, it seems permissible to use them here.

Two major problems remain. The first is that Ojala omits any estimate for the period of the

[1] Turner, 'Output and prices', p. 43.

[2] E. M. Ojala, *Agriculture and economic progress* (1952), pp. 208, 215; J. C. Tasker, 'An Investigation of Farm Income 1867 to 1939' (unpublished BSc (Hons) dissertation, University of Plymouth, 1994), pp. 43, 66; the MAFF DNIC figures are reported in H. F. Marks (ed. D. K. Britton), *A hundred years of British food and farming: a statistical survey* (1989), p. 149.

[3] Tasker, 'Farm Income', p. 42, app. C; C. H. Feinstein and S. Pollard (eds), *Studies in capital formation in the United Kingdom, 1750–1920* (1988), p. 269.

[4] Ojala, *Agriculture and economic progress*, p. 215; Marks (ed. Britton), *A hundred years*, p. 149.

[5] Turner, 'Output and prices', pp. 42–3.

First World War. One way of dealing with this problem would be to produce a new estimate of output for 1914–19 using Ojala's methods. Unfortunately, many of the figures required are not easily available. A cruder approach was therefore adopted, in which Ojala's estimate for 1911–13 output was increased by the proportion in which the API rose between 1911–13 and 1914–19, giving a figure of £399.41 million. This method obviously takes no account of the changes in the pattern of agricultural production which occurred in 1914–19. However, it can be checked against Dewey's detailed calculation for the First World War years and Ojala's estimate for the 1920–22 period.[6] Dewey does not in fact estimate an output for 1919, so if his 1918 estimate is raised to 1919 prices, and all his figures for the whole 1914–19 period are then averaged, an estimated average gross output for the period of £286.5 million is produced. But this applies to Great Britain only, whereas Ojala's figures are for the United Kingdom, so the Irish output (from Turner[7]) needs to be added in. Taking Turner's 1911–13 Irish output figures, again raised by the proportionate increase in the API, gives an Irish 1914–19 output estimate of £87.4m, which, added to Dewey's figure for Great Britain, gives an estimate for the UK of £373.9m, which is only 6.4 per cent less than the crude estimate derived from proportionately increasing Ojala. Incidentally, using the API-proportionate method to go from Ojala's 1911–13 figure to 1920–22 produces agreement with Ojala's original figure to within 3 per cent. Therefore, despite their methodological simplicity, these figures have been incorporated into the output series reported below.

The other problem is Irish output. Ojala, in his output tables (pp. 208–9) simply points out that the UK excludes Eire after 1922. Since this paper attempts to trace changes in output in the long run, this approach is not ideal. The ideal would involve adjusting UK output to remove all of the Irish output, except for that produced in Northern Ireland, for the period before 1922, but Turner's estimate of Irish agricultural output deals with the whole island. Again, adopting the simplest possible procedure, Northern Ireland accounts for a little less than 20 per cent of the area of the whole of Ireland, so assuming that it produces roughly 20 per cent of the total Irish output should produce an estimate of the right order of magnitude, and there are sufficient sources of error in other parts of the calculation to render the pursuit of pinpoint accuracy, in this point, redundant.[8] Therefore eighty per cent of the Turner's Irish output figures have been deducted from Ojala's estimates, as modified by Tasker, for the years before 1922. For the years after 1940, the MAFF DNIC figures, reported by Britton and Marks, have been used, and the whole output series is shown in Table A1. However, since table A1 is reported in current price terms, and inflation, especially in the second half of the twentieth century, has not been insignificant, it is necessary to convert these estimates to constant price terms. This process requires a retail price index covering the whole period, which has had to be constructed.

6 P. Dewey, *British agriculture in the First World War* (1989), pp. 244–8.

7 M. Turner, *After the Famine. Irish agriculture 1850–1914* (1996), p. 108.

8 *Ibid.*, table 4.2, p. 108. O'Grada has produced a different set of output estimates for Irish agriculture in 1912 (see C. O'Grada, 'Irish agriculture north and south since 1900', in B. M. S. Campbell and M. Overton (eds) *Land, labour and livestock. Historical studies in European agricultural productivity* (1991), pp. 439–456). He reporrts figures for all Ireland, and also the south and the north separately. His estimates are higher than Turner's, but he calculates the output of the six counties of the north to be 21.3 per cent of the total for all Ireland. Clearly, since Turner's figures are the only ones covering the whole period back to 1850 they have to be used here, but assuming a Northern Ireland output of 20 per cent of the total is not in violent disagreement with O'Grada.

TABLE A1. Gross output estimates for UK agriculture in current prices

	Ojala's Gross Output (£m)	*Ojala adjusted to DNIC (£m)*	*Irish output x 0.8 (£m)*	*Adjusted Ojala minus adjusted Irish output*
1867–69	229.83	236.43	31.94	204.49
1870–76	247.18	254.29	35.46	218.83
1877–85	219.20	225.62	31.61	194.01
1886–93	187.80	192.96	28.64	164.32
1894–03	182.78	186.94	29.81	157.13
1904–10	200.75	205.05	34.50	170.55
1911–13	222.12	226.92	38.87	188.05
1914–19	no data	404.21	69.92	334.29
1920–22	489.97	493.97	84.62	409.35
1923–19	279.67	283.67		283.67
1930–34	236.46	245.47		245.47
1935–39	244.53	293.00		293.00
1940–45				556.33
1946–50				818.40
1951–55				1258.60
1956–60				1541.40
1961–65				1817.20
1966–70				2213.20
1971–75				3735.60
1976–80				7498.40
1981–85				11454.40

Sources: E. M. Ojala, *Agriculture and economic progress* (1952), pp. 208, 215; J. C. Tasker, 'An Investigation of Farm Income 1867 to 1939' (unpublished BSc (Hons) dissertation, University of Plymouth, 1994), pp. 43, 66; M. Turner, *After the Famine. Irish Agriculture, 1850–1914* (1996), p. 108; Marks (ed. Britton), *A hundred years*, p. 149.

(ii) A Retail Price Index for 1867–1986.

Feinstein's retail price index covers most of this period, but stops short in 1965.[9] Britton and Marks report gross output in both current and constant price terms back to 1938, thus implying a price index.[10] The two therefore overlap, and in fact bear a virtually constant relationship to each other. The Feinstein index has therefore been rebased on the 1986 base of the Britton and Marks index by means of a simple proportional calculation, and the results are shown in Table A2.

[9] C. H. Feinstein, *Statistical tables of national income, expenditure and output of the UK 1855–1965* (1972), table 61.

[10] Marks (ed. Britton), *A hundred years*, pp. 149–50.

TABLE A2. A retail price index, 1867–1986 (1986 = 100)

Year	*RPI*	*Year*	*RPI*	*Year*	*RPI*	*Year*	*RPI*
1867	2.58	1897	2.38	1927	4.95	1957	12.32
1868	2.58	1898	2.39	1928	4.94	1958	12.64
1869	2.58	1899	2.40	1929	4.89	1959	12.72
1870	2.59	1900	2.53	1930	4.76	1960	12.85
1871	2.64	1901	2.54	1931	4.55	1961	13.21
1872	2.76	1902	2.54	1932	4.44	1962	13.74
1873	2.84	1903	2.55	1933	4.34	1963	14.01
1874	2.75	1904	2.54	1934	4.34	1964	14.47
1875	2.69	1905	2.55	1935	4.37	1965	15.13
1876	2.69	1906	2.55	1936	4.40	1966	15.72
1877	2.67	1907	2.58	1937	4.55	1967	16.16
1878	2.61	1908	2.59	1938	4.62	1968	16.89
1879	2.49	1909	2.61	1939	4.92	1969	17.79
1880	2.57	1910	2.63	1940	5.46	1970	18.94
1881	2.54	1911	2.63	1941	6.58	1971	20.75
1882	2.57	1912	2.71	1942	7.04	1972	22.22
1883	2.56	1913	2.70	1943	7.26	1973	24.21
1884	2.48	1914	2.69	1944	7.40	1974	28.09
1885	2.41	1915	3.03	1945	7.53	1975	34.97
1886	2.38	1916	3.58	1946	7.62	1976	40.65
1887	2.36	1917	4.48	1947	8.14	1977	47.17
1888	2.38	1918	5.47	1948	8.76	1978	51.02
1889	2.41	1919	6.02	1949	8.97	1979	57.80
1890	2.41	1920	6.94	1950	9.23	1980	68.49
1891	2.41	1921	6.35	1951	10.06	1981	76.34
1892	2.42	1922	5.46	1952	10.68	1982	83.34
1893	2.38	1923	5.13	1953	10.86	1983	86.96
1894	2.38	1924	5.09	1954	11.04	1984	90.91
1895	2.35	1925	5.11	1955	11.43	1985	97.07
1896	2.35	1926	5.07	1956	11.92		

Source: see appendix text

(iii) An Agricultural Price Index for 1867–1986.

Once a retail price index is available, it can be used to express the index of prices of agricultural products in constant price terms. The most recent published agricultural price index for the UK is the one produced by Turner covering the period 1867–1914.[11] This overlaps with the MAFF estimates for 1906–66 reported in *A Century of Agricultural Statistics*, which are part of the same series as that used by Britton and Marks.[12] Thus it is possible to produce a consistent API, based on 1986 = 100 (this base being chosen as the one used by Britton and Marks and the same base as the RPI calculated above.) The annual API is shown in Table A3, which also shows the effect of deflating this index by the RPI.

(iv) Gross output, prices, and the volume of output.

The data available in tables A1–3 make it possible to express the two series of gross output data, originally produced by Ojala and MAFF, but now modified to be consistent with each other over the whole period 1867–1986, in constant price terms, and to compare them with the constant-price agricultural price index. The data so produced are shown in Table A4. The final stage of the calculation requires the gross output figures, now expressed in constant price terms, to be converted into volume terms. The decline, in constant price terms, of the API, implies that a greater volume of farm products had to be sold in the latter years of the century to generate the same revenue (in real terms) as in earlier years. For example, the API in Table A4 shows that agricultural products that were sold for £100 in 1986 would have realized £206 in 1951–5. Since the argument in this paper is concerned with the factors which produced more tons of wheat, gallons of milk, dozens of eggs, and so on from UK agriculture – in other words, with the *volume* of production – it is necessary to allow for the changes in the real farm prices. This can be done using the following formula:

$$\text{volume (£m)} = \text{gross output} \times \frac{100}{\text{API}(1986{=}100)}$$

This operation obviously has little impact when the API is close to 100, and increasingly more as the API increases. It is essentially the same as Turner's method (although he calculates the figures on an annual basis, expresses them as an index, and reports them as a graph) and, unsurprisingly, produces similar results for the period up to 1914.[13] These, together with those for subsequent years, are also shown in Table A4.

[11] Turner, 'Output and prices', p. 47.

[12] MAFF, *A century of agricultural statistics*, p. 85.

[13] Turner, 'Output and prices', p. 48.

TABLE A3. (1) an agricultural price index (1986 = 100) (2) deflated by the RPI (1986 = 100)

	(1)	(2)		(1)	(2)		(1)	(2)
1867	5.90	228.7	1907	5.15	199.6	1947	17.24	212.2
1868	6.03	233.7	1908	4.94	190.7	1948	17.85	203.8
1869	5.71	221.3	1909	5.07	194.3	1949	18.62	207.6
1870	5.54	213.9	1910	5.18	197.0	1950	19.33	209.4
1871	5.88	222.7	1911	5.42	206.1	1951	21.21	210.8
1872	6.10	221.0	1912	5.74	211.8	1952	21.92	205.2
1873	6.50	228.9	1913	5.67	210.0	1953	22.33	205.6
1874	6.23	226.5	1914	5.65	210.0	1954	22.23	201.4
1875	6.14	228.3	1915	7.12	235.0	1955	23.65	206.9
1876	6.02	223.8	1916	8.95	250.0	1956	23.14	194.1
1877	6.04	226.2	1917	11.24	250.9	1957	23.14	187.8
1878	5.90	226.1	1918	12.97	237.1	1958	23.35	184.7
1879	5.39	216.5	1919	14.45	240.0	1959	22.90	180.0
1880	5.69	221.4	1920	16.33	235.3	1960	21.72	169.0
1881	5.49	216.1	1921	12.26	193.1	1961	22.13	167.4
1882	5.72	222.6	1922	9.46	173.3	1962	22.33	162.5
1883	5.52	215.6	1923	8.80	171.5	1963	22.38	159.7
1884	5.20	209.7	1924	9.00	176.8	1964	22.69	156.8
1885	4.97	206.2	1925	8.90	174.2	1965	22.94	151.6
1886	4.82	202.5	1926	8.44	166.5	1966	23.45	149.2
1887	4.61	195.3	1927	8.04	162.4	1967	23.71	146.7
1888	4.76	200.0	1928	8.29	167.8	1968	24.14	142.9
1889	4.78	198.3	1929	8.04	164.4	1969	25.00	140.5
1890	4.82	200.0	1930	7.38	155.0	1970	26.3	138.9
1891	4.86	201.7	1931	6.82	149.9	1971	27.6	133.0
1892	4.85	200.4	1932	6.56	147.7	1972	30.4	136.8
1893	4.78	200.8	1933	6.27	144.5	1973	36.0	148.7
1894	4.71	197.9	1934	6.31	145.4	1974	41.3	147.0
1895	4.47	190.2	1935	6.66	152.4	1975	50.0	143.0
1896	4.28	182.1	1936	6.71	152.5	1976	65.5	161.1
1897	4.66	195.8	1937	7.38	162.2	1977	67.1	142.3
1898	4.84	202.5	1938	7.32	158.4	1978	68.6	134.5
1899	4.57	190.4	1939	7.38	150.0	1979	75.6	130.8
1900	4.88	192.9	1940	10.22	187.2	1980	79.6	116.2
1901	4.91	193.3	1941	12.31	187.1	1981	88.3	115.7
1902	5.22	205.5	1942	13.12	186.4	1982	95.2	114.2
1903	4.88	191.4	1943	13.38	184.3	1983	100.2	115.2
1904	4.79	188.6	1944	13.63	184.2	1984	100.3	110.3
1905	4.86	190.6	1945	14.04	186.5	1985	98.7	101.7
1906	5.10	200.0	1946	14.85	194.9	1986	100.0	100.0

Source: Turner, 'Output and prices', p. 47 (using the values for yearly weights); MAFF, *A Century of Agricultural Statistics*, p. 85; Central Statistical Office, *Annual Abstract of Statistics* (various years); Marks (ed. Britton), *A hundred years*, p. 150.

TABLE A4. Gross output, prices and the volume of output.

	Gross Output £m (Current Prices)	*RPI 1986=100*	*Gross Output £m (Constant Prices)*	*API 1986=100*	*Volume of Output (£m)*
1867–69	204.49	2.58	7926.0	227.9	3477.84
1870–76	218.83	2.71	8075.0	223.6	3611.36
1877–85	194.01	2.54	7638.2	217.8	3506.99
1886–93	164.32	2.39	6875.3	199.9	3439.37
1894–03	157.13	2.44	6439.8	194.2	3316.07
1904–10	170.55	2.58	6610.5	194.4	3400.46
1911–13	188.05	2.68	7016.8	209.3	3352.51
1914–19	334.29	4.21	7940.4	237.2	3347.55
1920–22	409.35	6.25	6549.6	200.6	3265.01
1923–29	283.67	5.03	5639.6	169.1	3335.07
1930–34	245.47	4.49	5467.0	148.5	3681.48
1935–39	293.00	4.57	6411.4	155.1	4133.72
1940–45	556.33	6.88	8080.8	186.0	4344.52
1946–50	818.40	8.54	9526.6	205.6	4633.56
1951–55	1258.60	10.81	11617.2	206.0	5639.42
1956–60	1541.40	12.49	12337.6	183.1	6738.18
1961–65	1817.20	14.11	12871.8	159.6	8065.04
1966–70	2213.20	17.10	12943.8	143.6	9013.79
1971–75	3735.60	26.05	14255.4	141.7	10060.27
1976–80	7498.40	53.03	14248.6	137.0	10400.44
1981–85	11454.40	86.93	13185.2	111.4	11835.91

Sources: Tables A1-A3 above. Note small discrepancies due to rounding errors in the RPI and constant price figures after 1940. These arise because the figures for gross output at constant prices after 1940 have been calculated on an annual basis, and the annual series has then been averaged into year groups.

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(PART I)

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CHAPTER 6

FARMING SYSTEMS

A
INTRODUCTION

BY PAUL BRASSLEY

Every farm is unique, but most farmers can usually describe the sort of farming system they operate: a mixed farm, a dairy farm, a hill farm, and so on. The purpose of this chapter is to describe the farming systems which were found in England and Wales between 1850 and 1914, in order to set in context the regional variations described in the previous chapter, and the technical changes described in the next chapter.

The principal sources for any account of farming systems in this period are the well-known surveys of the agricultural industry produced by Caird in 1850, Clarke in 1878, and Hall in 1910–12, together with the prize reports on individual counties which appeared in the *Journal of the Royal Agricultural Society of England* in the middle of the nineteenth century.[1] All of these share the same strengths and weaknesses: they were written by men with an extensive range of contacts in agriculture, but mostly with the bigger landowners and their agents and tenants. Thus, when they travelled the country or the county, the farms and estates of which they saw most, and the people to whom they usually spoke, were not a truly random sample of English or Welsh agriculture. They were those with whom they had social or professional contacts, or those recommended to them as expert practitioners or interesting innovators. Caird certainly made no pretence of having written an unbiased survey of the ordinary state of agriculture: 'I was careful to note good examples of farming in the several counties, and have described them in minute detail . . . I have also sometimes noticed objectionable practices in order to reprobate them.' His purpose, in other words, was to produce 'a book

[1] James Caird, *English Agriculture in 1850–51* (2nd edn, London, 1967); J. A. Clarke, 'Practical agriculture', *JRASE*, 2nd ser., 14, 1878, pp. 445–642; A. D. Hall, *A Pilgrimage of British Farming* (London, 1914); the prize reports are listed in Lord Ernle, *English Farming Past and Present* (6th edn, London, 1961), pp. cii–ciii.

of reference for the best systems of agriculture at present practised in the various counties of England'.[2] In consequence, therefore, it is easier to find out what was happening on the big commercial farms, among those farmers who were making exciting changes, than on the ordinary run of tenant or smaller family farms – the practitioners of what might be described as 'vernacular agriculture'.[3] In these circumstances, detailed local studies by modern historians become especially valuable.[4]

The question of what a farming system is immediately arises. Perhaps the simplest approach is Caird's, dividing the country into corn and grazing counties in the often-reproduced frontispiece to his 1850–1 survey.[5] But although there were indeed farming systems which were based on corn production, and others which depended on grazing, there is more to a farming system than this simple division. At the other extreme is Scott Watson's discussion of farming systems, in which he argues that natural, economic and political conditions, together with private circumstances, must be taken into consideration, so that 'it is not surprising to find an infinite variety of farming systems in any particular country'.[6] Some idea of just how infinite the variety was in early twentieth-century England can be judged from McConnell's article on rotations, published in 1908, and based on a questionnaire sent to 'leading farmers' in each English county. Respondents were asked about the rotations in their district. Out of 107 replies, McConnell found 3 examples of three-course rotations, 32 of four-course, 40 of five-course, 35 of six-course, 5 of even longer rotations, 7 which included catch-cropping, several which defied classification, and 6 which disclaimed 'the use of any rotation or system at all'. And all but eight respondents admitted that the rotations they had listed might be varied from time to time. McConnell concluded that '. . . a hard and fast system of rotation is neither desirable nor necessary . . . provided the land is kept clear of weeds and in good manurial condition the farmer may follow any system or no system at all . . . The principle to follow nowadays is to grow what will pay best, or what will suit the circumstances or the occasion.'[7] Farming systems, in other words, might be easier to identify at a distance of space or time, or in theory, than on a specific farm at a particular point in time.

In fact, most late nineteenth-century farming systems were types of

[2] Caird, *English Agriculture*, p. xxxiii.

[3] The phrase 'vernacular agriculture' was coined by B. A. Holderness in an unpublished paper.

[4] See, for example, E. H. Hunt and S. J. Pam, 'Essex agriculture in the "Golden Age", 1850–73', *AHR*, 43, part 2, 1995, pp. 160–77, and Bethanie Afton, 'The great agricultural depression on the English chalklands: the Hampshire experience', *AHR*, 44, part 2, 1996, pp. 191–205.

[5] Caird, *English Agriculture*, frontispiece.

[6] J. A. Scott Watson, 'Farming systems', in H. Hunter (ed.), *Bailliere's Encyclopaedia of Scientific Agriculture* (London, 1931), pp. 313–21.

[7] P. McConnell, 'Rotations', *JRASE*, 69, 1908, pp. 26–32.

mixed farming. Although some farmers – Prout of Sawbridgeworth is the best known – attempted to run a continuous corn system, and some pastoral farms, mostly hill farms, had very little arable, most farms of necessity integrated crops and livestock.[8] In the pastoral areas some of the enclosed land around the farmstead might be ploughed from time to time for a crop of oats or potatoes, and in the arable districts sheep and cattle were needed to supply manure, which might be augmented but rarely replaced by artificial fertilisers. This, tradition, and the requirements of the tenant's lease ensured the maintenance of mixed systems. Nevertheless, within this overall similarity, there were significant differences, depending on whether the farm was in the uplands or the lowlands, in an arable or a pastoral area, on light or heavy soil, in the east or the west, or the north or the south, and whether it was big or small, owner-occupied or tenanted. Most farms probably fell roughly into one of six categories: three mainly arable (light-land sheep and corn, heavy-land crops and cattle, and arable dairying) and three mainly pastoral (dairying, hill farming, and lowland fattening). In addition, there were specialist systems such as pig and poultry production and intensive horticulture. All of these are discussed in the following pages. It is important to remember, however, that these categories represent a simplification of reality, made only to ease the task of explaining what happened on the farms of Victorian England; they might perhaps be seen as themes, upon which farmers improvised their own variations to cope with their local conditions, the exigencies of the season, and the vagaries of trade.

[8] C. S. Orwin and E. H. Whetham, *History of British Agriculture, 1846–1914* (2nd edn, Newton Abbot, 1971), p. 129.

B

ARABLE SYSTEMS

BY PAUL BRASSLEY

Light-land farming

On the light soils underlain by the chalk and limestone of southern and eastern England, the principal farming system was the one made famous by the improvers of the late eighteenth and early nineteenth centuries, in which sheep and cattle ate roots and temporary leys ('seeds') to provide the fertility required to produce wheat and barley. This basic model, or some variation of it, could be found on the big tenanted farms which were laid out on this sort of land from Dorset to Yorkshire from before 1850 to after 1914.

Numerous and detailed descriptions of mixed farming on the wolds and downs were written, from Caird in 1850 to Hall in 1912. To choose almost at random, one might examine the account of light-land farming in Lincolnshire, by John Algernon Clarke and published in his account of 'Practical agriculture', part of the Royal Agricultural Society's memoir on the agriculture of England and Wales prepared for the International Agricultural Congress held in Paris in 1878.[9] Lincolnshire has two areas of light land, overlying the oolitic limestone on the western side of the county and the chalk wolds on the east. The limestone belt, known as the Heath to the south of Lincoln, and the Cliff to the north, is a northward extension of the same limestone formation which forms the Cotswolds and runs up through Northamptonshire. In Lincolnshire, it runs straight from south to north, with a marked west-facing scarp slope rising abruptly from the Midland plain, and a gently sloping dip which disappears under the silt and peat of the Fens in the south of the county and under a clay vale to the north. East of these clays lie the chalk wolds, which again are a northward extension, this time of the chalk hills which run north-east from Salisbury Plain, through the Chilterns to the low hills of west Norfolk. By the time Clarke wrote, in the 1870s, many archetypical examples of light-land farming could be found on these uplands.

As Clarke pointed out, the Heath and Cliff had been better known for waste and rabbit warrens until the end of the eighteenth century. Then enclosure, followed by high farming, had made it 'a district of large farms, large flocks, fine farmsteads and stately rickyards'. He described a system

[9] Clarke, 'Practical Agriculture', chapter VII.

in which almost all of the land was 'under the plough' in the sense of being part of the arable rotation. Most farmers used the four-course rotation. The roots, which received much of the artificial and farmyard manure, were generally turnips, with a smaller proportion of swedes, although mangolds and kohl-rabi were increasingly popular. Roots were followed in the second year by barley undersown with grass and clover (the seeds crop), which provided hay and aftermath grazing for sheep in the third year, until it was ploughed up and put down to winter wheat. Sheep were fed on the roots and the seeds, often with supplementary rations of oil-cake, and bullocks were kept in yards and fed on oil-cake, roots and straw to produce the farmyard manure. Clarke saw this as high farming, and claimed yields averaging 'fully 30 bushels of wheat and 40 bushels of barley per acre'. The system on the Wolds was similar. Fertility was maintained 'by the consumption of great quantities of cake and other feeding-stuffs in the fold and yard, and by heavy applications of artificial manures'. Sometimes the four-course was converted into a five-course by taking an oat crop before the wheat, and sometimes the seeds were kept down for a second year, while catch-crops of green forage and late roots were being introduced.[10]

This system, or something akin to it, could be found on most of the farms on the light soils overlying the calcareous rocks of southern and eastern England, from the middle of the nineteenth to the early twentieth century. Clarke's 1878 survey found that much of the downland in Dorset and Hampshire had been converted into arable 'by the usual practice of paring and burning, for roots, followed by wheat, barley, or oats, and then seeds'. The change to the four-course was not universally satisfactory, and many variations were tried or discussed, but all were based on the principle of no more than half of the arable in corn at any one time in order to produce both sheep and corn together. The Wiltshire downs were less likely to be enclosed, and in the arable rotation barley followed wheat, and was succeeded by two years of fodder crops. Many farms also had up to a tenth of the arable sown to sainfoin, the amount varying according to the water-meadow and downland grazing available. Those sheep which had grazed upon the down during the day were still folded on the arable at night, or used to consolidate newly drilled wheat seedbeds. The Southdown sheep which were kept on the Sussex downs were similarly managed, to produce lambs for sale in autumn to be fattened on the richer soils of West Sussex. On the big farms (200 to 1,000 acres), on the Cotswolds, the standard four-course of roots–barley–seeds–wheat might be extended to five by keeping the seeds down for two years, and a few farms took an oat crop after the wheat. In the *locus*

[10] *Ibid.*, pp. 612–13.

classicus of this type of farming – the Coke estates in West Norfolk – the standard four-course was being modified to the extent of replacing some of the turnips by mangolds, and following mangolds by wheat instead of the barley which would normally follow turnips. Sainfoin was also used to replace some of the clover in order to produce an eight-year gap between clover crops and so avoid the 'clover sickness' (*Sclerotinia trifoliorum*) to which that crop was prone. On the Yorkshire Wolds, the most northerly of these light land/big farm districts, the same problem was overcome by introducing beans and peas into the rotation, and leaving the seeds down for two years, in order to produce a six- or seven-course shift. Here sheep, a mixture of Leicesters and Lincolns, were the main product, although Irish cattle were also bought in to make straw into manure during the winter.[11]

These similarities in the management of big farms on light land underlain by chalk and limestone were recognised by Caird, writing in the middle of the nineteenth century. He noted that the 'style of farming [on the Lincolnshire Heath] very much resembles that of the Wolds, except that the crops are somewhat more generously treated', although oil-cake was seldom given to sheep on turnips or seeds. A 500-acre farm, he thought, would overwinter about 1,000 sheep, usually Lincolns, on turnips. The oil-cake seems to have been reserved for the cattle which, as on the Wolds, were often fed as stores, and sent to the lower ground to be fattened on summer pastures.[12]

Caird's accounts of the farming of these light-soil districts, from Dorset to Yorkshire, are more detailed than those of Clarke, but the system he describes is the same. This might be expected, since one was writing at the beginning of the period which Ernle identified as the Golden Age, and the other at the end.[13] Alternatively, their work might be seen as descriptions of the classic high-farming areas in the classic high-farming period. What is perhaps more surprising is the extent to which this system is recognisable in the late nineteenth- and early twentieth-century surveys of farming regions and methods. The evidence of the national agricultural statistics is that the area of arable land decreased after 1880.[14] Comparing data from the tithe files of the 1840s with the agricultural statistics for 1872, and with earlier data, Kain and Prince concluded that a peak in arable cultivation was reached at some point between 1840 and 1875, and quoted Stamp's conclusion that between the 1840s and the 1930s there had been stability of land use on the best and

[11] *Ibid.*, pp. 589–615; J. Coleman, 'Report on the agriculture of the north of England for the Royal Commission on Agriculture', BPP, 1881, XVI, pp. 133–42. [12] Caird, *English Agriculture*, p. 190.

[13] Ernle, *English Farming Past and Present* (6th edn), p. 373, specifically referred to the years 1853–62 as the golden age.

[14] MAF, *A Century of Agricultural Statistics* (London, 1966), table 42, p. 94.

poorest land, with the most change occurring on intermediate-quality land.[15]

If Stamp was correct, much depends on what he meant by best, and whether it would include light land on calcareous soils. However, Hall's survey, undertaken in 1910–12, suggests that the pattern of farming on such soils had changed little from what Clarke was describing more than thirty years earlier. The Lincolnshire Heath he portrayed as a region of big farms, thin soils and large fields, mostly in arable, the only permanent grass being found around the farmsteads. The rotation was based on a succession of wheat, roots, barley and seeds (clover or sainfoin), manured by artificials and the cake eaten by the sheep feeding on the seeds. Hall found a similar system of farming on a large farm on the Lincoln Wolds, although here there was more permanent grass, grazed by Lincoln red Shorthorns. 'The whole farm afforded a very good example of the old strict style of farming', he wrote; 'only corn and meat were sold off the holding; everything else was consumed and came back to the soil . . . it is the strict four course pursued with rigour and thoroughness, very conservative in its methods, and neither spending much upon nor taking very much out of the land.'[16] Similarly, A. G. Street, recalling the Wiltshire farming of his youth in the first decade of the twentieth century, described the same Wiltshire rotation as that outlined by Clarke, 'as unalterable as the law of the Medes and Persians . . . any slight variation was considered a sin . . .'[17] Nevertheless, there were variations, sometimes. Mr Wilson Fox, reporting on Cambridgeshire to the 1895 Royal Commission, found that on the chalk, although the four-course remained the recognised system, 'since the depression it has been frequently modified by the prolongation of the seeds period, and by taking barley after wheat, or substituting barley for wheat'.[18] Likewise, Coppock found some modification of the system on the Chilterns in the 1890s. To some extent, perhaps to a large extent, these changes would have been a result of the decrease in corn prices; nevertheless, some part of the reason for them might have been due to increased perceptions of the shortcomings of the system, even on the light lands on which it had been developed.[19]

Not all of the light lands lay over the chalk and limestone. Sandy soils formed a sub-class of their own, scattered across lowland England from the Bagshot sands of Surrey and the sandy coastal strip of Suffolk,

[15] R. J. P. Kain and H. C. Prince, *The Tithe Surveys of England and Wales* (Cambridge, 1985), pp. 174–6. [16] Hall, *Pilgrimage*, p. 100.

[17] A. G. Street, *Farmer's Glory* (new edn, London, 1959), p. 29.

[18] H. Wilson Fox, 'Report on Cambridgeshire to the Royal Commission on Agriculture', BPP, 1895, XVII, p. 151.

[19] J. T. Coppock, 'Agricultural changes in the Chilterns, 1875–1900', *AHR*, 9, pp. 1–16.

through the Brecklands on the Norfolk–Suffolk border around Thetford, to the thin soils of the Bunter sandstone in Nottinghamshire, on which the remains of Sherwood Forest lay undisturbed by agriculture because often in the past the land had hardly been worth the expense of reclamation. Nevertheless, it was easy to cultivate, and could respond to high levels of fertilisation. Caird described a 50-acre farm near Worksop in Nottinghamshire, much of it 'a light poor sand, requiring a large expenditure in manures and cake to keep it in a profitable state'. Five hundredweight of rape dust, three of guano, and ten loads of well-rotted dung per acre were laid in drills, covered by the plough, and had turnips and swedes sown on top. The resulting crop was fed to a breeding flock of 400 Leicester ewes and their lambs, which were also given half a pound each of oil-cake per day. Most of the lambs were fat by the time they went out to grass in their second spring. Thirty cattle were also fattened each winter on four pounds of oil-cake each per day, and swedes. The best land was in a four-course rotation, and the worst in a five-course.[20]

A four-course rotation of roots–barley–seeds–wheat was also common in East Anglia, in Breckland and on the sands of the Suffolk coast, although swedes and mangolds were not grown on the very lightest land. On these 'blowing sands', here and on the Bagshot sands of Surrey, rye was sometimes grown on the poorest land in preference to wheat or barley. In Surrey, however, many of the farms were smaller than in the other sandy-soil areas, many being between 50 and 100 acres, although others were up to 400 acres in extent. Here, by the 1850s, there was a growing trade in liquid milk and vegetables, especially carrots and peas, for the London market. Further away from metropolitan markets these options were not available, and farmers responded to the lower prices of the 1880s and 1890s by reverting to old established rotations in which the seeds break was lengthened and input levels reduced: a return, as it were, to 'low' farming.[21]

Arable farming on heavy land

If arable farming on light land had advanced most rapidly in the century before 1850, the heavier or clay soils still possessed the greater potential fertility. 'They constitute the best wheat, bean, and clover lands in the country, and are often looked upon with envy by the occupiers of light

[20] Caird, *English Agriculture*, p. 204; R. W. Cottingham, 'The agriculture of Nottinghamshire', *JRASE*, 6, 1845, pp. 2–21.

[21] H. Raynbird, 'On the farming of Suffolk', *JRASE*, 8, 1847 pp. 285–304; H. Evershed, 'On the farming of Surrey', *JRASE*, 14, 1853, p. 400; J. Wrightson, 'The agricultural lessons of "The Eighties"', *JRASE*, 3rd ser., 1, p. 281.

and "weak" lands.'[22] Well managed, they could produce a succession of saleable crops over many years, but they were difficult to reduce to the fine tilth required for turnips, and in any case they could not stand winter folding by sheep. Thus the alternation of corn and fodder crops which had proved so successful on the big light-land farms was inappropriate on the clay lands, where farms were often smaller. As Caird wrote:

> In former times the strong clay lands were looked upon as the true wheat soils of the country. They paid the highest rent, the heaviest tithe, and employed the greatest number of labourers. But modern improvements have entirely changed their position. The extension of green crops, and the feeding of stock, have so raised the productive quality of the light lands, that they now produce corn at less cost than the clays, with the further important advantage, that the stock maintained on them yields a large profit besides. In all parts of the country, accordingly, we have found the farmers of strong clays suffering the most severely under the recent depression of prices.[23]

Thus heavy-land arable farming required a different approach from that used on the lighter soils. Even in an early twentieth-century agricultural textbook it is possible to find the statement that for such soils '. . . the basal rotation is the three-course of wheat, beans, bare fallow', although there rapidly follows the qualification that a modern rotation replaces the fallow with cabbage, rape, or, on the less stiff clays, mangolds, with an oat crop after the beans to extend the rotation to a four-course.[24] In practice, the wheat–beans–fallow rotation was rarely found in the surveys of heavy-land farming by such authorities as Caird and Clarke, although they describe something which is not essentially very different from it. In Warwickshire, for example, they both mention the six-course rotation of wheat, beans, wheat, fallow (with swedes, mangolds or turnips), wheat or barley, seeds. In 1850, apparently, both winter beans and mangolds were relatively recent but increasingly popular innovations. Farmyard manure was spread upon the wheat stubbles and ploughed in as quickly as possible. Then roots were sown in the following spring, some being fed on the land and the remainder carted off. The seeds were sown on the barley, and half mown for hay and the rest grazed by sheep which received supplementary feeds of corn or oil-cake. In Suffolk, in contrast, the heavy land was farmed in a four-course shift of roots, barley, half clover and half pulses, and wheat. Caird was enthusiastic about the 'success with which heavy land farming is carried on' in Suffolk, and attributed this in part to the extensive drainage (by bush rather than tile

[22] C. E. Green and D. Young, *Encyclopedia of Agriculture* (Edinburgh and London, 1907), vol. I, p. 388.
[23] Caird, *English Agriculture*, p. 476.
[24] R. P. Wright, 'Rotation of farm crops', in R. P. Wright (ed.), *The Standard Cyclopedia of Modern Agriculture and Rural Economy* (London, n.d., c. 1905–14), vol. x, p. 150.

drains), 'the primary improvement on this description of land', and the custom of ploughing in stetches of ten or twelve furrows. The furrows between the stetches acted as gutters to carry away rainwater, and as trackways for the horses, so preventing their poaching of the land. The various implements used – harrows, rollers, drills and horse-hoes – were made so as to fit the width and height of these stetches. Caird was less enthusiastic about the management of the beef cattle on these farms. Stores were bought in the autumn and fed on straw, mangolds and large quantities (14 to 18 lb per day) of corn and cake, in the hope that they would be fat enough to be sold off in the spring. There was a great variety of breeds, from polled Galloways to Shorthorns and Irish cattle, the best of which were probably fattened at home, and the cost of feeding them was such that Caird calculated a loss of £6 on each animal. This, he thought, was 'a most expensive mode of making manure'.[25] Neighbouring Essex, proverbially a heavy-land county, employed a similar rotation, which Primrose McConnell later described as 'an irregular four-course shift: wheat, bare fallow, roots, English broad red clover, beans and peas, were grown in various orders, to suit particular circumstances, the wheat and fallow occurring as often as possible'. One of every fifteen arable acres in Essex was in fallow according to the Agricultural Returns 'some time ago' (he was writing in 1891), compared with one in twenty-seven in England as a whole, and McConnell thought it proof of the great natural fertility of the Essex clays that they could stand 'this scourging system for so long without absolutely giving out'. Caird, too, argued that the Essex farmer was dependent upon corn, and a recent investigation of Essex farming has confirmed that farming practices in 1870 were little different from those in 1850.[26]

The two recurring questions with regard to heavy land in this period are those of drainage and conversion to pasture. In theory, drainage allowed heavy-land farmers to adopt some of the techniques successfully used on lighter soils; in practice, it is difficult to isolate the effects of drainage from other changes, such as the adoption of new feeds, fertilisers and implements, which occurred at the same time.[27] Equally, there seems to be little doubt that some of the clay lands which had been in mixed arable farming before the 1880s were among those converted to

[25] Caird, *English Agriculture*, pp. 152–6, 225; Clarke, 'Practical agriculture', pp. 605–9.

[26] Caird, *English Agriculture*, pp. 137–8, 142; P. McConnell, 'Experiences of a Scotsman on the Essex clays', *JRASE*, 3rd ser., 2, 1891, p. 316; Hunt and Pam, 'Essex agriculture', p. 176.

[27] This question is discussed further in chapter 8. It was discussed in detail in R. W. Sturgess, 'The agricultural revolution on the English clays', *AHR*, 14, 1966, pp. 104–21; R. W. Sturgess, 'The agricultural revolution on the English clays: a rejoinder', *AHR*, 15, 1967, pp. 82–7; E. J. T. Collins and E. L. Jones, 'Sectoral advance in English agriculture, 1850–80', *AHR*, 15, 1967, pp. 65–81; E. H. Whetham, 'Sectoral advance in English Agriculture 1850–80: a Summary', *AHR*, 16, 1968, pp. 46–8.

grass after the 1880s, and the example of Scottish farmers who moved to Essex and made a living from dairy farming is well known. 'An article on clay-land farming would be wanting in practical character if it did not lay stress upon the importance of laying down land to grass', wrote the author of just such an article in 1907, but nevertheless most of his discussion was devoted to the cultivation of such land.[28] When A. D. Hall travelled through the Roothings, 'a country of heavy clay land of the kind that is usually associated with "derelict" Essex' to the west of Chelmsford, he found that it was still largely arable, 'farmed in a conservative fashion in medium-sized holdings', on a rotation of beans, wheat and barley, with a frequent bare fallow. A little further north, on a chalky boulder clay, a greater variety of crops was grown and sheep were folded on green crops. Here Hall emphasised the importance of the seed trade, for clover as well as seed wheat and barley, in maintaining 'a quiet unexcited prosperity'. In other words, where clay-land arable was maintained, the farming systems employed do not seem to have changed markedly from those described by Caird in the middle of the nineteenth century.[29]

Thus the basic pattern to emerge from a study of the arable farming systems of Victorian England appears to be one in which the main division is between light-soil areas, where the corn crops were interspersed with roots and seeds, and sheep were relatively more important than cattle, and heavier land, on which fattening cattle and wheat took precedence. Nevertheless, it is important to remember that there was a third option, that in which arable farming was combined with dairying. At the beginning of the period Caird found that although the bigger farmers in the central parts of Dorset were converting their downland to arable, so that sheep became the principal livestock enterprise, the smaller farmers of the vales continued to combine arable with dairy farming, mainly for butter production. Similarly Algernon Clarke's survey of farming systems in 1878 noted the prevalence of wheat, barley and beans among the rich grazings of the Vale of Blackmore in Dorset and the combination of dairying and arable in the vales of Gloucestershire. In the oolite district in north-western Wiltshire, farms and fields were smaller than on the chalk downs, and grazing and dairying were often combined with potato growing. The farms in the Avon and Stour valleys of Hampshire often combined butter and cheese production from the cows on the water-meadows with arable farming higher up the hill. Further north, Caird described the management of Sir Robert Peel's estate in Staffordshire, where the light land was generally in a four-course rotation, the heavier in a six-course, and the management of livestock variable: some farmers

[28] McConnell, 'Experiences'; Green and Young, *Encyclopedia*, vol. I, p. 387.
[29] Hall, *Pilgrimage*, pp. 66–9.

had specialised in dairying (mostly for cheese), others combined dairying and cattle fattening, 'and all keeping more or less of a sheep stock'. Longhorn cows were giving way to Shorthorns. Sixty years later, Hall described a similar farm, of about 400 acres near Leicester, operating on a five-course rotation of roots, barley, seeds, wheat and oats, with a herd of Shorthorns selling liquid milk, fattening cattle, and a sheep flock.

In contrast to these large tenanted farms, holdings in or near the industrial districts of Yorkshire and Lancashire were often smaller and dependent upon a combination of dairying and intensive arable. One prizewinning farm of this type was run by Mr Hugh Ainscough at Banks, near Southport. He had 37 acres of arable in a three-course shift of potatoes and other roots, followed by wheat, followed by seeds for hay. There were also 8 acres of pasture. Ainscough kept sixteen milking cows and sold milk worth £600 per year, in addition to feeding fourteen pigs. His hay yields – up to four tons per acre – were astonishing, and presumably resulted from his large purchases of stable manure, fertilisers and artificial feedingstuffs. Clearly, there are enough examples to demonstrate that the combination of arable and dairy farming persisted, at least in some parts of the county, during the 1850s and 1860s; conversely, it seems clear that in East Anglia commercial dairying (for butter and cheese production) was less common in these two decades than it had been in the earlier part of the nineteenth century, or would be (for liquid milk production) in the years after 1880. The attention paid to the incomers from Scotland or the west country who began to produce liquid milk in Essex perhaps reflected short memories rather than completely new farming systems. Equally, although such farmers attracted most attention for their dairying enterprises, it is clear that they combined them with not inconsiderable proportions of arable cropping.[30]

[30] Caird, *English Agriculture*, pp. 58, 249; Clarke, 'Practical agriculture', pp. 589–99, 620; Hall, *Pilgrimage*, p. 416; McConnell, 'Experiences', pp. 317–18.

C

PASTORAL FARMING SYSTEMS

BY PAUL BRASSLEY

There were three main types of pastoral farming: rearing, fattening and dairying. In general, and with some exceptions, one would expect to find the farms on which rearing was the main enterprise on the higher and/or less good land, with fattening farms on the better land. Dairy farms, of various kinds, might be found on both. Caird, in his account of Lancashire farming, described the large, highly capitalised farm run by Mr Neilson at Halewood, near the Mersey in the south of the county, with its light tramway for getting turnips carted off in wet weather, its large stock of dairy cows, fed indoors both winter and summer, and a herd of two hundred pigs. In contrast, there were the small farms on the hills on the eastern edge of the county, all or mainly in grass, selling liquid milk to the neighbouring manufacturing towns. On the better land dairying might be combined with arable cropping and the fattening of sheep and cattle, as it often was in Devon, which Caird found to be 'justly celebrated for dairy management, the perfect cleanliness and freshness of the dairies we examined forming a marked contrast to what we saw in some other counties'. Such dairies produced butter and clotted cream, and were often operated on a share-farming basis, with the dairyman managing the herd and renting the cows from the farmer at £9 per year each. The other counties which formed such a marked contrast to Devon presumably included Gloucestershire, where Caird found underfed cows shivering in the dripping rain in wet, dirty, uncomfortable yards. He was a little more complimentary about the grass farms of the Vale of Aylesbury in Buckinghamshire, where the best land was devoted to fattening and the worst to dairying, with cows bought in to produce butter for the London market from grass in summer and hay and oil-cake in winter. One herd had up to one hundred cows, fed, cleaned and milked by twelve men. Smaller herds were more common, however – 'Dairy farming requiring much personal attention, the occupations are generally small', as he found in Cheshire, where he formed the opinion that there was no other county in England where 'wet cold clay yields so much to the landlord, and so small a proportion to the tenant'. On this land only a small part of the farm was in tillage, and never more than a quarter. When a grass field was finally ploughed up it was put into oats, followed by fallow, and then wheat followed by oats again, with this rotation perhaps being repeated before the land was again put down to grass: 'such is the unimproving course on the stiff clays'.[31]

The pattern described by Hall sixty years later is remarkably similar, with the same family farms on the higher land, in Derbyshire and Lancashire, for example, all in grass, with more mixed husbandry lower down the hill, as in Cheshire, Devon and Somerset. By this time changes in transport and international trade patterns had markedly affected the dairy industry, but what went on at the farm level was perhaps not so different from the mid-nineteenth-century picture.[32]

Cattle- and sheep-rearing on upland pastures, to produce the stock for fattening on the lowlands, could be found all over England and Wales, from the south coast to the Scottish borders and beyond, and from Kent to Cornwall, but it was most common in the hills of the west and north: Dartmoor, Exmoor, the Welsh mountains, the Pennines from Derbyshire to Northumberland, and the Lake District fells. On the flanks of the hills farmers sometimes had both hill land for rearing and vale land which could fatten a bullock or a lamb bred on the higher part of the farm. In general, however, the hill farms were small family holdings, making a living, often a hard living, by selling store stock which was ready for fattening but not yet for the butcher. This may be why many of the authors who wrote at length about all aspects of Victorian farming often seem to be strangely silent on hill farming. They were interested in agriculture as it might be more than agriculture as it was,[33] and so they were more careful to note the high-farming, capital-intensive improvements of the landowners and the larger tenants rather than the quotidian survival strategies of the small owner-occupiers and tenants. The comments that they do make about the smaller farms have the appearance of over-the-hedge observations made as they passed by, rather than the results of conversations with the farmers as they toured the fields and farmsteads. Presumably this pattern follows naturally from their methods of working, which capitalised on their contacts with landowners and their agents to make arrangements to meet the leading farmers. Thus Milburn said nothing about hill farming in his prize essay on the farming of North Yorkshire, nor did Tanner mention Dartmoor farming in his prize essay on Devonshire. Carrington's essay on livestock farming is largely confined to its practice in the lowlands.[34] On the other hand, attempts to introduce lowland methods and large-scale improvements, such as those of the Knights on Exmoor, attracted wide-

[31] Caird, *English Agriculture*, pp. 4, 42–3, 54, 253–5, 270–1.

[32] Hall, *Pilgrimage*, pp. 24, 222, 234, 360–6, 408. Developments in the dairy industry are discussed in more detail below. [33] See n. 2 above.

[34] M. M. Milburn, 'On the farming of the North Riding of Yorkshire', *JRASE*, 9, 1848; H. Tanner, 'The farming of Devonshire', *JRASE*, 9, 1848; W. T. Carrington, 'Pastoral husbandry', *JRASE*, 2nd ser., 14, pp. 701–18.

spread attention, then and more recently, atypical of the hills though they were. It is also worth nothing that by the 1840s the attempts to integrate sheep and corn production on Exmoor had largely been abandoned, and most farms were concentrating on rearing.[35]

Thus the typical upland farm specialised in stock rearing. The Welsh hills in the 1840s were said to be 'wholly occupied in grazing black cattle and sheep' on farms which were large in extent but not in size of business. According to Rowlandson, the cattle were not brought to the homestead in the winter but kept in detached sheds, where the forage could be collected, in groups of six or eight. Transport of winter fodder clearly presented a major problem. The fields which could be mown for a crop of hay might be scattered around the farm, and often at some distance from the farmstead, and transport technology was often limited to a small sledge; hence the practice of storing the hay near where it was made and leaving the cattle close to it. The same practice of keeping the hay in isolated barns was found in the Yorkshire dales. On the Cumberland fells the cattle were turned out to pasture on winter days and then tied in sheds and cowhouses at night. On these farms it was thought to be 'an extravagance to purchase any kind of cattle food, except rarely a little hay towards spring'. Herdwick sheep were noted for their ability to survive without any supplementary feeding at all. On some of the small Welsh mountain farms gorse was planted for 'winter provision', a practice which was only just beginning to be discontinued in the early twentieth century. When grazing and hay were so vital it is not surprising to find arguments about stocking rates: in Westmorland the rule, in theory, for stocking common pastures was that no farmer should attempt to graze more animals in summer than he could keep on the farm in winter, but in practice many farmers were tempted to maximise the summer numbers and send their animals away in winter. In the kinder climate of Exmoor the hill farmers kept a breeding flock of ewes and a flock of wethers on the hill in both summer and winter. The size of the ewe flock depended on the amount of water-meadow available for grazing the ewes and their lambs after lambing, whereas the number of wethers kept depended upon the farmer's common rights. Often, as in Cumberland, hill sheep were hefted: accustomed to the particular part of the hill upon which they were born.[36]

[35] Hence the discussion on the advisability of growing turnips in the hills in T. Dyke Acland, 'On the farming of Somersetshire', *JRASE*, 11, 1850, p. 676; see also E. J. T. Collins, *The Economy of Upland Britain: an illustrated review* (Reading, Centre for Agricultural Strategy, paper 4), May, 1978, p. 16; C. S. Orwin and R. J. Sellick, *The Reclamation of Exmoor Forest* (revised edn, Newton Abbot, 1970), chapters 4–7.

[36] T. Rowlandson, 'On the agriculture of North Wales', *JRASE*, 7, 1846, pp. 572–5; Collins, *Economy of Upland Britain*, p. 41; W. Dickinson, 'On the farming of Cumberland', *JRASE*, 13, 1852, pp. 257, 264; Hall, *Pilgrimage*, p. 325; Acland, 'Somersetshire', p. 678.

Several tough breeds were kept in these conditions. In Cumberland the Blackfaced mountain sheep were kept on Crossfell, but across the Eden valley in the Lake District proper the Herdwicks were dominant. Blackfaces, and also Cheviots, were brought down from Scotland to several farms on Exmoor in the 1870s and 1880s to replace the local breeds, which could not be wintered out on the hills. Galloways were the most common breed of cattle around Bewcastle, but in Westmorland the Shorthorn was beginning to oust the Longhorn.[37] Acland spoke warmly of the debt owed by Exmoor farmers to Mr Quartly of Molland in Devon, who had bred the North Devon cattle which were so extensively used there. Both cattle and sheep might have to be kept for a long time before they were ready to be sold to lowland farmers for fattening. In the Welsh hills the cattle and sheep were kept to three or four years old before the drovers took them to be fattened on the richer lands in the east of the country. Even the better farmers on Exmoor allowed their bullocks to shift for themselves on rough ground or in straw yards until they were two or three years old, although Acland found a tendency to sell them off younger than hitherto, and some farmers were even attempting to feed and fatten some of their stock. In Cumberland ponies were bred in considerable numbers. They were allowed to fend for themselves on the moors both winter and summer, the surplus being sold at Brough fair in September.[38]

By the time Daniel Hall and his companions travelled through the Lake District in 1911, the Scotch blackfaces were beginning to become more established; otherwise, the farming system was much as Dickinson and Webster had described it fifty or sixty years earlier. It is possible to discern the greater influence of the liquid milk trade in the activities of a Forest of Bowland hill farmer, who, although he kept a few milking cows and made some butter, earned most of his living by selling heifers to the cow-keepers in and around the neighbouring industrial towns. But the farming of the Welsh hills, as described by Hall, with the black cattle sold to Midland graziers as 'big-framed stores of two to two and a half years', and the sheep flock 'moved off the hills in October, going back in April to lamb', producing three-year-old wethers to be fattened off turnips in the lowlands, is virtually indistinguishable from the farming of the mid-nineteenth century.[39]

Many of the sheep and cattle raised on the hills were fattened, as has already been noted, on the mixed farms of lowland England, on grass in the summer, or roots, chopped straw and cake in the winter.[40] But there were other systems:

[37] Orwin and Sellick, *Exmoor Forest*, p. 119; Dickinson, 'Cumberland', pp. 247, 252, 263; C. Webster, 'On the farming of Westmorland', *JRASE*, 2nd ser., 4, 1868, p. 12.

[38] Acland, 'Somersetshire', pp. 677–80; Dickinson, 'Cumberland', p. 247.

[39] Hall, *Pilgrimage*, pp. 238–9, 252, 330–1.

[40] Carrington, 'Pastoral husbandry', p. 708.

There is in England much rich grass-land, especially in some of our river valleys, which has not been ploughed for generations, and is very well adapted for feeding cattle in the summer and autumn; and on such land this is more profitable than rearing young cattle. If suitable cattle can be bought in the spring, and made fat and sold before the grass season is over, there is no necessity for providing a supply of dry fodder, and there is little labour involved in the system.[41]

Whether there was much land of this type is perhaps a matter of debate, but there is no doubt that there were some districts which were famed for this type of farming. The best known were the fattening pastures of Leicestershire and Northamptonshire, which even the combined pressures of agricultural fashion and high corn prices had not succeeded in converting to mixed farming. There was too much money to be made in finishing the stores coming from Wales and the north of England, and, of course, endless hedged fields of well-cropped grass provided excellent hunting country. Similarly, in the Vale of Aylesbury in Buckinghamshire, Caird found three parishes with less than a hundred acres of arable between them, the best land being devoted to fattening cattle and sheep and the less good to dairying.[42] There were also parts of the West Midlands which fed locally raised Herefords, and in the South Hams of Devon rearing and fattening were combined: cattle were fed for three years, and then fattened for sale to the neighbouring towns and the provisioners of the Navy in Plymouth.[43] Romney Marsh, in Kent, was also a specialist grazing area, but, in contrast to the others, the farmers there specialised in breeding and fattening sheep. In the mid-nineteenth century breeding land there was said to keep two or three ewes to the acre in winter and twice that number in summer, while fattening land would finish four or five sheep per acre. Cattle were said to 'occupy in all respects a very subordinate place to sheep' in the management of the Marsh, and were only brought in if the grass was growing faster than the sheep could eat it.[44]

The management of the grass was crucial to the profitability of these grazing districts. Great skill was required to maintain a high output of nutritious herbage. If the fields were overgrazed, weed species could get a foothold, bare patches could develop, and the rate of growth was reduced; if undergrazed, the grass grew long and coarse and its feeding value was reduced, and again weeds flourished. Thus the stocking rate and the different grazing habits of cattle, sheep and horses all needed to be balanced to keep the grass fairly short but still growing well. Sometimes old men and boys were employed to remove the dung to

[41] *Ibid.*, p. 706. [42] Caird, *English Agriculture*, pp. 1–3. [43] Tanner, 'Devonshire', p. 479.
[44] G. Buckland, 'On the farming of Kent', *JRASE*, 6, 1845, p. 299.

prevent the development of rank patches; later in the season it would be sufficient to spread the dung about – 'knocking the clots', as the process was known. It was also important to keep the thistles mown, the fences mended, and the drains working. Not everybody did. In Northamptonshire, Bearn reported examples of rich pastures overrun with thistles, nettles and 'hassocks', or unusable in winter for want of drainage.[45]

The graziers would buy much of their stock – Herefords, Devons, Shorthorns, and Welsh, Scots and Irish cattle – in the spring, from March to May. They would be turned into the feeding pastures in May, and drafted out fat from July to November. Those few which were still not fat would be finished off indoors before Christmas. In autumn, when one year's stock had been sold, a few more stores would be bought to eat any autumn growth of grass – the 'rough knawing' – until Christmas, when they would be put into the strawyard, or kept on the land and fed supplementary hay. This basic pattern applied in both Leicestershire and Northamptonshire, but there are some differences in the mid-century accounts of the two counties. William Bearn, writing about Northamptonshire in 1852, noted that cattle formed the bulk of the stock, and were allowed two acres per beast, with only a few wethers or ewe and lamb couples in addition. In Leicestershire, however, in 1866, an acre of the best grassland, which would attract a rent of up to £3, could fatten a bullock of 50 or 60 stones (approx. 700–800 lb) and an 80-lb sheep during the summer and keep a sheep (usually a Lincoln/Leicester cross) in winter. A few horses would also be grazed, but not more than six or twelve on a 300-acre farm. The fields were commonly between 10 and 20 acres, surrounded by 'huge whitethorn hedges', and the grazing farms were generally between 100 and 300 acres. The smaller farms, which might range from 20 to 70 acres, tended to concentrate on dairying, and specialised in Stilton cheese production. Potentially, therefore, farmers who were good judges of what to buy and when to sell, and paid attention to their grassland, could make a good living from grazing.[46]

Lowland grazing was perhaps the most geographically and technically specialised of the major farming systems employed in this period. Hill farming and dairying could certainly be found over a greater area. These were the pastoral systems. The arable systems, discussed earlier, were all types of mixed farming: corn and sheep on the light lands, cropping and cattle on the heavier land, and dairy and arable farming where physical and commercial conditions made it appropriate. It must be remembered that these are imprecise distinctions. Even the most cursory reading of

[45] W. Bearn, 'On the farming of Northamptonshire', *JRASE*, 13, 1852, pp. 77–82; W. J. Moscrop, 'A report on the farming of Leicestershire', *JRASE*, 2nd ser., 2, 1866, pp. 292–7.

[46] Bearn, 'Northamptonshire', p. 78; Moscrop, 'Leicestershire,' pp. 293–5.

the large number of accounts of farming in England and Wales between 1850 and 1914 demonstrates the enormous range of local variation. Differences in location, altitude, soil type, farm size, capital provision and all the other factors which determine the profit-maximising combinations of inputs and outputs produced significant differences between neighbouring farms, let alone different parishes or counties. Nevertheless, although the variations are legion, a perception of the themes helps to set them in context, and these six systems accounted for most of the mainstream agriculture in the country. There were in addition some more specialised farming types, and these are discussed in the following sections.

CHAPTER 7

FARMING TECHNIQUES

A

INTRODUCTION

BY PAUL BRASSLEY

In volume VI of this *History*, Professor Mingay listed the technical changes in agriculture which occurred in the century after 1750 – new crop varieties, fertilisers, breeds and implements, and advances in drainage – and went on to enumerate subsequent innovations that were still to appear in the years after 1850: further improved drainage methods, new types of fertilisers, further changes in livestock breeding, and the development of veterinary science.[1] To these, it only remains to add farm buildings, weed and pest control, and animal feeds to produce a complete agenda for the historian of technical change in late nineteenth-century agriculture. Nevertheless, before beginning the detailed individual consideration of each of these topics, it is perhaps worth pointing out that technical change does not occur in a scientific, educational, social, institutional, political or economic vacuum.[2] Equally, discussion of it does not occur in an historiographical vacuum, and clearly any consideration of technical change in this period must imply some comment on Professor Thompson's concept of a second agricultural revolution based on the replacement of the resources of the farm by purchased inputs, especially of feeding stuffs and fertilisers.[3] Consequently, the subsequent sections of this chapter contain much discussion, not only of technical innovation, but also of the extent to which innovation was followed by adoption. Clearly the one need not necessarily follow immediately upon the other, for reasons which are too complex to be discussed in detail at this point.[4]

[1] G. E. Mingay (ed.), *AHEW*, vol. VI, *1750–1850* (Cambridge, 1989), p. 275.

[2] Scientific and educational change is discussed in chapter 9, social and institutional change in chapter 10, and political and economic change in Parts I and VII of this volume.

[3] F. M. L. Thompson, 'The second agricultural revolution, 1815–1880', *EcHR*, 2nd ser., 21, 1968.

[4] Two different approaches to the issue are taken in P. Brassley, 'Agricultural research in Britain, 1850–1914: failure, success and development', *Annals of Science*, 52, 1995, esp. pp. 477–80; and P.

However, it is important to recognise that there were differences between technical leaders and followers, and that the downturn in prices, especially cereal prices, in the second half of the period under consideration almost certainly had some impact on technical change. In addition, it probably follows from this that any precise assessment of the overall impact of technical change in this period is likely to be more problematical than judgments of the effects of individual developments, which are themselves difficult enough. On balance, it appears that the labour-saving (albeit capital-using) innovations in machinery and buildings perhaps had more impact than the potentially land-saving changes in varieties, feeds and fertilisers, but this conclusion must be hedged about with numerous exceptions and reservations, as the following pages demonstrate.

D

LAND DRAINAGE

BY PAUL BRASSLEY

Several kinds of land drainage problem have to be overcome in England and Wales. Some land is poorly drained because it lies close to or below sea level, so that water cannot easily run off it: the Fens and the Somerset Levels are examples of such areas. In the Fens the drainage of Whittlesey Mere in the 1850s and subsequent investment in sluices and pumping engines throughout the region led to major advances in drainage and corresponding advances in agriculture. Likewise large areas of the Lancashire moss lands had been brought into cultivation by the 1870s. In contrast, in the Somerset Levels, '. . . it is probably safe to say that the drainage situation in 1900 was no better, and probably worse in some localities, than it was a hundred years before'.[78] Land which is well above sea level may also be poorly drained because rivers and streams are inadequate to carry away water without periodic flooding. In 1854 J. A. Clarke wrote seventy-three pages in the *Journal of the Royal Agricultural Society* on this problem, and the resultant damage, and concluded by encouraging landowners to support schemes for river improvement, contending that many had not. More commonly, and sometimes at high altitude, there may be local patches of wet land around springs, and, most commonly, there are many areas which are poorly drained because water permeates too slowly through an impermeable soil. Both of these latter problems may be treated by underdrainage, which was one of the most important forms of agricultural investment in the second half of the nineteenth century. It was expected to produce, according to a contemporary expert, an earlier harvest, a more abundant harvest, a better quality of produce, a greater variety of crops, lower tillage costs, more effective applications of manure, healthier livestock and a healthier rural population. Whether or not it did so has been a matter of controversy ever since.[79]

In 1842 Philip Pusey estimated that 10 million acres of England needed draining. In 1847 Joshua Trimmer increased the figure to 25 million acres by adding in 15 million acres of pasture. Mid-nineteenth-century surveys of agriculture argued the case for drainage. Caird, for example, found drainage defective in Warwickshire, and badly needed at Willesden near

[78] H. C. Darby, *The Changing Fenland* (Cambridge, 1983), p. 187; M. Williams, *The Draining of the Somerset Levels* (Cambridge, 1970), p. 230.

[79] J. A. Clarke, 'On trunk drainage', *JRASE*, 15, 1854; J. Wrightson, *Agricultural Textbook* (n.d., probably 1880s), pp. 67–9.

London, and much of Hampshire 'either very imperfectly drained or not drained at all'. In 1849 it was reported that 'No part of the kingdom requires draining more than South Wales'. The only detailed nineteenth-century estimates of the area of land which required underdrainage were made by Bailey Denton, the principal engineer of the General Land Drainage and Improvement Company. Although he would obviously have no interest in minimising the need for drainage, the detailed nature of his survey made it the best source of information available to his contemporaries. His estimates appeared in 1855, when he put the figure at over 15.3 million acres in England, or 48.1 per cent of the total area, and in 1883, when he increased the figures to 16.5 million acres or 50.5 per cent of the total area. Since Denton based his figures on the area of various geological formations known to have drainage difficulties, without taking account of the proportion of the land which was not cultivated, it was likely that his figures would be on the high side. In recent years the Soil Survey of England and Wales has produced estimates of the area of 'clayey and loamy soils with impeded drainage' or 'slowly permeable, seasonally waterlogged clayey and loamy soils'. These are the soils which require drainage, and they cover about 40 per cent of the total area of England and Wales or about 13 million acres in England. They are not evenly spread over the country, but are concentrated in the midland counties such as Leicestershire and Northamptonshire and the north, especially Northumberland and Durham. In each of these counties more than half the area needs drainage. In contrast, in Wiltshire, Cambridgeshire, Derbyshire and Herefordshire less than 30 per cent falls into this category.[80]

Drainage had long been recognised as a most desirable improvement of land, and various techniques were used in the early nineteenth century and earlier. Apart from open ditches, underdrainage was carried out by filling trenches with furze, turves, branches or stones. Stone-filled drains were the most effective, and were still being discussed in some detail in one agricultural textbook published in the 1890s, but they were expensive. Stone drainage cost £6 per acre in the 1820s, and £8 per acre if the stones had to be carted for any distance. It seems, therefore, that by the end of the eighteenth century effective underdrainage had not been carried out on any great scale. By that time drainage tiles were available, but they, too, were expensive, being hand made and subject to excise duty. Even after the removal of duty they might cost between £2 and £3 per thousand, and two thousand might be required to drain an acre. They were in the shape

[80] Caird, *English Agriculture in 1850–51*, pp. 89, 226, 466; C. S. Read, 'On the farming of South Wales', *JRASE*, 10, 1849, pp. 146, 155; A. D. M. Phillips, *The Underdraining of Farmland in England during the Nineteenth Century* (Cambridge, 1989), chapter 2. Much of this section is based on Dr. Phillips's book. See *infra*, pp. 888–93, for further discussion of this theme.

of a flattened horseshoe. Initially these seem to have been placed in the bottom of the trench, in which case they often sank into the soil and so were rendered useless. They were therefore provided with a separate flat tile or sole-plate to stand upon, but still 'favoured the slow progress of water, and hence were often filled up with silt'. Cylindrical pipes were better, but were still expensive when hand-made. The development of machine-made tiles was therefore a major breakthrough.[81]

Robert Beart of Huntingdonshire produced a machine for making tiles and soles in 1835, and by the 1840s his machines and several others were in use. In 1842 Thomas Scragg of Calveley in Cheshire produced a machine for making drainage pipes, and by 1853 there were forty-five pipe-making machines on the market. Costing between £23 and £50, they could produce one-inch diameter pipes for between 10s. and 15s. per thousand and two-inch pipes at between 20s. and 25s. per thousand. A wide variety of pipes was produced; some were flat-bottomed and horseshoe shaped, others oval, others round, with or without collars or feet. Initially, in the 1840s, pipes of one inch diameter were used on several estates, but since they were more likely to silt up than larger pipes their use was virtually discontinued by the early 1850s, and two inch diameter or larger pipes were most commonly used. Thus the cost of an effective and reasonably permanent drainage system was brought down to about £5 per acre, comparable with the costs of the traditional and much less effective methods. Clearly the cost depended upon the nature of the land being drained: in the 1890s the cost of draining clayey loam, requiring drains at 3 feet depth and 22 feet apart, was put at £5 9s. 5d. per acre, whereas a heavy clay, requiring drains 15 feet apart, might cost as much as £8 0s. 6d. and deep gravelly sand, requiring drains 55 feet apart, might be drained for as little as £2 19s. 9d. Conflicts arose as to depth and spacing. Shallower and wider drainage systems were cheaper to install than deeper drains set closer together, but they were not always appropriate. Daniel Hall summarised the argument most concisely when he wrote about

> . . . the mistaken theories advocated in the early days of tile drainage, when it was not clearly realised that drains ought to be set deep or shallow, according to whether the water rises from below or is only the rain soaking down. On the heavy clays of the Midlands the function of the drains is to get the rain away from the land, so they should not be set more than 30 in. deep.

In the 1850s the result of increasing the depth of drains from 3 feet to 4 feet was to increase the labour cost from £3 3s. 0d to £3 18s. 10d. per acre for drains at 21-foot intervals, and tenants who were responsible for

[81] H. J. Webb, *Advanced Agriculture* (London, 1894), pp. 377–8; G. E. Mingay (ed.), *AHEW*, vol. VI, *1750–1850* (Cambridge, 1989), p. 285; Phillips, *Underdraining*, p. 159.

drainage labour were sometimes tempted to economise. The administrators of drainage schemes financed by public loans were anxious to establish a national standard, and insisted on a minimum depth of 3 feet 6 inches. Privately financed schemes, where the estate paid the full cost of the system, often followed these recommendations, especially between 1850 and the late 1870s. Thereafter, the series of wet years up to the early 1880s suggested to some that the removal of surface water would be carried out more effectively by shallower drains more closely spaced.[82]

Cutting a drain was a skilled job. At the Benington (Lincolnshire) Labourers Society Agricultural Championships in 1860 an underdraining competition was held. The drainer used a long narrow draining spade or gouge, with a blade about 20 inches long, 5 inches wide at the top and 3 at the bottom, to cut a narrow trench. He used a sight pole to keep the trench straight, and water to gauge the correct level. Drawing and pushing scoops would be used to take mud out of the bottom. Then the pipe man, using a tile hook, would lay the tiles in the bottom of the trench, often covering them with thorn branches or wheat straw before backfilling with earth. Thus drainage gangs were often experienced professionals working on piece rates. On the Duke of Northumberland's estate from 1844 drainers worked in gangs, each under a foreman, supervised by the estate drainer, John Loraine. In 1849 the seven draining gangs employed ninety-six men. If a tenant wanted land drained, the work had to be carried out under Loraine's supervision. Estate bailiffs reported on the effectiveness of the work, and when drains failed, the estate was responsible for cleaning, repairs or redraining. In short, drainage was completely under the control of the estate. On the Duke of Bedford's estate in Northamptonshire tenants were responsible for carrying out the work before 1850, but it then became apparent that it was not always being done efficiently, and so the estate took charge and a draining superintendent was appointed. A similar system was used on the Bedford, Fortescue and Duchy of Cornwall estates in Devon. But on the estate of the Earl of Devon, the tenant was required to make a major contribution to the cost of drainage, while on the Buccleuch estates in Northamptonshire an allowance of half of the cost was given to the tenant, or the estate found the materials and the tenant the labour. This system lasted until 1880, when the estate took over the whole cost of drainage.[83]

[82] Phillips *Underdraining* pp. 160, 206–13; M. C. Livesley, *Field Drainage* (London, 1960) p. 5; Hall, *Pilgrimage*, p. 418; John Higgs, *The Land* (London, 1964), plate 173; E. Hart, *Victorian and Edwardian Farming from Old Photographs* (London, 1981), pp. 28–90; Webb, *Advanced Agriculture*, pp. 378, 383.

[83] J. Dear and T. Taylor, *Aspects of Yellowbelly History* (Spalding, 1988), p. 82 (I owe this reference to the kindness of Mr N. E. Whitaker of Boston); Webb, *Advanced Agriculture*, p. 376; Phillips, *Underdraining*, pp. 167–73.

It is therefore clear that the development of the requisite technology was an important factor in bringing about the drainage of land in the second half of the nineteenth century. The other vital need was the necessary capital. At between £4 and £8 per acre, the cost of drainage was comparable to the cost of parliamentary enclosure. The Public Money Draining Act of 1846 made available £2 million which landowners could borrow for drainage projects, the money to be repaid over twenty-two years. In 1849 the Private Money Draining Act was passed, which allowed landowners to borrow from private sources for the same purpose. At about the same time several land improvements companies, such as the General Land Drainage and Improvement Company, the Lands Improvement Company, and the Land Loan and Enfranchisement Company, were brought into being, again by Act of Parliament. Working from a sample of estates in Devon, Northamptonshire and Northumberland, Dr Phillips has estimated that loan-financed draining represented about 20 per cent of the expenditure on drainage, totalling about £27.5 million. Most of the other 80 per cent came from the landlords' own resources, for the contribution of the tenants was mostly made through their payment of interest on the capital sums expended on draining the land they farmed. The larger landowners were among the first to take out loans: half the estates of 10,000 acres or over had contracted loans by 1857, whereas many of the smaller estates (those of 1,000 acres or less) were only beginning to employ loan capital in the late 1870s and 1880s, when prices and rents had passed their peak levels. Larger landowners were also more likely to take out loans than smaller ones, although the extent to which they relied on borrowed money was less. In general, it appears that drainage was far more likely to be carried out on larger estates than on the smaller estates of less than 1,000 acres.[84]

The peak period of draining activity was in the years between 1840 and 1870. Of the £5.5 million loaned for drainage purposes in the period 1847–99, 70 per cent had been taken up by 1870. A similar trend was evident in landlords' expenditure from their own resources: in Dr Phillips's sample of estates, activity was at a maximum between 1840 and 1870 and fell off thereafter. The technical developments in drainage pipe production described above probably explain the expansion of activity at the beginning of this period; moreover, it was a period of generally increasing rents, and when prices and rents began to decline in the 1870s, so did expenditure on drainage in many parts of the country. At the beginning of the twentieth century Mr Cady, who farmed 700 acres near Long Melford in Suffolk, told Rider Haggard '. . . that all the land about there wanted draining. This they did with bushes, as the cost of pipes was

[84] Phillips, *Underdraining*, pp. 16, 50–62, 120, 167–85, 204.

greater than the state of affairs would warrant.' In the following decade Hall was told that 'Landlords were nowadays . . . indisposed to spend money on draining.' On the other hand, Hall's informant, who farmed on heavy clay land in Leicestershire, had successfully mole-drained one of his fields in partnership with his landlord. Rider Haggard, too, reported successful examples of mole draining on clay land in Essex and Hertfordshire. Under pasture land, it was said that mole drains made in 1863 were still working. By the early twentieth century, when he was writing, a mole plough might be pulled on a wire rope between two steam engines, producing drains eighteen inches deep and twelve feet apart at a cost of 15s. per acre in addition to the cost of coal and water.[85]

One of the issues which has produced most controversy in the literature on drainage concerns the amount of land actually drained. Clearly, much land (a million acres, according to a government estimate) was still in need of drainage in the First World War. Contemporary estimates, and those made since, have produced figures varying between a minimum of 2 million and a maximum of 12 million acres. While it is possible to demonstrate that the low estimates are too low and the high ones too high, it is another matter to decide which is nearer the truth. The easier question to answer concerns the amount of land drained with the assistance of loans, since it is known that these amount to very nearly £5.5 million. Although the loan companies' records do not provide acreage figures, Dr Phillips, who has produced the most detailed study of the question, shows that, over a sample of more than 76,000 acres, the sum borrowed was equivalent to a cost of £6 per acre. Thus the total borrowed would have financed the drainage of some 916,000 acres. His work on estate archives in three counties also suggests that loan-financed drainage amounted to about one-fifth of the total, suggesting a total expenditure on drainage in England of some £27.5 million, which at £6 per acre would allow the drainage of 4.583 million acres. These were not evenly spread over the country. Most eastern and south-eastern counties had less than 30 per cent of the area with impeded drainage drained, whereas more than 45 per cent of similar land was drained in the north-eastern counties, the west midlands, Dorset, Somerset and Wiltshire. In Wales, which is not included in these totals, drainage activity does not seem to have been extensive, and a report on the agriculture of Pembrokeshire in 1887 was still calling for further work.[86]

[85] Phillips, *Underdraining*, pp. 125, 130, 134, 158; Rider Haggard, *Rural England*, vol. I, pp. 476, 507, 559, 567; vol. II, p. 396; Hall, *Pilgrimage*, p. 418.

[86] P. Dewey, 'Farm labour in wartime: the relationship between agricultural labour supply and food production in Great Britain during 1914–18, with international comparisons', PhD thesis, University of Reading, 1979, p. 263; Dr Phillips summarises the controversy in his chapter 1. See also Phillips, *Underdraining*, pp. 76–7, 86, 118–20, 246; W. Barrow Wall, 'The agriculture of Pembrokeshire', *JRASE*, 2nd ser., 23, 1887, p. 98.

Until more estate archives have been examined and the typicality of his three counties is tested, Dr Phillips's estimate must rate as the most accurate currently available. Nevertheless, there are grounds on which it might be criticised. The estimate of £6 per acre for drainage cost might be thought high in the light of Thompson's figure of £4 10s. as a 'reasonable average figure incurred by landowners' for drainage and fencing, and Holderness's estimate of £5 for the average cost of effective underdraining. It might also be argued that it neglects the self-financed draining activities of owner-occupiers, although since only 0.2 per cent of landowners with less than 100 acres, and only 4.4 per cent of those with between 100 and 999 acres, used loans, it would seem unlikely that these activities were extensive. On the other hand, it might be argued that Phillips's figure is an overestimate of the land effectively drained, since it does not appear to take account of the need to redrain land on which previous work had failed. Holderness argues that the area in need of redraining was not insignificant, and, although little replacement work was necessary on estates in Northumberland, much more had to be done in Northamptonshire, especially where the original work had been carried out by tenants.[87]

No single measure of the effect of drainage is possible. It might appear that the change in total output of agriculture over the whole country would provide the most complete assessment, but even if such estimates were available (and they are not), several factors, such as new crop varieties, increased use of fertiliser and improved cultivation techniques, could equally affect output, so it is necessary to examine other indicators, not all of which can be quantified. It is clear that drainage increased the amount of land which could be cultivated, and reduced the cost of cultivating it, but by how much is less clear. Attempts to quantify the effect of drainage on yields are confused by the fact that the comparison was usually made between drained and undrained land. Undrained land might differ from the drained in other ways than permeability. Ideally the comparison would be made for the same land over many years, pre- and post-drainage, keeping all other potential sources of influence constant. Not surprisingly, this does not seem ever to have been done. Some data from Northumberland compare drained and undrained land on the same farms, which perhaps comes as near to the ideal as is practically possible, and this indicates yield increases on drained over undrained land of 14 per cent for wheat, 6 per cent for barley, 10 per cent for oats and 9 per cent for turnips. If drainage cost £5 per acre and the tenant paid an

[87] C. H. Feinstein and S. Pollard (eds.), *Studies in Capital Formation in the United Kingdom, 1750–1920* (Oxford, 1988), pp. 24–5, 273; Phillips, *Underdraining* pp. 183, 214–17. Elsewhere, *infra* p. 893, Holderness estimates the area drained in England and Wales, 1841–1900, at 3.4 million acres, costing £29.92 million.

annual interest payment of 5s., the increased wheat yield would have been worth £1, and the attractions of drainage were plain. But these increases were not always achieved: in the East Riding of Yorkshire, for example, conflicts between neighbouring landowners over the installation and maintenance of main drains seem to have reduced the efficiency with which field drains worked. Moreover, where a standard scheme was designed in the estate office without reference to local conditions, it was not always satisfactory: what looked good on paper might not always work so well in practice.[88]

Drainage increased yields. Also, and more importantly, it was hoped that drainage might enable farming systems to be changed and, in particular, that wasteful fallows might be replaced by useful fodder crops. On the lighter land this did indeed happen, but clay land remains heavy even when well drained, and the question of whether or not drainage produced revolutionary change in farming systems has exercised several agricultural historians. Sturgess, for example, claimed that drainage increased the flexibility of clayland farming systems, especially in the north and west of England, and so enabled livestock numbers to be increased in the latter decades of the nineteenth century. In response to this Collins and Jones argued that drainage produced no revolution in techniques, in part at least because it was not always accompanied by increased use of oilcakes and purchased fertilisers. Thus drainage did not have the same impact on heavy land as sheep and turnip husbandry had had on the light lands in the first half of the nineteenth century. Yet fallows were reduced to some extent, and the root and green-crop area and cereal yields increased. If investment in drainage was a mistake, it was a mistake made by many landowners over many years. Consequently, as with many other agricultural innovations, the impact varied from region to region, but overall, to quote Phillips, 'draining must be seen as a major component in increasing agricultural productivity in the middle decades of the nineteenth century'.[89]

[88] Phillips, *Underdraining*, pp. 224–8; M. G. Adams, 'Agricultural change in the East Riding of Yorkshire, 1850–80: an economic and social history', PhD thesis, University of Hull, 1977, p. 111; Livesley, *Field Drainage*, p. 7.

[89] R. W. Sturgess, 'The agricultural revolution on the English clays', *AHR*, 14, 1966, pp. 104–21; R. W. Sturgess, 'The agricultural revolution on the English clays: a rejoinder', *AHR*, 15, 1967, pp. 82–7; E. J. T. Collins and E. L. Jones, 'Sectoral advance in English agriculture, 1850–80', *AHR*, 15 (1967), pp. 65–81; E. H. Whetham, 'Sectoral advance in English agriculture, 1850–80: a summary', *AHR*, 16, 1968, pp. 46–8; Phillips, *Underdraining*, p. 246.

E

CROP VARIETIES

BY PAUL BRASSLEY

The emergence of new crop varieties

Numerous crop varieties were used by late-nineteenth-century farmers, and the popularity of varieties changed as new ones were developed. Thus this section attempts to assess the distribution of the different varieties and to explain how new ones emerged. The impact of the changes is discussed in the following section.

Cereal crops

A pattern is discernible in the development of wheat, barley and oat varieties in this period: some fortunate and accidental discoveries were made in the eighteenth and early nineteenth centuries; in the 1840s, 1850s and 1860s a number of more organised attempts were set up to find superior specimens; and during the very late nineteenth and earlier twentieth centuries, a spate of selections, introductions and hybridisations produced a whole range of new varieties, some of which were very successful, although they did not entirely replace all the older varieties.

Examples of the discoveries of the pre-1850 period which were popular in the middle of the century may be found in all three kinds of cereal crop. Among the wheats were Talavera, raised in Jersey by a Colonel Le Couteur, Hopetoun, produced in 1839 by Patrick Shirreff, who farmed in East Lothian, Chidham, derived from a single ear found growing near the village of that name in Sussex, and Browick, found by a Mr Banham on his farm at Browick in Norfolk, in a field of Scotch Annat wheat. The original ears of Spalding, or Spalding's Prolific, were found by a labourer of that name in the 1830s while threshing at Barningham in Suffolk. He planted them in his garden and within four years had enough to sow ten acres.[90] Chevallier barley was found growing in the garden of John Andrews, a labourer, by his landlord, Dr Charles Chevallier.[91] The Potato oat was grown from a specimen found growing

[90] John Percival, *Wheat in Great Britain* (London, 1943), pp. 74, 84, 110; H. Evershed, 'Improvement of the plants of the farm', *JRASE*, 2nd ser., 20, 1884, p. 77; W. G. R. Paterson (ed.), *Farm Crops*, vol. 1 (London, 1925) pp. 62–3; F. F. Hallett, 'On "pedigree" in wheat as a means of increasing the crop', *JRASE*, 22, 1861, p. 371; J. Le Couteur, 'On pure and improved varieties of wheat lately introduced into England', *JRASE*, 1, 1840, p. 113; J. A. Scott Watson and M. E. Hobbs, *Great Farmers* (London, 1951), p. 81; H. Raynbird, 'On the farming of Suffolk', *JRASE*, 8, 1847, p. 301.

[91] E. S. Beaven, *Barley* (London, 1947), spells Chevalier with only one 'l', but most other writers

in a field of potatoes, Sandy's oat was also named after its discoverer, and an oat variety named Hopetoun, again selected by Shirreff, came this time from a field of Potato oats. The obvious point about all of these varieties is that they were selections from a single particularly fine or productive individual grain, ear or plant, which were multiplied up; they were not produced by deliberate crossbreeding, nor were they introductions from abroad (although Friesland and Poland oats had been introduced in the eighteenth century).[92]

These varieties were among the most popular of those grown in the mid-nineteenth century. Twenty-five of the *Prize Reports* on the agriculture of the English and Welsh counties carried information on varieties, and, of the wheats, Talavera, Browick, Childham, Golden Drop, Hopetoun, Red Lammas and Spalding each appeared in between six and ten counties. Another seventy varieties were named, most of which only appeared in a single county.[93] To a lesser extent the same pattern was

History of British Agriculture, 1846–1914 (2nd edn, Newton Abbot, 1971), p. 6; Beaven, *Barley*, p. 90 gives two versions of the origin of Chevallier. In one, John Andrews, a labourer of Debenham, Suffolk, plucked a few ears of barley as he passed through a field in about 1820. On arriving home he threw them to the fowls in his garden, and in time they grew, matured, and appeared so fine that they attracted the attention of his landlord, Dr Charles Chevallier, who subsequently cultivated and multiplied them. In the second version Andrews originally discovered the barley by finding part of a particularly fine ear in his shoe after a day spent threshing. He planted the few grains from this in his garden, where the resulting crop was seen by Dr Chevallier.

92 Orwin and Whetham, *History of British Agriculture*, p. 6; Patterson (ed.), *Farm Crops*, vol. 1, p. 153; W. M. Findlay, *Oats* (Edinburgh, 1956), p. 22.

93 The other varieties were American Red, April Bearded, Australian White, Blood Red, Bristol Red, Britannia, Brown Kent, Brown's 10-rowed Prolific, Burrell's Red, Burwell Red, Castle Glory, Clovers, Cluster, Cobham, Copdock or Marygold, Cone, Creeping, Dantzic (white), Defiance, Devonshire Red, Duke William, Egyptian Mummy, Essex Rough Chaff, Fluff, Hardcastle, Hoary White, Holderness White Chaff, Hunters White, Improved Lincolnshire White, London Red, Malaga, Morton's Prolific, Nursery, Old Brown Lammas, Old Creeping Red, Old Cornish White, Old Kent Red, Old Red, Old Suffolk, Oxford Prize, Peacock White, Pearl, Rattling Jack, Red Chaff, Red Cluster, Red Cornish, Red Russian, Red Straw, Rivett, Rough Chaff White, Russell, Salmon, Scotch, Seer, Smoothy, Soothy's, Sparling's Prolific, Spencer, Suffolk, Swan, Syers, Taunton, Trump, Tunstall, Uxbridge White, White Kent, White Rough Chaff, White Velvet and Whitington. The Prize Reports were published in the *Journal* of the Royal Agricultural Society of England and are listed in Lord Ernle, *English Farming Past and Present* (6th edn, London, 1961), pp. cii–ciii. Other sources for the list of varieties are: R. C. Gaut, *A History of Worcestershire Agriculture and Rural Evolution* (Worcester, 1939), p. 336; Percival, *Wheat*, pp. 91ff; W. Loft, 'On different varieties of wheat', *JRASE*, 9, 1848, p. 281; F. Woodward, 'On a method of breaking up inferior pasture land', *JRASE*, 9, 1848, p. 54; H. M. Jenkins *et al.*, 'Farm reports', *JRASE*, N.S., 5, 1869, pp. 385–508; H. W. Keary, 'Report on the farm-prize competition, 1870', *JRASE*, N.S., 6, 1870, pp. 251–75; J. Wilson, *Our Farm Crops* (London, 1860) vol. 1, pp. 5–15, which gives a list of varieties without stating the regions in which they were grown. Percival (*Wheat*, p. 89) discussing the period around 1850, found that 'not far short of a hundred different names were being applied to the wheats in cultivation in England, but how far these represented really distinct kinds it is not now possible to determine. From the specimens and descriptions which exist, it is clear that there were many well-defined sorts; some, however, were strains of a single form to which

apparent with oat varieties: Black Tartar, Poland and Potato oats were each listed for at least five counties, but another eleven varieties were each mentioned in between one and three counties.[94] The barley crop, in contrast, was dominated to a much greater extent by one variety: Chevallier. According to Beaven, 'It is fairly certain that before 1886, 80 to 90 per cent of the barley grown in England was the progeny of one plant of this race.' In the *Prize Reports* it is mentioned as important in all thirteen counties for which barley varieties are listed, from Hampshire to Northumberland and from Worcestershire to Norfolk.[95] It was noted for both high yield and good malting quality, and eventually selections were made from it by other breeders and sold as named varieties: Hallett's Chevallier, for example, was still on sale in 1914.[96] Although several other varieties were mentioned in individual counties, none was adopted as widely, or over such a long time, as this.[97]

The Royal Agricultural Society had held variety trials in the early 1840s, especially for wheat, but no major changes in the names of the most popular varieties occurred for another thirty or forty years. Then, from the 1870s, several new varieties of wheat, barley and oats, which would dominate the market by 1914, were produced. Initially, they were produced by the old process of selection followed by multiplication. Thus, among the wheats, Squarehead appears to have been discovered among a field of Victoria wheat in 1868, propagated, and sold by a Mr Scholey of Eastoft Grange, near Goole in Yorkshire, in 1870. Price's Prolific was selected by Mr Price of Pauntley in Gloucestershire in 1886, Ambrose Standup by Mr Cole Ambrose of Studley Hall, Cambridge, in 1892, and the French variety, Japhet, by Vilmorin of Paris in the 1890s (it was introduced into England as Red Marvel in 1904).[98] Goldthorpe barley, which was widely grown in the northern and western counties of England in the latter years of the nineteenth century, was selected by Mr

[94] The other eleven were Angus, Canada, Dutch, Friezeland, Hopetoun, Red, Scotch, Sovereign, Tartarian, White Tartar and Yellow. For sources n.93 above.

[95] Beaven, *Barley*, p. 90; for other sources see n.93.

[96] Country Gentlemen's Association, *C.G.A. Farm Seeds and Manures, 1914* (Letchworth, 1914), p. 6.

[97] Other varieties were Archer, Brewer's Delight, Golden Melon, American, Annat, Golden Drop, Potters, Welsh, Nottingham and Spratt. Stephens referred to the existence of thirty varieties in the museum of the Highland and Agricultural Society, although he did not name them. Henry Stephens, *The Book of the Farm* (2nd edn, London, 1851), vol. 1, p. 445; and see n.93 above.

[98] A. E. Humphries and R. H. Biffen, 'The improvement of English wheat', *Journ. Agric. Science*, 2, 1907, p. 2; Hall, *Pilgrimage*, pp. 317, 363; Country Gentlemen's Association, *C.G.A. Farm Seeds and Manures, 1914*; Percival, *Wheat*, pp. 100–20; R. N. H. Whitehouse, 'Barley breeding at Cambridge', *Report of the Plant Breeding Institute, Cambridge* (Cambridge, 1968), p. 6; F. G. H. Lupton, 'Historical Survey', in Joan Green (ed.), *The Plant Breeding Institute: 75 years 1912–1987* (Cambridge, 1987), p. 7.

Dyson of Goldthorpe in Yorkshire in a field of Chevallier.[99] One of the most influential producers of new barley varieties was E. S. Beaven, who became interested in barley through his connections with the malting trade, and in 1893 began work on the improvement of the crop near Warminster in Wiltshire. Shortly afterwards, he received a collection of '300 ears, all different and botanically named, from Mr Karl Hansen of Lyngby in Denmark'. Between 1902 and 1904 he selected Beaven's Plumage, the progeny of a single plant from Hansen's collection, and Beaven's English Archer, and by 1909 both were in general cultivation.[100] In Scotland, Patrick Shirreff adopted more systematic methods of searching which enabled him to select three new varieties of oats in the 1860s, which he sold as Early Fellow, Fine Fellow and Long Fellow, and Major Hallett, who had his own pedigree selection methods, produced his own variety of Black Tartary Oats.[101]

Increasingly, however, new varieties were being produced by hybridisation. Among the wheats, Squareheads Master was a cross of Squarehead and Golden Drop made in the late nineteenth century, and the Dutch variety, Wilhelmina, was a complex cross of Squarehead and Zealand White made in 1889, and introduced into England in about 1910. The seed firm, Gartons of Warrington, produced several successful hybrids: Victor wheat, a cross of Squarehead, Red King and Talavera; The Standwell barley, a cross of Golden Melon and Fan, which was being grown on experimental plots by 1900; and the Abundance oat, a cross of two Swedish varieties, White Swedish and White August. With the rediscovery and application of Mendel's laws of inheritance a greater degree of predictability was introduced into the activities of plant breeders. Foremost among these was R. H. (later Sir Rowland) Biffen, a lecturer at Cambridge University, who began work on hybridisation in 1901. By 1910 he had released Little Joss, which was resistant to the fungal disease Yellow Rust, and was the result of a cross between Squareheads Master and the rust-resistant Russian spring wheat, Ghirka. He also advised the barley breeder E. S. Beaven, who in 1905 crossed Plumage and Archer to produce Plumage-Archer, which was one of the two varieties which dominated the barley trade between the wars. The other, Spratt Archer, was bred by Herbert Hunter when he was working in Ireland as head of

[99] Whitehouse, 'Barley breeding', pp. 6–29; J. T. Riggs *et al.*, 'Comparison of spring barley varieties grown in England and Wales between 1880 and 1980', *Journ. Agric. Science*, 97, 1981, p. 599; N. T. Gill and K. C. Vear, *Agricultural Botany* (2nd edn, London, 1966), p. 274; Beaven, *Barley*, p. 84; Hunter, *Barley Crop*, p. 55.

[100] Beaven, *Barley*, p. 104; Hunter, *Barley Crop*, pp. 108–9; Whitehouse, 'Barley breeding', p. 6.

[101] Findlay, *Oats*, pp. 26, 32, 39; H. Hunter, *Oats: their varieties and characteristics* (London, 1924) pp. 16–18; Paterson, *Farm Crops*, pp. 150–4; Rider Haggard, *Rural England*, vol. I, pp. 26, 563; vol. II, pp. 80, 112, 149; 332; Hall, *Pilgrimage*, p. 363.

the Plant Breeding Division of the Department of Agriculture and Technical Instruction. He was convinced that Archer, which had good malting qualities, was the highest-yielding variety, but it had weak straw and ripened late. He therefore crossed it with a strong-strawed variety, Spratt, in 1908, and by 1920 Spratt-Archer was being widely grown in England.[102]

Potatoes

As with cereals, the names of potato varieties found in one part of the country were rarely replicated in another in the middle of the nineteenth century.[103] The study of potato varieties in the nineteenth century is complicated by the existence of many synonyms for varieties which were identical to each other. In the 1920s the Potato Synonym Committee found over two hundred synonyms for the popular variety Up-to-Date, and over seventy each for Abundance and British Queen.[104] Breeders and merchants had some incentive to claim special attributes for their varieties because disease susceptibility was the major problem for the potato grower in the second half of the nineteenth century and, in the absence of an effective fungicide (until Bordeaux mixture was introduced in the 1890s), varietal resistance was the only solution to it. Thus varieties such as Irish Cups, the Black Potato, the Apple, the Ox Noble and the Lumper, some of which had been grown since the eighteenth century, did not long survive the blight epidemic of 1846.[105] William Paterson of Dundee attempted to overcome the problem by importing potatoes from America, Australia and the Cape of Good Hope and crossing them with existing British varieties. Over forty years between the 1830s and the 1870s he produced many commercial varieties, the most successful of which was Victoria, introduced in 1863.[106] As with cereals, however,

102 Humphries and Biffen, 'The improvement of English wheat', p. 2; Hall, *Pilgrimage*, pp. 317, 363; Country Gentlemen's Association, *C.G.A. Farm Seeds and Manures, 1914*; Percival, *Wheat*, pp. 100–20; Beaven, *Barley*, p. ix.

103 In the *Prize Reports* the varieties grown in Cheshire were listed as Ash-Leaved Kidneys, Blue Farmers, Bread Fruit, Foxes Seedlings, Irish Cups, New Ink-Eyes, Radicals, Red-Apple, Scotch Inkeyes, Short Wertzle and Short Tops; in Cornwall, Cornish Red and Early Kidney; in Lincolnshire and Oxfordshire, Regent: see *JRASE*, Prize reports; W. G. Burton, *The Potato* (London, 1948) pp. 36–7; R. N. Salaman, *The History and Social Influence of the Potato* (rev. edn, Cambridge, 1985), p. 165.

104 Salaman, *History and Social Influence*, p. 173.

105 Blight is caused by the fungus *Phytophthora infestans*. Wart disease, caused by another fungus, *Synchitrium endobioticum*, was not recognised as a major problem until the early twentieth century. The other major problem of this period, usually known as the 'curl', is a virus disease.

106 There is some uncertainty about whether Paterson introduced new varieties from South and Central America, or merely reintroduced genetic material originally distributed from Europe. In the USA the Rev. Chauncey Goodrich of Utica, New York, selected seedlings from South American varieties, some of which were incorporated into European varieties later in the century. D. R. Glendinning, 'Potato introductions and breeding up to the early 20th century',

most breeders relied upon selection. Varieties such as Magnum Bonum (introduced in 1875), Champion (1876) and Up-to-Date (1891) all seem to have been produced by this process, as were Epicure (1897), an early variety, and Majestic (1911), both of which lasted as commercial varieties well into the twentieth century.[107] They were produced by men who were successful selectors, basing their choice on yield and visual assessment of the quality and shape of tubers. The introduction of King Edwards (properly King Edward VII) exemplified the process. Originally raised by a gardener in Northumberland and named 'Fellside Hero', it passed into the hands of a grower in Yorkshire and a merchant in Manchester before coming into the possession of Mr J. Butler of Scotter in Lincolnshire who multiplied the stock, renamed it King Edward, and put it on the market in 1910 at £12. 10s. per ton. Such men, Salaman wrote, '. . . were not guided by any scientific doctrines as to heredity and immunity. . .'[108] At times they may have been tempted to exaggerate the virtues of their varieties as seed prices rose. In the 1902 and 1905 seasons there was what was later described as a 'boom' in the seed potato trade, mostly brought about by adverse weather conditions which produced a supply shortage. A single tuber of Eldorado (which, Salaman alleged, was simply an old and not especially good variety known as Evergood) sold for £100. Others bought seed for £160 per pound, or even their weight in gold. Hence the large number of synonyms, noted earlier, for the better varieties. Primrose McConnell recalled having to leave a conversation with fellow-farmers before he had '. . . heard all that one of them had to say to prove that the "Radium" is just another variety of the "Up-to-Date"'.[109]

By the time that the King Edward was introduced, changes were already in train which would involve the scientists more deeply in the study of potato varieties. In 1908 the Board of Agriculture, concerned about the problems caused by Wart disease, appointed a technical inspector to investigate it, under the provisions of the Destructive Insects and

New Phytology, 94, 1983, p. 491; Salaman, *History and Social (Influence*, pp. 171–2, 165–7; R. P. Wright (ed.), *The Standard Cyclopedia of Modern Agriculture and Rural Economy*, vol. x (London, 1910) p. 22; T. P. McIntosh, *The Potato* (Edinburgh, 1927), pp. 21–3; A. Findlay, *The Potato: its History and Culture* (Cupar, 1905).

107 Wright, *Standard Cyclopedia*, vol. x, p. 22; Salaman, *History and Social Influence*, p. 168; McIntosh, *Potato*, pp. 23–4; Glendinning, 'Potato introductions', p. 492; Rider Haggard, *Rural England*, vol. I, p. 180; vol. II, p. 195; Salaman, *History and Social Influence*, pp. 167–8. Epicure was still being grown in the writer's garden in 1997.

108 Salaman, *History and Social Influence*, pp. 167–9; McIntosh, *Potato*, p. 26.

109 Wright, *Standard Cyclopedia*, vol. x, p. 22; McIntosh, *Potato*, p. 25; A. Mutch, 'Rural society in Lancashire, 1840–1914', PhD thesis, University of Manchester, 1980, pp. 59–60; Glendinning, 'Potato introductions', pp. 494–5; Salaman, *History and Social Influence*, p. 169; Primrose McConnell, *The Diary of a Working Farmer* (London, 1906), p. 51.

Pests Act 1907. The Inspector, George Gough, found that the disease was widespread in Lancashire, Cheshire and Staffordshire, but some varieties were resistant to it. In order to determine which these were, Wart Testing Stations were set up, the first being at Ormskirk which began work in 1915. In 1919 this work came under the control of the National Institute of Agricultural Botany, which appointed a Potato Synonym Committee.[110] The extent of the confusion in varietal nomenclature soon became apparent.

Other crops

Beans, peas, turnips, swedes and mangolds are all cross-pollinated, so that any one variety is unlikely to breed true over many generations. Thus, although many different varieties are mentioned in this period, it is difficult to be sure about the reality of the apparent differences between them, geographically and over time. Contemporary commentators recognised the problem: as Fream wrote, 'There are several distinct varieties of turnips, and there are almost innumerable selections of these varieties, which are very similar in everything but their names.' Henry Stephens's view in 1851 was quite straightforward: 'There are a great many more varieties of turnips cultivated in the country than seems necessary.'[111] Perhaps the most interesting development, hardly surprising in view of the increasing area of pasture in the latter part of the century, was in grasses. Varieties of grass seed were not specified in the mid-nineteenth-century *Prize Reports*, but by the early twentieth century much more interest was shown in the germination and purity of grass seed mixtures, and four different varieties of perennial ryegrass (Selected Perennial Evergreen, Pacey's, Devon Eaver, and ordinary quality perennial) and three of Italian ryegrass were advertised in the catalogue of the Country Gentlemen's Association for 1914.[112]

[110] In 1920 Salaman, who had been working on potato genetics since 1906, became chairman of the committee. Salaman, *History and Social Influence*, pp. xxx, 173–5.

[111] John Wrightson, 'Turnip crop', in C. E. Green and D. Young (eds.), *Encyclopedia of Agriculture*, vol. III (Edinburgh and London, 1908), p. 558; W. Fream, *Elements of Agriculture* (3rd edn, London, 1892), p. 253; Stephens, *Book of the Farm*, vol. I, p. 197; vol. II, p. 90; R. P. Wright (ed.), *Standard Cyclopaedia*, vol. XII (1911), p. 25; Raine Morgan, *The root crop in English agriculture, 1650–1870*, PhD thesis, Reading University, 1978, pp. 31–2; J. C. Morton, *A Cyclopedia of Agriculture* (1856), vol. II, p. 308; *JRASE*, Prize Reports, *passim.*; E. P. Foquett Sutton, 'Farm roots and their development', *J. Bath and West*, 6th ser., 13, 1937–9, pp. 87–93; Professor [J]. Wrightson, 'Mangel wurzel', in C. E. Green and D. Young (ed.), *Encyclopedia of Agriculture*, vol. III (1908), p. 87; R. P. Wright (ed.), *Standard Cyclopedia*, vol. VIII (1910), p. 164; Country Gentlemen's Association, *Farm Seeds*. By 1870 Gibbs Selected Golden Globe was being grown on Mr Treadwell's farm at Upper Wichenden near Aylesbury in Buckinghamshire, so presumably merchants' names were being given to varieties by that date. Keary, 'Report on the Farm Prize Competition, 1870', p. 259.

[112] Country Gentlemen's Association, *C.G.A. Farm Seeds and Manures 1914*.

The significance of varietal change

Whether the new varieties were better than the old was not a question which could be answered with any certainty at the time; nor can it be answered with any more certainty now.[113] James Caird, writing in the 1890s, thought that progress had been made: 'By careful selection, and more recently by hybridisation, improved varieties of wheat, barley and oats have been introduced with much success, and the same with potatoes, mangel and other vegetable crops'. Conversely, Professor Malden, in 1908, asserted that 'All farm crops have been subjected to improvement, especially during the past half century', although he went on to say that cereal seeds had not been improved as much as some other crops, and that perhaps the greatest improvement had been in the root crops. The reason for this, he thought, was that seedsmen had depended upon selection, while comparatively little had been done about crossbreeding. Moreover, of the crosses that had been made, comparatively few had been successful, and some were more apparent than real:

> We have personal knowledge of a variety of oat appearing in the seed list of a prominent firm which it is stated was the result of their own cross-breeding, and which we have unassailable evidence that it was imported from New Zealand, and moreover we grew it for some years before this firm knew of it. It is a good oat, but it is an old variety. In view of this and other facts, we place but little faith in statements respecting cross-breeding until within recent years.

[113] Apart from its intrinsic qualities ('the original and indestructible powers of the soil' as Ricardo termed them in the days before widespread soil erosion), the output of the land will be affected by the amount of labour applied to it, the machinery and horsepower used by that labour, the level of fertiliser, the type of seed used, climate and weather, and so on. In a list of this length it may not be easy to isolate the effects of varietal changes. Modern workers have made the attempt for recent varietal change, and concluded that about half of the increased output was a result of advances in plant breeding. However, there is no report in the literature of similar experiments being carried out to compare varieties which were current in 1850 with those which were in use at the outbreak of the First World War. See D. Ricardo, *The Principles of Political Economy and Taxation* (London, 1969 edn), p. 33; V. Silvey, 'The contribution of new varieties to increasing cereal yield in England and Wales', *Journ. of the National Institute of Agricultural Botany*, 14, 1978, pp. 367–84. Silvey's method has been criticised in D. Godden, 'Comparison of two techniques for estimating the effects of new cereal varieties on crop yields', *Plant Varieties and Seeds*, vol. 1 (1988), pp. 37–52; see also S. K. Sinha *et al.*, 'A comparison of physiological and yield characters in old and new wheat varieties', *Journ. Agric. Sci.*, 97, 1981, 1, pp. 233–6; and R. B. Austin *et al.*, 'Genetic improvements in winter wheat yields since 1900 and associated physiological changes', *Journ. Agric Sci.*, 94, 1980, pp. 675–89, which makes the point that grain yields have increased, not because total dry matter production has increased, but because more of the dry matter is in the grain and less is in the straw. Thus, given the same fertiliser treatments, Little Joss (1908) gave 5.22 tonnes per hectare of grain with straw length 142 cm to base of ear, while Hobbit (1977) gave 7.30 tonnes per hectare with straw length 80 cm. There is a similar discussion in relation to potatoes in P. M. Harris, 'Agronomic research and potato production practice', in R. G. Hurd *et al.* (eds.), *Opportunities for Increasing Crop Yield* (London, 1990), pp. 205–17.

Malden excepted the workers at Cambridge University and Gartons of Warrington from his strictures. While admitting that 'it is only fair to give credit to selectors for having exercised great skill and care', he felt that '. . . until the last few years farmers have benefited comparatively little from the result of cross-breeding among cereals'.[114]

Even if the new varieties were an improvement on the old, they still had to be adopted if they were to have any impact on national output. But farmers do not seem to have been especially interested in varieties. One source of evidence is the *Prize Reports*, appearing in the *Journal of the Royal Agricultural Society of England* around the middle of the nineteenth century. Seventeen of forty-two such reports contained nothing on varieties and in those that did the coverage was variable, creating the impression that the details given reflected little more than the interests of the reporter. This is reinforced by an examination of contemporary diaries: farmers usually referred simply to wheat or barley, etc., and not the variety. Caird, in his survey of 1850–1, does not mention varieties. Even merchants, buying and selling seed corn and other seeds, were not always specific about varieties. In the ledgers of Edward Bell, corn merchant and seedsman of Chesterton in Cambridgeshire, for the years 1914 and 1915, the clerk sometimes distinguished between pea and bean varieties, but, with only two isolated exceptions, cereals were always referred to as wheat, barley or oats, without any variety being specified. Only about a dozen varietal names are recorded in 125 pages of the journals of Edward Bell covering the period between October 1911 and September 1914.[115]

These impressions suggest that farmers may not have gone to great lengths to specify the varieties they used, or may not have perceived great differences between varieties. This leads on to the question of the extent to which new varieties were adopted. New varieties were certainly available from seed merchants such as the Country Gentlemen's Association or Bells of Chesterton, but Daniel Hall and his companions found old varieties still being grown in their travels round the country just prior to the First World War.[116] The great seed potato boom in the early years of

[114] James Caird, 'Fifty years of progress of British agriculture', *JRASE*, 3rd ser., I, part I, 1897, p. 32; Professor Malden, 'Seeds', in C. E. Green and D. Young (eds.), *Encyclopaedia of Agriculture* (1908), vol. III, p. 422–3.

[115] The Prize Essays are listed in Lord Ernle, *English Farming Past and Present* (6th edn, 1961, G. E. Fussell and O. R. McGregor, eds.), pp. cii–ciii; E. E. Swan (ed.), *The Diary of a Farm Apprentice: William Carter Swan, 1909–1910* (Gloucester, 1984); C. Miller (ed.), *Rain and Ruin: the Diary of an Oxfordshire Farmer, John Simpson Calvertt, 1875–1900* (Gloucester, 1983); Cambridgeshire R O, Farm Diary of Martin Pate of Ely, 1907–9 (283/) and Ledger (R73/63) and Journals (R81/132) of Edward Bell of Chesterton.

[116] The Country Gentlemen's Association, Limited, *C.G.A. Farm Seeds and Manures 1914*; Hall, *Pilgrimage, passim.*

the twentieth century perhaps suggests a growing interest in varietal innovation, but it may rather illustrate the opportunities open to the unscrupulous to make a quick profit in the absence of any facilities for the objective testing of new varieties. A study of the grass seed trade in the Aberystwyth College area in 1914 revealed a large amount of poor seed on the market, bought by farmers attempting to cut costs: '. . . quite half the grassland of the district under discussion is sown with seed purchased locally, much of this being of inferior quality'. The writer, Mr (later Professor) George Stapledon, concluded that it was not possible to put down a six-year ley 'at something under a sovereign an acre', but that many farmers were attempting to do so.[117]

This calculation of Stapledon's suggests a method of assessing the use of seedsmen's varieties for the whole country. It was calculated in 1915 that 'The amount spent on the principal farm seeds in this country (cereals, pulses, roots, rape, vetches, lucerne, sainfoin, clovers and grasses) reaches millions of pounds sterling annually, the value of the seeds named sown in Great Britain in 1914 being estimated at nearly £7,000,000.'[118] If this estimate is reliable, it may be compared with the total cost of sowing the acreage under these crops at seedsmen's prices (i.e. the recommended seed rate, multiplied by the cost of the seed from a merchant, multiplied by the total crop acreage in Great Britain). This is shown in Table 7.1.

Estimates of average seed costs on Midland farms in 1911 were roughly half the figure calculated here. The figures for 1917–18 are slightly greater than those for 1914, but cereal prices had about doubled between 1914 and 1917. Clearly the total figure in Table 7.1 is something of an overestimate, because not all fields in temporary grass would be just one-year leys. Nevertheless, farmers appear to have been spending significantly less than if they had bought all their seeds from the merchants, and therefore the suspicion must arise that they used home-saved seed to a significant extent. There are several reasons why they may have done so: firstly, since most farmers operated a mixed farming system, the gains from a varietal improvement in one of their crops might not make a great difference to their total output or profitability;[119] secondly, it was probably cheaper to use home-saved seed, so farmers looking for ways of reducing costs in the face of falling prices might have taken this option, especially if they believed that the seedsman's product might not be greatly superior to their own; and thirdly, no reliable system was available for testing new varieties.

117 Anon., 'The condition of the seed trade in mid-Wales', *Journ. Board of Agriculture*, August 1914, pp. 427, 430.

118 Board of Agriculture and Fisheries Leaflet No. 297, *Seed Testing* (April 1915, revised October 1916) in Board of Agriculture and Fisheries, *Leaflets* Nos. 201–300, 4th edn (London, 1917).

119 I am grateful to Miss Edith Whetham for this suggestion.

Table 7.1. *Costs of seed at merchants' prices, c. 1914*

	Total acreage (000)	Cost (£ per acre)	Total cost (£m)
Wheat	1,869	0.9	1.682
Barley	1,699	0.75	1.274
Oats	2.849	0.9	2.564
Pulses	529	1.3	0.688
Potatoes	613	3.0	1.839
Roots/greens	2,401	0.2	0.480
Temporary grass	3,864	0.75	2.898
TOTAL			11.425

Sources: Acreage: C. S. Orwin and E. H. Whetham, *History of British Agriculture 1846–1914* (2nd edn, 1971) pp. 350–1; costs per acre: Country Gentlemen's Association, *C.G.A. Farm Seeds and Manures 1914*; Ledger of Edward Bell of Chesterton, Cambridge C.R.O. R73/63; R. P. Wright (ed.), *The Standard Cyclopedia of Modern Agriculture and Rural Economy* vol. VIII (1910), p. 164; Anon., 'The condition of the seed trade in mid Wales', *Journal of the Board of Agriculture*, August 1914, p. 426; W. Fream, *Elements of Agriculture* 3rd edn, (London, 1892), p. 257; J. R. Ainsworth-Davis, *Elements of Agriculture* (10th edn, London, 1921), pp. 358–9; C. S. Orwin, *Farming Costs* (Oxford, 1921), pp. 80–4.

Some discussion took place about the problems of buying grass seed, for example, in the publications of the Board of Agriculture and Fisheries just before the First World War. In particular, the problems of germination and weed seed contamination were emphasised, and the better ordering of such things in other countries alluded to: 'It is upwards of forty years since seed testing was established in Denmark and Saxony . . .'[120]

With crop varieties, as with other technical inputs, there appears to have been a gap between the innovators and the early adopters, and the majority of farmers who were slow on the uptake, partly for lack of encouragement, and partly for what appeared to them as sound commercial reasons. Whether this applied only to varietal changes, or was a general feature of English and Welsh agriculture in this period, will be examined further in the following pages.

[120] Board of Agriculture and Fisheries Leaflet No. 297, *Seed Testing*. See also *Report of the Departmental Committee appointed by the Board of Agriculture to Inquire into the Conditions under which Agricultural Seeds are at present sold*, Cd.489, 1901 (BPP 1901, vol. IX, p. 1); W. M. Findlay, 'Seed testing', *Journ. Board of Agric.*, July 1913, p. 301; S. F. Armstrong, 'Seed analyses', *Journ. Board of Agric.*, Jan 1913, p. 827; W. Borlase, 'The study of agricultural seeds', *Journ. Board of Agric.*, Oct. 1912, p. 529.

F

PLANT NUTRITION

BY PAUL BRASSLEY

Farmyard manure

J. A. Clarke, writing on 'Practical agriculture' in 1878, declaimed that '... farmyard dung ... remains yet the English farmers' "sheet-anchor" ...' The textbook writers agreed with him. 'The system of manuring by stock is the backbone of farming', said Fream. 'Of all the manures that the farmer applies to his land', wrote Webb in his *Advanced Agriculture*, farmyard manure '... is the one on which he places most reliance, and which occupies his attention to the greatest extent'. Throughout the whole of this period it was commonly carted from the yard to the field, piled into small heaps and then spread over the land by hand-forking, or, for potatoes, by laying it in the drill. Although numerous attempts were made to mechanise the process, none was completely successful or widely used.[121]

The reports and surveys of agriculture, from the middle of the nineteenth century onwards, contain many examples of the extensive use of farmyard manure, often produced with the aid of great expenditure on oil-cake. In 1878 Mrs Millington, farming 890 acres at Ardley in Oxfordshire, applied four hundredweights of superphosphate per acre of swedes and spent £1200 a year on cake, and Mr Charles Howard of Biddenham, Bedfordshire, spent about £100 on artificial manure compared with £1,720 on cake. In Devon, in the middle of the century, the traditional practice involved a dressing of 6–8 hogsheads of lime and 10–12 cartloads of manure per acre applied to turnip land, followed by wheat, then barley, then oats, and then seeds for up to six years. H. Rider Haggard, on his own farm at Ditchingham in Norfolk in 1898, had 250 loads of farmyard manure carted directly from the yards to the fields on which they were to be spread between harvest and 4 October. He was also an advocate of 'that noble mixture, Bungay compost', refuse from the middens and open drains in the town of Bungay (Suffolk), which cost 2s. per load, and as much again to cart, and was mixed with old tins and broken glass: 'for a root crop I would rather use it than any expensive

[121] J. A. Clarke, 'Practical agriculture' in H. M. Jenkins (ed.), 'Memorial of the agriculture of England and Wales, prepared ... for the International Agricultural Congress, Paris, 1878', reprinted in *JRASE*, 2nd ser., 14, 1878; Fream, *Elements of Agriculture* (3rd edn), p. 62; Webb, *Advanced Agriculture* p. 349; J. A. Voelcker, 'Farmyard manure', in R. P. Wright (ed.), *The Standard Cyclopedia of Modern Agriculture and Rural Economy*, vol. v (1914), p. 168.

artificial dressing on the market'. In his survey of *Rural England* in 1901–2, Haggard reported the extensive use of farmyard manure, sometimes in large quantities, as did Daniel Hall in his *Pilgrimage* round the British Isles a decade later. He found that farmyard manure was the chief source of soil nutrients on the Yorkshire Wolds, while market gardeners in Bedfordshire continued to rely on town manure from London, on the grounds that artificials alone would not suffice. They complained that the price had risen from 1s. 0d in 1905 to 4s. 6d per ton in 1912 because supplies were running short 'as motors displace horses with the omnibus and carrying companies'.[122]

These surveys suggest that the textbook writers took a correct view of the importance of farmyard manure and animal dung. Liberal feeding with concentrated feeds, either bought-in oil-cakes or home-produced cereals, was the basis of 'high farming'. Pusey, one of its greatest advocates, called it alternatively 'high feeding'. Sometimes, as in the eastern counties, it mainly involved the winter feeding of cattle; sometimes the supplementary feeding of oil-cake to sheep on turnips. Sometimes it paid in the extra output of livestock produce, sometimes in the extra output of dung producing extra corn. It was not totally dependent on dung, for artificial manures were involved as well (see *infra*). But it was, originally, a light-land mixed farming system, developed in eastern England and on the southern chalk and limestone hills, and centred on roots.[123]

According to R. W. Sturgess the problem in the early nineteenth century, especially on the poorer clays, was that all the farmyard manure went on to the wheat, that little manure was available for purchase, and that poor grassland could only support a few livestock, which had to be wintered on hay and straw alone. The clays did not benefit from turnips

[122] G. E. Mingay (ed.), *AHEW*, vol. VI (1989), pp. 80, 198; Mutch, 'Rural society in Lancashire', pp. 39–40, 61, 98; G. E. Fussell, 'Home Counties farming', *Econ. Journ.*, 57, 1947, pp. 324, 326, 334; D. W. Howell, *Land and People in Nineteenth-Century Wales* (London, 1977), p. 128; G. E. Fussell, '"High farming" in the West Midland counties 1840–1880', *Economic Geography*, 25, no. 3, 1949, p. 178; Clarke, 'Practical agriculture', pp. 621–2; G. E. Fussell, '"High farming" in south-western England, 1840–1880', *Economic Geography*, 24, 1948, p. 68; J. Thirsk and J. Imray, (eds.), *Suffolk Farming in the Nineteenth Century* (Suffolk Red. Soc. 1, 1958), p. 30; Leonce de Lavergne, *The Rural Economy of England, Scotland and Ireland* (Edinburgh and London, 1855), pp. 54–5; H. Rider Haggard, *A Farmer's Year* (1st edn 1899, reprinted 1987), pp. 262, 364, 383, 47; Rider Haggard, *Rural England*, vol. I, pp. 27, 181, 242, 392, 486, 528, 539, 542, 545; vol. II, pp. 132, 167, 233, 194; Hall, *Pilgrimage*, pp. 4, 5, 31, 36, 63, 70, 120, 126–7, 358, 127, 316, 353–8, 427–8; Howell, *Land and People*, p. 128; A. W. Jones, 'Agriculture and the rural community of Glamorgan *c.* 1830–1896', PhD thesis, University of Wales, 1980, pp. 58–72; D. Jenkins, *The Agricultural Community in South West Wales at the Turn of the Twentieth Century* (Cardiff, 1971), p. 41.

[123] E. L. Jones, 'The changing basis of agricultural prosperity, 1853–73', reprinted in W. E. Minchinton (ed.), *Essays in Agrarian History*, vol. II (Newton Abbot, 1966), pp. 221–2; B. A. Holderness, 'The origins of high farming', in Holderness and Turner (eds.), *Land, Labour and Agriculture*, pp. 149–51.

as the light lands did in the eighteenth century. It was drainage (which made it possible to grow more fodder crops), oil-cake, and artificials in the 1850s and 1860s which increased their productivity. Stocking rates were estimated to have increased, for example, from 20 to 33 dairy cows per 100 cultivated acres in Somerset in the decade of the 1850s, and most of the expansion came in extra dairy produce, pigs and beef. As the railway network expanded it became easier to carry the new inputs all over the country. This view provoked some dissent, especially about the extent to which these improvements occurred on the clay lands in the south and east of the country, but there seems little doubt that increases in output were achieved in the north and west.[124]

It should follow, therefore, that the story of farmyard manure in the second half of the nineteenth century was one of increasing usage, ready availability and unalloyed benefit. But was it? There were several problems. 'It is an unfortunate fact that dung cannot be produced in sufficient quantities to satisfy the wants of all the crops', wrote Webb in his textbook. 'The quantity of farmyard manure used per acre varies greatly in different parts of the country, and is regulated more by what is available than by anything else', affirmed Voelcker at the beginning of the twentieth century. In the mid-nineteenth century it was said that more wheat was being grown in Sussex than there was manure for, and the *Prize Report* on Cumberland bemoaned the fact that so much farmyard manure was required for the turnips that there was little left for anything else. At the end of the century Rider Haggard's Diary records the use of long (as opposed to well-rotted) manure 'which, having no other available, we were obliged to use . . .', and the manuring of a ploughed-up ley with 'road and yard scrapings, and anything else we could find to put on it', and explains that one of the reasons for using town compost was that '. . . it spares the farmyard, upon which the calls are heavy and continuous'.[125]

The agricultural literature of the later nineteenth century is full of complaints that insufficient care was taken of farmyard manure. By 1856 Voelcker had demonstrated that the nutrients in manure made under cover were protected from being washed out by rainwater, but an advocate of the greater use of farmyard manure writing in 1893 was still complaining of 'the running to waste of their rich brown juices' from many

124. Sturgess, 'The agricultural revolution on the English clays', p. 110; Jones, 'Changing basis', p. 229; Collins and Jones, 'Sectoral advance', pp. 65–81; Sturgess, 'The agricultural revolution on the English clays: a rejoinder', pp. 82–7; Whetham, 'Sectoral advance in English agriculture, 1850–80: a summary,' pp. 46–9.

125. Webb, *Advanced Agriculture*, p. 355; Voelcker, 'Farmyard manure', p. 168; G. E. Fussell, 'Four centuries of farming systems in Sussex', *Sussex Archaeological Collections*, 90, 1952, p. 97; T. Farrall, 'Report on the agriculture of Cumberland', *JRASE*, 2nd ser., 10, 1874; Rider Haggard, *A Farmer's Year*, pp. 100, 98, 47.

manure heaps. In 1878 the blame for 'much imperfect and wasteful management' of farmyard manure was laid on landlords who failed to provide their tenants with proper buildings, 'planned with a view to the economical manufacture and preservation of manure'. The most common form of housing for beef cattle was the open yard, sometimes with open-fronted shelters at the sides. It was cheap, there was no lack of ventilation to cause health problems, and although it might use a lot of straw (48 lb per animal per day was recommended by Webb), this was plentiful in arable areas. If the yard was roofed the nutrients in the manure were not leached out by the rain, and the cattle put more of their energy intake into growth and less into keeping warm, although obviously roofing costs had to be set against these advantages. By the middle of the century some impressive examples were to be seen of covered yards on a large scale, as at Eastwood Manor Farm in Somerset, which was built in 1850, and from the 1860s they became more common, either new constructions, or with a roof erected over existing open yards. More complex and expensive forms of housing were also possible, such as stalls and boxes, which were claimed to have advantages in producing better manure with less waste. Fattening boxes were also used for pigs, and at Coleshill Farm in Oxfordshire a sheep fattening house with a sparred or slatted floor allowed all the dung and urine to drop through into the space below. This kind of system was taken to its ultimate extent at Mechi's farm at Tiptree in Essex, where all the waste from the livestock was collected in a large tank, liquified by the addition of water, and steam-pumped round to all the fields of the farm through a system of iron pipes and rubber hoses. At about the same time, in the middle of the nineteenth century, the Rev. Anthony Huxtable in Dorset was using a very similar system.[126]

These were the exceptions, however. Schemes like those of Mechi and Huxtable, while they undoubtedly conserved nutrients, did so at a high cost. The same was said of covered yards. Bernard Dyer, writing in 1893 urged that '... the small farmer, who has them not, should be taught how he can best take care of his manure in their absence'. It may be argued that landlords were being rational when they decided against investing a lot of money in helping their tenants to conserve as manure the nutrients they had bought in the form of oil-cake. This was the argument put forward by Lawes when he pointed out that '... the consumption of £400 worth, or about forty tons of cake, would only add about ten tons of dry

[126] A. Voelcker, 'On the composition of farmyard manure', *JRASE*, 17, 1856, pp. 213–59; B. Dyer, 'The conservation of farmyard manure', *JRASE*, 3rd ser., 4, 1893, pp. 828–9; Clarke, 'Practical agriculture', p. 626; Brigden, *Victorian Farms*, pp. 63–7, 191–3; Webb, *Advanced Agriculture*, p. 354; Harvey, *A History of Farm Buildings in England and Wales*, p. 132; G. E. Fussell, 'Four centuries of farming systems in Dorset', *Proc. Dorset Nat. Hist. and Arch. Soc.*, 73, 1951, pp. 136–7; Leonce de Lavergne, *Rural Economy*, p. 190.

substance to the manure heap, whilst the weight of Peruvian Guano obtained for the same money would be about thirty tons'. On the other hand, Voelcker, a few years later, calculated the manurial value of one ton of decorticated cottonseed cake as £6 10s 0d.[127]

There were, therefore, several reasons why farmers did not extract as many plant nutrients as they might have done out of farmyard manure. Conversely, they were given an extra incentive to exploit bought-in feedingstuffs for their manurial value by the changes in tenant-right legislation during this period, especially the Agricultural Holdings Act of 1883, which made tenant-right effective over the country as a whole, and provided for compensation for unexpired values of investments in liming and bought-in feedingstuffs and manures. By 1914 Voelcker and Hall had worked out composition, manurial and compensation values of feedingstuffs and fertilisers which were approved by the Central Chamber of Agriculture and the Central Association of Agricultural and Tenant Right Valuers.[128]

Nevertheless, the major question remains: did farmers in England and Wales produce enough farmyard manure, and did production increase or decrease between 1850 and 1914? Various contemporary estimates were made of farmyard manure production, which, when compared, suggest that its use declined over the period.[129] However, these figures were based either on the measurement of national straw output, assuming that one ton of straw would make four of manure, or on the acreage under tillage, multiplied by a typical dressing. Consequently, if the cereal acreage decreased, as it did in the last quarter of the nineteenth century, either of these methods inevitably led to the conclusion that manure output was declining. But the tonnage of manure is less important than its nutrient content, as the straw itself contributes very few nutrients. What really

[127] Dyer, 'The conservation of farmyard manure', p. 830; J. B. Lawes, 'Farmyard manure', *JRASE*, 23, 1862, p. 47; A. Voelcker, 'The influence of chemical discoveries on the progress of English agriculture', *JRASE*, 2nd ser., 14, 1878, p. 841.

[128] J. V. Beckett in G. E. Mingay (ed.), *AHEW*, vol. VI, p. 617; D. B. Grigg, *The Agricultural Revolution in South Lincolnshire* (Cambridge, 1966), pp. 134–6; Adams, 'Agricultural change in the East Riding of Yorkshire', pp. 312–21; Primrose McConnell, *The Agricultural Notebook* (9th edn, London, 1919), pp. 177–83.

[129] In the 1850s Thomas Anderson, Professor of Chemistry in the University of Glasgow and Chemist to the Highland and Agricultural Society, calculated that one in four of the 24 million acres of land under tillage in the British Isles would be given ten tons of farmyard manure each year, which would amount to a total of 60 million tons. Lawes, in 1862, argued that the annual dressing should be 8.5 tons, which would give a total of 51 million tons. In 1893 Dyer estimated a national output of 40 million tons, and in 1916 Russell and Richards put it at 37 million tons. See T. Anderson, 'Instructions to farmers on the reading of analyses and the valuation of manures', *Trans. Highland and Agric. Soc.*, new series, 18, 1859–60, p. 433; Lawes, 'Farmyard manure', p. 46; Dyer, 'The conservation of farmyard manure'; E. J. Russell and E. H. Richards, 'On Making and storing farmyard manure', *JRASE*, 77, 1916, pp. 1–36.

Table 7.2. *Total nutrients in farmyard manure in England and Wales, 1854–1914*

Averages of the years	Tonnes of nitrogen	Tonnes of phosphates	Tonnes of potash
1854	151,108.85	73,436.67	314,604.79
1866–9	192,560.23	93,011.01	416,361.53
1870–9	207,808.49	99,284.89	445,343.13
1880–9	215,376.00	101,109.88	453,016.69
1890–9	229,662.42	107,727.14	482,563.95
1900–9	237,204.76	110,726.50	493,840.66
1910–14	245,014.00	114,506.83	497,182.05

Sources: The daily dung output of cattle, sheep, pigs, horses and hens (From R. J. Halley (ed.), *The Agricultural Notebook* (17th edn, 1982), pp. 87, 571) is multiplied by the nutrient content of each type of dung (From Halley, *ibid.*, p. 88 and Primrose McConnell, *The Agricultural Notebook* (9th edn, 1919), p. 135) to give an annual nutrient output for each animal, which is then multiplied by the number of animals of each species (from Ministry of Agriculture, Fisheries and Food, *A Century of Agricultural Statistics* (1966), Tables 63–70; the figures for 1854 are from the sample census of that year, in G. E. Mingay (ed.), *AHEW*, vol. VI, *1750–1850* (1989), pp. 1038–44) to give an annual total output of nitrogen, phosphate and potash. The decade averages are then calculated from these figures.

matters is the total output of crop nutrients, which was determined by purchases of feedstuffs, (which increased more or less steadily),[130] and livestock numbers.

Cattle numbers in England and Wales rose from four million or fewer before the middle of the 1860s to more than 5.5 million annually after 1904. Sheep numbers rose and fell over this period, as did pigs. Numbers of horses and poultry increased.[131] Rather than adding livestock numbers together it would seem sensible to recognise that different types of livestock produce different quantities of dung with different nutrient content. Thus the total output of nutrients, in the form of tons of nitrates, phosphates and potash, can be calculated. The results of this calculation, in decade averages, are set out in Table 7.2.

130 RC on Agriculture, *Particulars of Expenditures and Outgoings on certain Estates in Great Britain and Farm Accounts*, Reprinted from the Reports of the Assistant Commissioners, C.8125 (1896) pp. 74–80, 81–6, 186–95, BPP, 1896, XVI, p. 469; Thompson, 'The second agricultural revolution', p. 74; Voelcker, 'The influence of chemical discoveries on the progress of English agriculture', p. 836.

131 Ministry of Agriculture, Fisheries and Food, *A Century of Agricultural Statistics* (1966), tables 63–70.

From Table 7.2 it appears that the total quantity of available nutrients may have risen slightly. Converting these figures to a tonnage of farmyard manure gives figures of 42 million tons in the 1860s, which would allow 1.75 tons per acre on 24 million acres of crops and grass, and 50 million tons in 1914, giving 1.85 tons of farmyard manure per acre on 27 million acres of crops and grass.[132] These figures bear out Professor Wrightson's assertion, reported by Webb in the 1890s, that insufficient manure was produced. If thorough manuring meant sixteen tons of farmyard manure on each acre every four years (or, in effect, four tons per acre per year), then '. . . Professor Wrightson says there is scarcely more dung produced than would thoroughly manure one-half the total fallow breadth . . .' If Wrightson was correct, his impressionistic estimate of total manure output suggests that the results of the tortuous calculations set out above are at least of the right order of magnitude.[133]

Artificial manures

By the end of the nineteenth century farmers, it was said, were '. . . less dependent than of old time on home made manure . . .' and now bought '. . . large quantities of artificial manure supplying both nitrogen and phosphates', the price of which was decreasing. The range of artificial manures – those not made on the farm – was enormous. Perhaps the oldest-established was lime. The use of lime, which is not strictly a manure or fertiliser at all, but a soil conditioner, was well established in many districts by the middle of the eighteenth century, and almost everywhere by the middle of the nineteenth century. There is some evidence that its use declined in the second half of the nineteenth century. In Northumberland, just before the First World War, Daniel Hall found that liming 'has been far too much neglected for the last half-century, to the detriment of the fertility and health of the land'. The same thing happened in Devon, partly as a result of low prices at the end of the century, and partly because farmers thought that the new chemical fertilisers did the same job as lime (whereas in fact some of them, especially ammonium sulphate, increased soil acidity and therefore the need for lime). Clarke's treatise on 'Practical agriculture', published in 1878, reported that 'Liming . . . has given way before the introduction of artificial manures.' On the other hand he found that 'Of late years, the practice has extended of applying moderate dressings of lime to old pastures, the increase and improvement in herbage being very marked.' The other

[132] Lawes, 'Farmyard manure', p. 46; Anderson, 'Instructions', p. 433; Russell and Richards, 'Farmyard manure'; T. Farrall, 'Report on the agriculture of Cumberland', p. 420.

[133] Webb, *Advanced Agriculture*, p. 355.

interesting change, which seems to date from the 1890s, was the increasing use of pulverised limestone, as opposed to burnt lime, as the necessary machinery became available.[134]

Sewage, although hardly an artificial manure, was an exogenous source of nutrients. The expansion of Victorian towns and the invention of the water closet increased the volume of waste requiring disposal; Alderman Mechi demonstrated methods of spreading sewage over his Tiptree farm by means of steam pumps and hoses, in the 1840s and 1850s; the Metropolis Sewage and Essex Reclamation Company was founded in the 1860s with the aim of using London sewage to reclaim the Maplin Sands off the Essex coast. But the process was expensive, the nutrient content was low, and large areas of land were required. The debate on the sewage question occupied the pages of the agricultural press from the 1850s to the 1870s, and merited a Pariamentary Committee in 1862, but many of the sewage farms had been converted to treatment works by the end of the century, when it was judged that 'sewage farming . . . has not been a commercial success'.[135]

An enormous variety of manures, in the strict sense of the word, could be brought onto the farm. Discussing 'animal manures', Donaldson produced a list which included night soil, pigeon's dung, guano, blood, sea water, stagnant water, gas water (the liquid in which gas had been cleaned, useful for its ammonia content), gas lime, fish, blubber, whale oil, greaves ('the residuum of candle making' mixed with soil to make a compost), furrier's clippings, feathers, wool, linen rags, shoddy and fellmonger's poake (sheep's feet, scrapings of pelts, lime and hair), and to this list could be added soot, bones, salt, saltpetre, hoofs and horns, and rape dust. Perhaps the most useful distinction is between the slow-acting, organic manures, in which would be included farmyard manure, sewage, and most of the manures listed above, and the faster-acting fertilisers, often of inorganic origin or the result of a mining or manufacturing process, such as sodium nitrate, superphosphate, kainit, muriate of

[134] Hall, *Pilgrimage*, p. 127; M. A. Havinden, 'Lime as a means of agricultural improvement: the Devon example', in C. W. Chalklin and M. A. Havinden (eds.), *Rural Change and Urban Growth, 1500–1800* (London, 1974), pp. 129–30; Clarke, 'Practical agriculture', p. 625; Fream, *Elements of Agriculture* (3rd edn, 1892), p. 15; McConnell, *The Agricultural Notebook* (9th edn, 1919), p. 64; the corresponding page in the 5th edition (1894) of this book does not contain the reference to pulverised limestone.

[135] A. Briggs, *Victorian Things* (London, 1990), p. 252; N. Goddard, '19th century recycling: the Victorians and agricultural utilisation of sewage', *History Today*, 31, June 1981, pp. 32–6; H. J. Little, 'Sewage farming', *JRASE*, 2nd ser., 7, 1871, p. 392; B. Latham, C. S. Read and T. H. Thursfield, 'Report of the judges appointed by the Royal Agricultural Society of England to adjudicate the prizes in the sewage farm competition, 1879', *JRASE*, 2nd ser., 16, 1880, pp. 4, 5; J. C. Morton, 'Half-a-dozen English sewage farms', *JRASE*, second ser., 12, 1876, pp. 437–8; J. B. Lawes, 'Town sewage', *JRASE*, second ser., 1, 1865, p. 231.

potash, ammonium sulphate, cyanamide and basic slag. The slow-acting manures were mostly known and to a greater or lesser extent used before the 1850s; it was the faster-acting fertilisers which became popular thereafter, and formed one of the most significant innovations of the period.[136]

'The annual consumption of guano, nitrate of soda, bone dust, dissolved bones, superphosphate of lime, and compound artificial manures especially prepared for particular crops, is unquestionably greater in Great Britain than in any other country', wrote Augustus Voelcker, consulting chemist to the Royal Agricultural Society in 1878. The extent of the development of the artificial-fertiliser trade in the years between 1850 and 1914 is made clear by a simple examination of the consumption figures. At the beginning of the period usage was about 250,000 tons per year, made up mostly of guano and bones with a little superphosphate and sodium nitrate. By 1914 it had increased by more than a million tons.[137] The trade was dominated by superphosphate and basic slag, both phosphatic fertilisers, which accounted for about two-thirds of the total tonnage. The use of guano and bones had declined both absolutely and relatively, while that of nitrogenous fertilisers such as sodium nitrate and ammonium sulphate had increased considerably. Sources of potassium, such as kainit, were increasingly used, although this was a recent development, and farmers in Germany used much more. Numerous mixed or compound manures were also sold under the names of the firms which produced them, such as Vicker's special manure or Odams's nitrophosphate. Since, according to one estimate, there were at least 1,210 manure manufacturers by 1871, it can be seen why the number of proprietary brands was so large. By the first decade of the twentieth century organisations, such as the Country Gentlemen's Association, were producing their own brands. In 1914 the Association advertised a range of fourteen 'complete crop' fertilisers, selling at between £6 and £8 per ton, and designed for specific crops: C.G.A. Wheat Fertilizer, C.G.A. Swede Fertilizer, and so on. About half of the million tons increase was recorded before the mid-1870s, and the rest subsequently. Perhaps the rate of growth in fertiliser usage would have been maintained had arable crop prices and acreages not fallen in the

136 Dyer, 'The conservation of farm-yard manure', pp. 828–9; J. Donaldson, *British Agriculture* (London, 1860) pp. 251–98; Lord Ernle, *English Farming Past and Present* (6th edn, 1961), p. 369; Holderness, 'Agriculture and industrialisation in the Victorian economy', in Mingay (ed.), *The Victorian Countryside*, vol. 1, p. 193.

137 The figures given in F. M. L. Thompson, 'The second agricultural revolution, 1815–1880', p. 77, which cover the years up to 1891, and E. M. Ojala, *Agriculture and Economic Progress* (Oxford, 1952), p. 212, which cover the period from 1867, are in approximate agreement for the years in which they coincide. Thompson's figure for the consumption of fertiliser (excluding lime) for the UK in the years 1851–3 was 263,000 tons; Ojala's corresponding figure for 1911–13 was 1,281,000 tons.

second half of the period.[138] To put these changes into perspective, it should be remembered that although in the early part of the period the quantity of nutrients applied in the form of farmyard manure was greater than that derived from artificials, by the end of the period the reverse was true only for phosphatic, not nitrogenous or potassic fertilisers. Although the figures in Table 7.3 only indicate orders of magnitude, the differences are relatively enormous, and what would be expected in view of the fact that cereal yields and outputs did not change all that much during the period, although root crop yields probably did.[139] Most importantly, much of the artificial fertiliser was applied to the root crops, which were especially responsive to phosphates (see below).

The other important point is that although the use of artificial manures increased markedly during this period, the total quantities available meant that either many crops were not dressed at all with artificials, or that only small average amounts were used. Dividing the total quantity of artificials applied by the acreage of crops and grass gives the average artificial fertiliser applications shown in Table 7.4.

These figures may be compared with those of Middleton, writing about the period immediately before the First World War. He assumed a standard dressing of between two and three and a half hundredweights per acre of superphosphate (the lower figure on grass, the higher on root crops), and that 60 per cent of the swede, turnip and potato crops, but only 20 per cent of wheat and 25 per cent of barley would be manured in this way. Agricultural textbooks of the 1890s recommended between three and five hundredweight of superphosphate for turnips and swedes, assuming a full dressing of farmyard manure, and in addition one hundredweight of sodium nitrate if only a moderate dressing of farmyard manure had been given. For cereals, superphosphates were not advised except on light soils which had been only moderately dunged. A top dressing of one or one and a half hundredweights of sodium nitrate was also recommended. Voelcker in 1878 cited similar figures. He believed that on the majority of average good soils there would be little response to potash, except for the potato crop, and many farmers appear to have shared his opinion.[140]

[138] Voelcker, 'The influence of chemical discoveries', p. 828; Country Gentlemen's Association, *C.G.A. Farm Seeds and Manures 1914*; Clarke, 'Practical agriculture', pp. 620, 623.

[139] Holderness, in Mingay (ed.), *AHEW* vol. VI, p. 144, states that 'Turnips probably yielded eight to ten tons an acre.' This may be compared with an average yield of 12.3 tons per acre over the years 1910–14 reported in Ministry of Agriculture, Fisheries and Food, *A Century of Agricultural Statistics* (1966), p. 118.

[140] Crop and grass acreages are given in Orwin and Whetham, *History of British Agriculture 1846–1914* (2nd edn, 1971), pp. 121, 251, 350, and MAF, *Century of Agricultural Statistics*; Professor Middleton's estimate was reported in the *Report of a Departmental Committee on the Post-war position of the Sulphuric Acid and Fertiliser Trades*, Cmd. 23, 1919, BPP, 1919, XXIX, p. 803; Webb, *Advanced Agriculture*, pp. 359–63; Fream, *Elements of Agriculture* (3rd edn, 1892), pp. 74–7; Voelcker,

Table 7.3. *Quantity of plant nutrients applied as artificial fertilisers and farmyard manure (fym), 1850s–1914, in thousands of tons of nitrogen (N), phosphate (P) and potash (K)*

	artificial N	fym N	artificial P	fym P	artificial K	fym K
1850s	9	151	108	73	0	314
1860s		192		93		416
1870s	26	207	150	99	5	445
1880s		215		101		453
1890s	28	229	133	107	7	482
1900s		237		110		493
1910–14	40	245	280	114	13	497

Sources: The figures for farmyard manure-derived nutrients are taken from Table 7.2 (above). Estimates of the quantities of artificial fertilisers supplied are mainly derived from F. M. L. Thompson, 'The second agricultural revolution, 1815–1880', *EcHR*, 2nd ser., 21, 1968, with additional figures from the Agricultural Returns in BPP, CII, 1898, p. 192; XCVII, 1907, p. 291; LXXIX, 1914–16, p. 795, and J. Hendrick, 'The growth of international trade in manures and foods', *Trans. Highland and Agricultural Society of Scotland*, 5th ser., 29, 1917, p. 10; P. E. Dewey, *British Agriculture in the First World War* (London, 1989), p. 251; *Report of a Departmental Committee on the Post-War Position of the Sulphuric Acid and Fertiliser Trades* (Cmd. 23, 1919, BPP, XXIX, p. 803); E. J. Russell and E. H. Richards, 'On making and storing farmyard manure', *JRASE*, 77, 1916; A. N. Gray, *Phosphates and Superphosphate* (1944), *passim*; J. Hendrick, 'Artificial manures', in R. P. Wright, *The Standard Cyclopedia of Modern Agriculture and Rural Economy*, vol. I (1914), p. 211; *Report of the Departmental Committee on the Fertilizers and Feedingstuffs Act 1893*, Cmd. 2372 (1905), appendix XXV, p. 204; *Report of the Departmental Committee appointed by the Board of Agriculture to Inquire into the Adulteration of Artificial Manures, and Fertilizers, and Feedingstuffs used in Agriculture*, C.6742 (1892), Appendix 7, p. 129 (BPP, 1892, vol. XXVI, p. 217); and Ministry of Agriculture and Fisheries, *Fertilizers in Modern Agriculture* (Bulletin 28, 1931) p. 135. The fertiliser tonnages are then converted into plant nutrient figures for four periods – the 1850s, the 1870s, the 1890s and 1910–14 – using data from P. McConnell, *The Agricultural Notebook* (9th edn, 1919), p. 162; R. J. Halley, *The Agricultural Notebook* (17th edn, 1982), p. 92; and A. D. Hall, *Manures and Fertilizers* (1919), p. 162.

Thus the average farmer does not generally seem to have followed the textbook recommendations on fertiliser application rates. Although examples of heavy dressings of artificial manures can be found, such as half a ton per acre of superphosphate, nitro-phosphate or special manure on roots on the Lincolnshire Wolds and Heath, or the expenditure of

Table 7.4. *Average fertilizer applications in England and Wales, 1850s–1910s (pounds per acre)*

1850s	16
1870s	55
1890s	67
1910s	87

Source: see text

more than a suspicion that such figures were intended as an encouragement to others, rather than as an account of what was then typical practice. In the East Riding of Yorkshire artificial fertilisers were not uncommon by the 1870s, but were more frequently used by the large farmers on the Wolds, than by small and medium-sized farmers in the vales.[141] Even on some large farms in the south of England and East Anglia expenditure on fertilisers was only a small proportion (commonly between 0.1 and 4.0 per cent) of total outgoings in the 1860s and 1870s.

Yet it is clear that the use of artificials did increase, and there were several reasons why this should have been so. Most importantly, farmers could rarely make as much farmyard manure as they would have liked. Secondly, the price of artificials seems to have fallen relative to other costs and product prices from the 1860s, as Table 7.5 indicates.

A major technical reason for the increased adoption of artificials was that the nutrients supplied by most forms of artificial manure were more readily available to the crop than those in natural manures, so that the crop responded more quickly. This had some important implications: the early growth of root crops could be stimulated, so that the period of time in which they were most susceptible to attack by flea beetle was reduced. Thus the risk involved in growing the root crop was reduced, in addition to the yield being increased. Moreover, the availability of artificials to produce this quick spurt of growth in spring meant that it was no longer necessary to ensure that well-rotted farmyard manure was available for this purpose, meaning that muck could be spread straight from the yards

[141] Clarke, 'Practical agriculture', p. 622; Adams, 'Agricultural change in the East Riding of Yorkshire', pp. 39–9, 41–2; The much-quoted case of John Prout, of Blount's Farm, Sawbridgeworth, Herts., who began in 1861 to farm 450 acres under a system which he described as 'perpetual corn-growing on heavy land by means of deep and cheap steam-tillage, and plentiful applications of artificial manure', but virtually no farmyard manure, seems to have been very rare. John Prout, *Profitable Clay Farming under a Just System of Tenant Right* (3rd edn, London, 1881), pp. 9, 34–6, 37, 57, 61, 62.

Table 7.5. *Average price per ton (£) of all artificial manure, 1867–1913*

1867–9	10.4
1870–6	8.4
1877–85	6.0
1886–93	4.5
1894–1903	3.7
1904–10	3.8
1911–13	3.8

Sources: Prices were calculated by dividing Ojala's (*Agriculture and Economic Progress* (1952) pp. 212–13) estimate of fertiliser values by that for the corresponding quantities. Anderson's ('Instructions to farmers on the reading of analyses and the valuation of manures', *Trans. Highland and Agric. Soc.* new ser., 18, 1859–60, p. 432) estimate of fertiliser prices in 1860 suggests that the resultant figure for 1867–9 may be an overestimate, although Thompson ('The second agricultural revolution, 1815–80', *EcHR*, 2nd ser., 21, 1968) suggests a guano price of nearly £11 per ton for the 1860s.

in the autumn, rather than at the spring work peak. If the muck was then ploughed in over the winter, it was possible to produce a finer seed-bed by using the harrow and the roll, and this made it easier to use the seed drill. This virtuous circle was completed by the fact that artificials could be combine-drilled together with the turnip and mangel seeds. Since their nutrients were so much more concentrated than those of farmyard manure, artificials were cheap to transport, which meant that outlying fields could now be fertilised at a more reasonable cost. The heavier dressings were reserved for the root crops, but that did not mean that the succeeding cereals did not benefit. In fact, given the prolific straw growth of nineteenth-century cereal varieties, too much nitrogenous fertiliser seriously increased the risk of crop loss through lodging.[142]

Despite these advantages, it is clear from the foregoing discussion that artificial fertilisers could have been adopted to a much greater extent than they were. One problem was that many of the arguments in favour of their adoption were much more applicable to well-drained or light soils

[142] There is an interesting and detailed discussion of these points in Raine Morgan, 'The root crop', pp. 321–9.

than to heavy or poorly drained soils. This was the explanation given for the slow take-up of artificials in both Essex and Oxfordshire in the middle of the nineteenth century. Heavy-land farms had relatively more stock and less arable, and so made more of the farmyard manure that they needed. That heavy land tended to be associated with small farms was an additional check on their use, because small farmers had fewer resources to dispose of, and were usually more frugal than larger farmers. Tenurial customs might also have been a barrier: Caird quoted a farmer who said 'it might pay a man with a lease to use such purchased manures, but not otherwise'. In some parts of the country the costs of carriage, at least in the earlier part of this period, raised the price of artificials out of the reach of the ordinary farmer.[143]

One of the main problems, especially for the smaller farmer, was the difficulty of knowing precisely what he was buying when he bought artificial fertiliser. It was for this reason that the Chambers of Agriculture made representations to the Board of Agriculture, which resulted in the setting up of a Departmental Committee to enquire into the adulteration of artificial manures (and feeding stuffs) in 1892. The Committee found that 'There is a preponderance of evidence to the effect that a considerable amount of fraudulent dealing (especially in the case of compound manures) exists, and that there is a system of selling unguaranteed and comparatively worthless articles at an excessive price. These frauds are, however, less practised than formerly and have a tendency to diminish.' The bigger firms usually provided a guaranteed analysis stating the fertiliser constituents, but all firms regarded information about ingredients as a trade secret. The Committee therefore recommended that all manures should be sold with an analysis, that deficiencies in the items guaranteed should be treated as a fraud liable to criminal prosecution, and that analysts should be appointed by the Board to advise on whether prosecutions should be undertaken. As a result, the Fertilizers and Feedingstuffs Act, 1893, came into force from 1 January 1894. It accepted the major conclusions of the Report, and provided for a £20 fine for a first offence of failing to give an invoice correctly stating the nutrient content of a fertiliser. In addition, the offending vendor might be sued by the purchaser. The Board appointed a Chief Agricultural Analyst, and counties and county boroughs were empowered to appoint District Agricultural Analysts. By 1901 each county had an analyst, although some analysts were responsible for more than one county: Bernard Dyer serviced nine, and J. A. Voelcker six counties. They both gave London addresses. J. A. Murray of University College Aberystwyth was responsible for six Welsh

143 Raine Morgan, 'The root crop', pp. 329–30; Caird, *English Agriculture in 1850–51* (2nd edn, ed. G. E. Mingay, 1967), p. 6.

counties. Up to the end of 1900, 3,884 analyses of fertiliser samples had been carried out, nearly half of them in Scotland. In 1903 a further Departmental Committee was appointed to examine the working of the Act. It concluded that the general opinion was that the Act '. . . has been of very great benefit to the farming class . . .' It had suppressed fraud and made manufacturers more scrupulous, although many people, believing that the Act had suppressed adulteration, had not taken the opportunity to have their purchases sampled. There were also large variations between different counties in the enthusiasm with which the Act had been prosecuted. Carmarthen County Council made no charge for analysis, and published the results in the local papers, so that a large and increasing number of samples were taken; in Radnorshire the Council had not shown the same interest in the Act, and no samples had been taken. Therefore, for the smaller, less well educated farmer the act had to some extent been a failure, and the Committee made a number of proposals, the most important of which was that the work of detecting fraud should become mainly the function of the local authority.[144]

Thus it seems reasonable to conclude that the importance of purchased fertilisers did indeed increase in this period, but that their impact should not be exaggerated. There were good reasons both for their adoption and for their non-adoption. They produced a gradually increasing proportion of total nutrients, especially of phosphate; the bulk of nitrogen and potash continued to be derived from farmyard manure.

[144] *Report of the Departmental Committee appointed by the Board of Agriculture to inquire into the Adulteration of Artificial Manures, and Fertilizers, and Feedingstuffs used in Agriculture.* C.6742, 1892, BPP, 1892, XXVI, p. 217; *An Act to Amend the Law with respect to the sale of Agricultural Fertilizers and Feedingstuffs.* Public and General Acts 56 & 57 Victoria cap 56, pp. 298–302; Board of Agriculture, *Annual Report of Proceedings under (inter alia) the Fertilizers and Feedingstuffs Act 1893 . . . for the year 1900*, Cd. 654, BPP, 1901, XVII, p. 165; *Report of the Departmental Committee appointed by the Board of Agriculture and Fisheries to Inquire into . . . the working in Great Britain of the Fertilizers and Feedingstuffs Act 1893*, Cd.2372, 1905, BPP, 1905, XX, p. 259.

G

WEED AND PEST CONTROL

BY PAUL BRASSLEY

Weeds

Rider Haggard, passing along the road from Baldock to Ashwell in Hertfordshire at the turn of the century, noted a field of wheat infested with charlock and a cornfield 'stained blood-red with poppies'. On his own farm in Norfolk, a year or so earlier, part of a field of winter wheat '. . . produced more poppies than anything else – red weed we call it, which, although picturesque in appearance, is not satisfactory to the farmer'. A farm labourer might be occupied in weeding from March to August. In early spring the mowing fields would need to be cleaned before they were shut up for hay. May was a time for horse- and hand-hoeing cereals and potatoes. In June he (or, equally, she, for women were much involved, especially in hand-hoeing) would be hoeing mangolds, beans, cabbages and potatoes. Turnips and mangolds would be hoed in July, and again in August. In Lincolnshire in the 1860s thousands of women and children were employed in gangs for field work, which often included twitch-picking or hand-weeding cereal and root crops. In Lancashire, in 1894, up to forty weeders were employed at one time in a ten-acre field of carrots. Primrose McConnell, writing at the beginning of the twentieth century, estimated that 'from a third to a half of the field labour on a farm is devoted to the destruction of growing weeds', while another estimate put the costs of weeds in Great Britain on the eve of the First World War at £16.5 million, taking into account the reduction in crop yields and the cost of the labour expended in suppressing them. Experiments at Reading College farm suggested that moderately weeded areas yielded between 40 per cent and 50 per cent more than unweeded crops. In the absence of chemical control, weeds were clearly a major problem. On a weed-infested farm costs were higher because more labour was needed for hoeing, and more horses were needed to perform more autumn and spring cultivations. It might be necessary to plant a greater acreage of cleaning crops (i.e. those, such as fodder roots or potatoes, which could be hoed over a period of several months) or even to lose a crop altogether and take a bare fallow which could be regularly cultivated to kill the weeds after germination but before seeding. On the other hand, a 'clean' farm would require less casual labour for weeding and have higher yields and no restrictions on cropping. One of the great advantages of a four-course rotation was that the cleaning crop – the root crop – came round regularly and often; weeds were a major problem of those rotations of two or three cereal crops followed by several years in grass, common in the western counties.[145]

Most agricultural textbooks gave long lists of weeds. Stephens listed thistles, ragwort, docks, rushes, and ox-eyed and common daisies as the main weeds of pasture, and corn cockle, poppy, hairy tare, charlock, cleavers and thistles as the main weeds of cereals. Couch grass or twitch, and knot grass, together with various broadleaved weeds, such as chickweed, fumitory and shepherd's purse, were the main weeds of potatoes. A similar list was produced by a survey of 1909 in which twenty-nine 'practical agriculturists' were asked which they thought were the six worst weeds of arable and grass land. Couch, charlock, dock, thistle, coltsfoot, chickweed, bindweed and spurrey were mentioned most often among arable weeds, while thistle, buttercup, Yorkshire fog and soft brome were the worst weeds of grassland.[146]

If the weeds which were considered important did not change much over this period, neither did the methods used to control them. Mechanical destruction, by cultivation, hoeing, pulling, digging, or hand-rogueing, was most important. In July 1910 William Swan, a farm apprentice, spent nearly a whole day and two mornings hand-pulling kilk (probably charlock) in a field of maize in Sussex. John Donaldson, in a textbook published in 1860, recommended that for oat grass and twitch the land should be grubbed and scarified to bring the roots to the surface, whence they could be carried away and burned. Corn cockle required very complete fallowing, or the hand-hoeing of drilled grain crops. Although the principle of drilling and the resultant ease of hoeing had been known for a long time it was the search for higher yields from the 1830s onwards which brought them into widespread use. Writing in mid-century, Stephens felt it necessary to illustrate the weed hook, for use among broadcast grain crops. He assumed that the horse-hoe would only be used on larger farms: 'Where the extent of drilled crops is considerable, hand hoers are unable to clear the ground of weeds before the crops advance to a state in which it is improper to go amongst them. Hence the need of assistance from the more expeditious horse-hoe.' He thought that the horse-hoe produced by Garrett and Sons of Leiston in

[145] Rider Haggard, *Rural England*, vol. I, p. 553; Rider Haggard, *A Farmer's Year*, p. 63; J. C. Morton, 'Calendar of Farm Labour', in *Handbook of Farm Labour* (1861), reprinted in P. Horn, *Labouring Life in the Victorian Countryside* (1976), pp. 251–2; Orwin and Whetham, *History of British Agriculture*, p. 116–17; Mutch, 'Rural Society in Lancashire', p. 196; McConnell, *The Agricultural Notebook*, p. 278; H. Hunter (ed.), *Bailliere's Encyclopaedia of Scientific Agriculture* (London, 1931), vol. II, p. 1267; H. C. Long, 'Weeds and their eradiction', *J. Bath and West*, 5th ser., 6, 1911–12, p. 52.

[146] Stephens, *The Book of the Farm*, vol. II, pp. 246–63; Long, 'Weeds and their eradication', p. 45.

Suffolk was the best, but it was expensive, and he illustrated a cheaper model by Smith of Northampton which cost £4 10s for a version 4 feet 8 inches wide. The other main way of eliminating weeds was to grow smothering crops such as vetches, which would get rid of chickweed, or to improve the land so that the more desirable plants would be encouraged, by top dressing with artificial fertiliser, liming, or draining. Donaldson reported that drainage and lime would eliminate docks, and that ox-eyed daisy could be treated by a heavy top dressing followed by eating bare by sheep.[147]

The same principles were reiterated in an article on weeds written at the beginning of the twentieth century, but with some interesting additions. One was a plea for an official seed-testing station to improve the purity of seeds sold. Although such stations had been operating in several European countries since the 1880s, the only one in the United Kingdom had opened in Ireland in 1900. British seed firms seemed unwilling to support a similar venture, although there were facilities for seed testing at several of the agricultural colleges. The first seed-testing stations on the mainland were established in the First World War. The second development was the control of weeds by chemical means. Agricultural textbooks of the 1890s do not mention the possibility of weed control by spraying, except for the suggestion that watering with a solution of ferrous sulphate will injure dodder growing in clover. In 1896 a M. Bonnet, in France, observed that charlock had been killed when some surplus Bordeaux Mixture (copper sulphate and lime, used for controlling fungal diseases in vines) was accidentally spread on it. At about the same time, in the USA, a Mr Bolley also began to investigate the same subject. Thereafter, experiments began in a number of countries. In 1898 Mr G. F. Strawson, of Queen Victoria Street, London, manufacturer of the Strawsonizer, a machine for distributing seeds, solid and liquid manures, insecticides and fungicides, carried out trials near Chelmsford on the use of copper sulphate alone for the control of charlock. In this and subsequent experiments it was found that copper sulphate solutions of between 2 and 5 per cent would kill or injure charlock, spurrey, redshank, dock, dandelion, poppy, corn cockle, groundsel, cornflower, thistle and dodder. In an experiment with a crop of oats it was found that two sprayings of copper sulphate, costing 14s. 0d. per acre, produced an increase in yield of twenty-seven bushels of grain and nearly half a ton of straw per acre, worth about £4. Trials were also carried out with sodium arsenite and arsenate, corrosive sublimate (mercuric chloride), common salt, ferrous sulphate, carbolic, sulphuric and hydrochloric acids,

[147] Swan, *The Diary of a Farm Apprentice*, pp. 114–15; Donaldson, *British Agriculture*, pp. 641–57; G. E. Mingay (ed.), *AHEW*, vol. VI, p. 288; Stephens, *Book of the Farm*, vol. II, pp. 246–7.

liver of sulphur and kerosene. It was also found that very concentrated (15–40 per cent) solutions of fertilisers such as sodium nitrate and ammonium sulphate would kill young charlock plants. Fortunately, perhaps, only copper sulphate seems to have been successful enough to be the subject of extensive trials. In 1909 Strawson & Co. were advertising the 'Solubic' brand of copper sulphate in the Royal Agricultural Society's *Journal* and, in 1914, the Country Gentlemen's Association advertised its own brand of charlock spray. Sales of these preparations, and the extent to which they were adopted by commercial farmers, need further investigation, but there is little evidence that they were extensive. Weeds remained a problem, and the hoe continued to be the usual solution.[148]

Pests and diseases

If there were no easy answers to the weed problem, neither were there to the problem of crop pests and diseases. 'The remedies against the attack of this insect are, I fear, of a hopeless character', wrote Henry Stephens in 1851 of the turnip flea-beetle, and although Fream's textbook of 1892 listed some substances which might help in the control of insects, it also recommended that 'What is known as *good farming*, that is, thorough cultivation and liberal manuring, will prove highly serviceable in combating insect injury.'[149]

By the middle of the nineteenth century many of the insect and fungal diseases which attack crops had been identified, named and described. John Curtis's (1791–1862) *Farm Insects*, published in 1860, discussed each crop and the insects which attacked it, illustrated by coloured plates, and was a book of real value to the farmer who wished to know about the problem. Two thousand copies were printed, and a second edition produced in 1880. By the mid-1870s the Royal Society of Arts was attempting to persuade the government to appoint its own entomologist. Nothing came of it, but in 1877 Eleanor Ormerod (1828–1901), a lady with a private income and an interest in insect pests, began to publish annual reports on injurious insects at her own expense. Her reports were continued until 1900, by which time they amounted to twenty-two volumes containing about 3,000 main entries. At that point she felt that there was no point in producing further issues, as most of the information useful to farmers and gardeners had already been given. Additional, more specialised material, she felt, would be of more use to scientists than

[148] Long, 'Weeds and their eradication', pp. 53–8; Fream, *Elements of Agriculture* (3rd edn, 1892), *passim*; Webb, *Advanced Agriculture*, p. 39; R. P. Wright, *The Standard Cyclopedia*, vol. XI, pp. 98–100. Advertisements p. 27, in *JRASE*, 70, 1909; County Gentlemen's Association, *C.G.A. Farm Seeds and Manures*, 1914, p. 34.

[149] Stephens, *Book of the Farm*, vol. II, p. 74; Fream, *Elements of Agriculture*, p. 301.

to practical men. Over the period, she concluded, the most serious pests had been the turnip fly, the silver Y moth, wireworm, antler moth, hessian fly and beet carrion beetle. At the beginning of the twentieth century farmers were able to obtain free, from the Board of Agriculture, leaflets on forty-nine individual pest species, with information on identification and control, which incorporated much of the data she had gathered. In 1882 Miss Ormerod was appointed Consultant Entomologist to the Royal Agricultural Society. When she retired from the post owing to ill-health in 1892 she was replaced by Cecil Warburton of the University of Cambridge, who retained the title of Consulting Zoologist until 1944. On payment of one shilling (in the years before the First World War), members of the society could send specimens of crop pests to him for identification.[150]

A similar service, for the identification of 'fungoid diseases affecting farm crops', was offered by the Society's botanist. As with insect pests, naming and description of plant diseases preceded any major developments in their control. The work of Berkeley in Britain, the Tulasne brothers in France and De Bary in Germany meant that by the mid-1860s the life histories of the causal organisms of such economically important diseases as powdery mildew, potato blight, loose smut and stinking smut or bunt, and some of the cereal rusts, had been elucidated. Whereas Stephens in 1851 still considered that anbury and finger and toe in turnips were separate diseases, textbooks of the 1890s gave detailed and reasonably accurate accounts of the lifecycles of these and other fungal diseases.[151]

Methods available for the control of both insect and fungal attacks on crops did not change very much in the second half of the nineteenth century. Stephens knew that liming would help to control finger and toe in turnips, and that ladybirds would eat aphids, while Curtis, writing about the control of turnip flea beetle, discussed the effects of rolling, deep ploughing, thick sowing, dusting with lime or soot, destruction of cruciferous weeds and dragging a tarred board over the crop in fine weather in the hope that the insects would stick to it. As regards the caterpillars of the turnip sawfly he suggested the possibility of paying children to collect them by hand, or training young ducks to feed on them.

[150] G. Ordish, *The Constant Pest* (London, 1976), pp. 163–5; G. Ordish, *John Curtis and the Pioneering of Pest Control* (Reading, 1974), chapter 8; Board of Agriculture and Fisheries, *Leaflets* (collected edition, 1919). The first 200 leaflets also included 30 on fungal diseases; N. Goddard, *Harvests of Change: the R.A.S.E. 1838–1988* (London, 1988), pp. 127–9, 296–7; *JRASE*, 70, 1909.

[151] *JRASE*, 70, 1909; Ordish, *Constant Pest*, pp. 144–5 (the development of the scientific aspects of pest control is considered in more detail in the following chapter); Stephens, *Book of the Farm*, vol. II, pp. 80–1; Fream, *Elements of Agriculture* (3rd edn, 1892), chapter XVII; Webb, *Advanced Agriculture*, pp. 202–9.

Most control methods, in other words, were cultural (which is not to say that they were ineffective), and they remained so until after the First World War. The 1919 edition of the *Agricultural Notebook* virtually repeats the advice given by Curtis on the control of the turnip flea beetle half a century earlier.[152] However, there were some developments in the chemical control of pests and diseases. As early as 1856, Cooper's Wheat Dressing, based on arsenic and soda, and sold at 6d. a packet, was reckoned to treat six bushels of seed against smut. In 1868 the formulation was changed to one based on copper sulphate. By 1874 enough was being sold to treat 15,000 acres. 'Down's Farmers' Friend' for preventing the Smut in wheat and the ravages of the slug, grub and wireworm' was being advertised in 1865 at 9d. per packet. Some important innovations arose out of attempts in France to counter powdery and downy mildew on vines, which led, in 1885, to the production of Bordeaux mixture, composed of copper sulphate and lime. From 1890 it was used in Britain against a different fungal disease: potato blight. Spraying began in the Lincolnshire fens in 1901–2. Later Mr Arthur Worth designed a machine which could apply Bordeaux mixture as a dust, using as little as 10 lb per acre, and this became the most popular method of application after 1914. It was on the high-value crops such as potatoes, hops and fruit that many of the first fungicides and insecticides were used. Nicotine was available as an insecticide from 1880, first as a spray and later as a dust. Paris Green and London Purple, both arsenical compounds, were also available from this time, and suffered from the same drawback as nicotine, in that they were very poisonous and therefore dangerous to use. On the other hand quassia extract and soft soap, which was used as a spray from 1884 against aphids on hops, was more innocuous, and effective enough to be adopted fairly widely. In 1884 a system of stand-pipes with rubber hoses attached, through which this mixture was pumped by a steam pump, was installed in a hop garden near Tunbridge Wells. Less toxic, too, was derris, which was available as a spray or dust from 1911. In the USA the claims of salesmen, intent on promoting soapsuds, turpentine, whitewash, wood ashes, herbs and pepper as insecticides, led to the development of distrust between academic and public entomologists who were sceptical of such claims, and industrial entomologists who appeared to be employed to substantiate them. With the development of sprays and dusts went the machinery to apply them. By the early twentieth century there were hand-syringes, knapsack-sprayers and horse-drawn spraying machines. Products advertised in the *Journal of the Royal Agricultural Society* in 1909 included Clift's Insecticide, 'Apterite', a soil fumigant produced by

[152] Stephens, *Book of the Farm*, vol. II, pp. 78–81; Ordish, *John Curtis*, chapter 8; McConnell, *The Agricultural Notebook* (9th edn, 1919), p. 240.

Coopers of Berkhamstead, the 'Enots' limewashing and insecticide sprayer, Tett's Patent Motor Spraying Machine, illustrated at work in a Kentish cherry orchard, and 'Sodalin', a pink powder to be dissolved in water, for winter spraying of fruit trees. The Country Gentlemen's Association, in 1914, advertised its Soil Fumigant, for killing wireworm, leather jackets, millipedes, centipedes, slugs, beetles, ants and woodlice at £8.15. od. per ton, liquid seed dressing at 8s. 6d. per gallon, carbolised seed dressing ('a sure preventive of smut, bunt, rust, slug, grub and wireworm') at 5s. od. per dozen packets, finely ground vitriol for dressing wheat and sheep's feet, and Bordeaux paste at 9s. for 20 lb, sufficient to treat an acre of potatoes.[153]

Import controls were another important innovation in the battle against pests and diseases. They began with the Destructive Insects Act of 1877, which applied exclusively to the Colorado Beetle, then attacking potato crops in the USA. The Act provided for the destruction, with compensation, of crops or shipments in which the beetle was found, and proved effective in controlling an outbreak which occurred in 1901. The Destructive Insects and Pests Act of 1907 extended the provisions of the 1877 Act to all pests and diseases. It was effective in preventing the introduction of disease from outside the country, but when, in 1914, potato growers in the Fens were threatened by an outbreak of black scab and wart disease, for which there was no chemical control, they responded by persuading the Holland County Council to use the powers given to it to control contagious diseases in animals to prevent the entry of potatoes from infected districts unless they were accompanied by a certificate to the effect that they were disease-free.[154]

In the higher value crops, at least, the new chemical control methods seem to have had some impact by the early years of the twentieth century, and the producers of such crops seem to have become more aware of their possibilities. For the bulk of crops, the cereals and fodder crops, the extent to which the new technology was used is less certain; the answer will only be revealed by further analysis of farm diaries and account books. But it seems likely that most farmers were still using the cultural control methods available to them in the middle of the nineteenth century.

[153] A. M. Boyce, 'Historical aspects of insecticide development', *Advances in Environmental Science and Technology*, 6, 1976, p. 472; Ordish, *Constant Pest*, chapter 8; *JRASE*, 2nd ser., 1, part 2, no. 2, 1865; S. R. Haresign, 'Agricultural change and rural society on the Lincolnshire Fenlands and the Isle of Axholme 1870–1914', PhD thesis, University of East Anglia, 1980–1, pp. 285–6; *JRASE*, 70, 1909; Country Gentlemen's Association, *C.G.A. Farm Seeds and Manures 1914*, pp. 33–4.

[154] R. P. Wright, *The Standard Cyclopedia* vol. IV, pp. 139–40; S. Foreman, *Loaves and Fishes: an Illustrated History of the Ministry of Agriculture, Fisheries and Food, 1889–1989* (London, 1989), pp. 75–6; Haresign, 'Agricultural change', p. 286.

H

LIVESTOCK BREEDS

BY PAUL BRASSLEY

The development of cattle breeds

The Standard Cyclopedia of Agriculture, published in several parts between 1909 and 1914, distinguished between beef cattle, dairy cattle, and combined beef and dairy breeds. The beef breeds were Herefords, Devons, Sussex, Longhorns, Aberdeen-Angus, Galloways, West Highland, and Welsh cattle such as Pembrokes. The dairy breeds were Jerseys, Guernseys, Ayrshires and Kerries; and the combined were Shorthorns, Lincoln Red Shorthorns, Red Polls and Dexters. With a few exceptions, this list would have been as familiar to a cattle breeder of the mid-nineteenth century as it would to one of the mid-twentieth.[155]

The exceptions did not involve any major or significant change in cattle breeding. The Red Poll was formed in the mid-nineteenth century from the Suffolk Dun, a polled dairy breed, and the horned and polled cattle of Norfolk, which had a better reputation as beef producers. There is some disagreement over whether Galloway blood had been involved at some point in the production of the breed. There were classes for Red Polls at the Royal Show from 1862 and a herdbook was published in 1874, although they were still being referred to as Norfolk or Suffolk polls for a few years after that. The Dexter, a miniature version of the Kerry, was bred in Ireland by a land agent, Mr Dexter, before 1850, but was only introduced into England in 1882 by Martin Sutton, the Reading seed merchant. Similarly, although the Aberdeen-Angus had been developed in Scotland by the middle of the century it was not introduced into England on any significant scale until the 1890s. Devon cattle were established as a breed by 1850, but it was only in the 1870s that writers regularly began to distinguish between the moderate-sized, dark red North Devon cattle, sometimes known as Red Rubies, and the larger-framed, coarser built, lighter red South Devon or South Hams cattle. The North Devons were initially bred as beef and draught animals, whereas the South Devon, traditionally thought of as a cross between the North Devon and the Guernsey, was a better milk producer. In the grazing counties of the south and west of the country the pre-eminence of the Shorthorn was challenged by the Hereford, which had its own herdbook from 1858. Highland cattle and Galloways were also established as pure breeds,

155 R. P. Wright, *Standard Cyclopedia*, vol. III (n.d., *c.* 1909), p. 140.

although Galloways were best known in England as one of the parents (with the Shorthorn) of the blue-grey cross. Welsh cattle, too, although primarily thought of as beef animals, contained some good milking strains. By the middle of the nineteenth century three types, known as the Pembroke or Castlemartin, the Glamorgan and the Carmarthen, had emerged from the crosses which had been made in the southern half of the principality; in North Wales, the Anglesey, which was not dissimilar to the Pembroke, remained relatively pure. It was not until early in the twentieth century that Welsh Black cattle came to be recognised as a single breed as these various types were combined. Among the dairy breeds the Jersey and Guernsey were not usually distinguished until the 1880s, although the Jersey herdbook was started in 1866. Before that they were known as Alderneys. All these breeds were maintaining or expanding their numbers; the Longhorn, which had been so important in the previous century, had given way to the Shorthorn, and by the 1850s only a few herds were left. The Shorthorn was the dominant breed in the late nineteenth century, especially in the northern and eastern counties. Morton, discussing cattle breeds in 1855, seemed to argue that almost every other breed was inferior to the Shorthorn. According to one estimate, two-thirds of the cattle sold in the London market in 1863–4 were either Shorthorns or Shorthorn crosses. Although many dairy herds used Shorthorns or animals with Shorthorn blood, the main emphasis in the middle of the century was on the beef-producing capacities of the breed, especially in the arable areas, where they were fed on roots, oats and straw, often with oil-cake. Pure-bred animals grew quickly and matured early, and had the ability to pass on these characteristics to crossbreds. In Lincolnshire a local variant of the breed, the Lincoln Red Shorthorn, had been distinguished in Coates's *Herdbook* since 1822. In contrast, the rise of the Friesian was only just beginning in the early twentieth century. Dutch cattle had been imported from time to time for many years, and some had been involved in the improvement of the Shorthorn in the eighteenth century. After the middle of the nineteenth century thousands were brought in each year except when regulations for the control of animal diseases restricted importations, but these were of variable type and quality. By the 1880s there were perhaps up to forty established commercial herds of Friesians, and the animals which were eventually registered in the first Herdbook of the British Holstein Cattle Society in 1911 had their origin in cattle which arrived in the last quarter of the nineteenth century. They were much improved by the genetic influence of the consignment of pedigree Dutch animals which arrived at Tilbury docks only three days before the beginning of the First World War.[156]

[156] G. E. Mingay, *AHEW*, vol. VI, pp. 342–8; Orwin and Whetham, *History of British Agriculture*,

Sheep breeds

The basic division of the numerous breeds of British sheep into the longwoolled, shortwoolled and mountain breeds was accepted by the middle of the nineteenth century, but not all the breeds which would be recognised in the twentieth century were then established, and some, such as the Morfe, Worcester, Hereford, Notts Forest and Bampton, were to disappear, change, develop or become better known under another name. Among the mountain and hill breeds the Cheviot (and in Scotland the North Country Cheviot) had existed since the eighteenth century and the Herdwick was recognised by the 1850s. The various black-faced sheep found on the hills of England and Scotland were not, in the 1850s, distinguished from each other to the extent that they would be later; by 1914 several types of Scottish Blackface were recognised and the several English types were accorded the status of separate breeds: the Swaledale, Rough Fell, Dalesbred, Lonk and Derbyshire Gritstone. The various types of sheep found on the Welsh hills were treated as a single breed by the middle of the nineteenth century, albeit not always in complimentary terms: 'The sheep of North and South Wales need not be mentioned, as they are in every way inferior to the black-faced heath sheep . . .' The white-faced hill breeds of south-west England were also defined in this period. The Exmoor Horn developed from the breed found on the moor in the eighteenth century, perhaps with the addition of some Leicester blood. The precise origins of the two Dartmoor breeds, the Whiteface or Widecombe and the Improved or Greyface, are still a matter of controversy. Again, Leicester genes may have been involved in the development of the Whitefaced Dartmoor. What can be said with some certainty is that they were recognised as separate breeds by the beginning of the twentieth century.[157]

The new Leicester, developed in the century before 1850, never became the most numerous of the longwoolled breeds, but it was perhaps the most influential. Its propensity to mature early meant that it easily became too fat, but when crossed with other, later maturing breeds it improved them considerably. By the middle of the nineteenth century it had been used on the Lincoln, the Romney Marsh, the Welsh Mountain (to produce the Lleyn) and the Cotswold. The cross with the Teeswater

chapter 8; S. J. G. Hall and J. Clutton-Brock, *Two Hundred Years of British Farm Livestock* (London, 1989), pp. 19–94, *passim*; J. R. Walton, 'The diffusion of the improved Shorthorn breed of cattle in Britain during the eighteenth and nineteenth centuries', *TIBG*, n.s., 9, 1984, pp. 22–3; G. E. Mingay, *British Friesians: an epic of progress* (Rickmansworth, Herts., 1982), pp. 34, 47.

[157] T. Rowlandson, 'On the breeds of sheep best adapted to different localities', *JRASE*, 10, 1849, p. 444; Hall and Clutton-Brock, *British Farm Livestock*, pp. 112–28; Trow-Smith, *Livestock Husbandry*, p. 268; M. Thompson, 'A history of the West Country breeds of sheep', *The Ark*, 11,

produced the Wensleydale, which had become fixed in type by the 1860s, and by the 1870s the Devon and South Devon Longwools were established by crossing the Leicester with the Bampton Nott and the Southam Nott. But perhaps the most widespread of the breeds derived from the Leicester was the Border Leicester, developed by the Culley brothers in the early nineteenth century. It was recognised by the Highland and Agricultural Society in 1869. Its great value was in the ram which was combined with the Cheviot ewe to form the Scotch Half-Bred. The mothering abilities of the Half-Bred ewe, coupled with the conformation of a Down ram, produced an excellent fat lamb.[158]

The other influential breed of the nineteenth century was the Southdown, developed in the late eighteenth and early nineteenth centuries by John Ellman of Glynde in Sussex and Jonas Webb of Babraham in Cambridgeshire. Like the Leicester, its importance lay not simply in its numbers, but in its impact on other breeds. Most of the Down breeds contain Southdown genes to a greater or lesser extent, and they were all established by the 1870s. Some of the crosses used to produce the new breeds were relatively simple: the Suffolk was developed from a cross between the Southdown and the Norfolk sheep, first made in the early nineteenth century. By 1845 the pure Norfolk breed was rare, and there were classes for the Suffolk breed at the Suffolk Agricultural Association's Show from 1859. The Oxford Down, named as such in 1857, was a cross between the Cotswold and the Southdown. Other crosses were more complex. The Hampshire Down contained material from the Shropshire, Berkshire Nott, Hampshire Horn and Wiltshire Down, in addition to the Southdown. The Dorset Down was produced when this animal was crossed with the longwoolled Bampton Nott from Devon. The Shropshire, much admired in the 1850s and 1860s, and the Clun, also contained Southdown blood. By the middle of the 1870s most of the breeds which would be recognised in the twentieth century had emerged, and apart from the hill breeds, and a few others, such as the Dorset Horn, Kerry, and Radnor, they all owed some of their more valuable qualities to those two important legacies of the early part of the century, the Leicester and the Southdown.[159]

Pig and poultry breeds

During the last quarter of a century, and mainly owing to the stimulus given by the Royal Agricultural Society's and other great shows, the breeding of pigs has

[158] Trow-Smith, *Livestock Husbandry*, pp. 269–76; Hall and Clutton-Brock, *British Farm Livestock*, pp. 135–60; Thompson, 'A history of the West country breeds of sheep', pp. 118–19.

[159] Trow-Smith, *Livestock Husbandry*, pp. 276–83; Hall and Clutton-Brock, *British Farm Livestock*, p. 166; A. K. Copus, 'Changing markets and the development of sheep breeds in Southern

been brought to such perfection, and the best and most profitable kinds have been so rapidly multiplied, that most of the old breeds have been displaced or completely remodelled by crossing; and at the present time it is difficult to find any really distinctive breeds, except the Berkshires, the improved Dorsets, the Tamworth variety, and the Suffolk and Essex blacks; and the remainder are classified together as large-breed, middle-breed and small-breed, principally Yorkshire.[160]

So wrote J. A. Clarke in 1878, and, comparing his list of breeds with those recognised in the 1850s and the early 1900s, it is quite clear that the changes in the first quarter-century were much greater than those in the second. In 1850 Thomas Rowlandson, writing 'On the breeding and management of pigs', mentioned the Hampshire, Berkshire, Suffolk, Lancashire, Yorkshire, Cheshire, Essex and Rudgwick breeds. At the Royal Show at Exeter in that year the prizes were won by a Cumberland, several Leicesters, a Tamworth, and a Yorkshire Sow of a Large Breed exhibited by Joseph Tuley of Exleyhead near Keighley in Yorkshire. All pigs competed in the same class. When the show was at Plymouth, in 1865, there were classes for a large white, a small white, and a small black pig, and for the Berkshire breed, and the same arrangement applied in the 1875 show. At the 1885 show in Preston there were classes for Large, Middle and Small Whites, Small Blacks, Berkshires and Tamworths. With a few additions and subtractions this pattern was maintained up to 1914. After 1890 there were no longer classes for Small Blacks, by 1905 Large Blacks had been introduced, and in 1907 Lincolnshire Curly-coats. Otherwise there was little change in the breeds exhibited. By the 1880s, therefore, many of the breeds which would last into the second half of the twentieth century had been developed.[161]

The Berkshire pig was recognised as a breed by the end of the eighteenth century, and by the middle of the nineteenth century it was highly valued, as either a pure-bred animal or a crossing pig. It began as a sandy red, sometimes spotted animal, but by the 1850s it had been developed by the addition of genetic material from the early maturing, dished-face oriental breeds to produce the Improved Black Berkshire. The Tamworth arose from the development of the Berkshire without this oriental influence. The oriental breeds, either Chinese, Siamese or Neapolitan, were much used in the eighteenth and early nineteenth centuries to produce earlier maturity, which was especially useful in animals destined to be slaughtered for consumption as pork. For bacon, later maturity was preferable, so that a larger carcass would not be over-fat. The smaller breeds, such as the Small and Middle Whites, and the Small Black, were much influenced by the oriental breeds, the larger breeds less so. The

160 Clarke, 'Practical agriculture', p. 573.

161 T. Rowlandson, 'On the breeding and management of pigs', *JRASE*, 11, 1850; annual reports of Royal Show prizewinners in the *Journals* of the RASE, vols. 11, 1850; new series, 1, 1865; 11,

Large White, or Large White Yorkshire, with which Joseph Tuley attracted so much attention at the shows of the 1850s, was said to be a cross of the Old Yorkshire and the Leicester, which had been improved by Bakewell. But there is so little hard evidence, and so many possibilities of introducing genetic material from various sources, that it is exceedingly difficult to be dogmatic about the origin of any breed before the end of the nineteenth century.[162]

The National Pig Breeders' Association was formed in 1884 in response to the complaints of overseas buyers that British pigs often failed to breed true. The Association therefore encouraged the recording and registration of pedigree animals, and consequently it is possible to be a little more confident about the development of breeds from the early twentieth century onwards. The formation of the Association also resulted in the appearance of a number of new breeds, or, perhaps more accurately, in the formal registration of a number of breeds which already existed, such as the Gloucester Old Spot (the breed society for which was formed in 1914), Cumberland (1915) and Ulster (1907) and, after the First World War, the Welsh and the Long White Lop. The other major factor affecting the development of breeds in the latter part of the nineteenth century was the expansion of the bacon factories specialising in the Wiltshire cure, which required that the skin of the animal should not be removed during the curing process. Too great a depth of subcutaneous fat could not therefore be removed by trimming. In 1887 Messrs Harris of Calne complained that pigs were often too fat for their purposes, and there were references to Small Whites as 'animated tubs of lard' and Black Dorsets as 'roly-poly pigs'. Even the Berkshire had been spoiled for the bacon trade by too much crossing with early-maturing breeds. The main beneficiaries of this development were the late-maturing breeds, the Tamworth and, especially, the Large White, which became by far the most common breed by the end of the century. Among the black breeds, the reaction against early maturity gave an impetus to the development of the Large Black, a combination of the smaller East Anglian with the larger West Country black breeds, the herdbook for which began in 1898.[163]

The proliferation of pig breeds can therefore be seen, to some extent, as the work of fancy breeders, as opposed to commercial breeders. Although they were often blamed for the production of over-fat pigs which were only of use in the show ring, it should be pointed out that Joseph Tuley, who was such an important figure in the origin of the major commercial breed, the Large White, would probably come into this cat-

[162] The complex origins of most breeds have been described in detail in J. Wiseman, *A History of the British Pig* (London, 1986), chapter 5. See also Trow-Smith, *Livestock Husbandry*, pp. 288–96, and Hall and Clutton-Brock, *British Farm Livestock*, pp. 202–22.

[163] Wiseman, *History of the British Pig*, pp. 67, 70, 86–94.

egory, since he was usually described as a weaver. In pig breeding, which, unlike cattle or sheep breeding, did not require much land, both working men and gentlemen could play a part. The diversity of animals which could be produced was the greater because of the shorter generation interval and greater fecundity of the pig, as compared to sheep or cattle.

The same considerations also applied to poultry, and it is interesting to note the enormous number of poultry breeds in the early twentieth century. For egg production there were the Ancona, Braekel, Campine, Hamburgh, Houdan, Leghorn, Minorca, Redcap and Scotch Grey breeds, and for table poultry, the Bresse, Courtes Pattes, Crevecoeur, Dorking, Indian Game, La Fleche and Sussex. There were also general-purpose breeds such as Faverolles, Langshans, Malines, Orpingtons, Plymouth Rocks, Rhode Island Reds and Wyandottes. As the names suggest, many of these were imported breeds, or their derivatives. Spanish hens, noted for their large white eggs, had been introduced in the eighteenth century to join the native Dorkings, Sussex and Redcaps, but the number of imported breeds increased rapidly after the popularity of the Cochin at poultry shows in the 1850s. Some of these breeds, such as the Minorca, Ancona, Crevecoeur, and Houdan, were of European origin. The Leghorn was developed in the United States from Italian stock and introduced to England in about 1870, and Plymouth Rocks, Rhode Island Reds and Wyandottes were also produced by American breeders. It was perhaps the brown egg laying asiatic breeds which caused most excitement. Langshans, for example, were imported from the Langshan district of northern China in 1872. In the 1880s they were used by a Mr Cook in the creation of the black Orpington. In the years between 1840 and 1875 other Asiatic breeds, such as the Brahma (one was presented to the Queen in 1853), Cochin, Silkie and Yokohama, were introduced, poultry breeding became fashionable, poultry shows expanded and *Punch* wrote about 'poultrymania'. But it was a mania of fanciers, not farmers. Whether or not it increased the production of eggs or table birds was a matter for debate at the time, and remains so. Edward Brown, writing in 1906, summed up the arguments: fancy breeders, it was alleged, concentrated on 'show points, useless for practical purposes, and in many cases antagonistic to production of eggs or meat. But, on the other hand, the enthusiasm of fanciers has led to the introduction of some of our most valuable breeds . . .' Although 'the balance is on the right side', Brown felt that 'we have obtained nearly all the benefit to be derived from the exhibition system', and that the time had come to concentrate on 'the development of economic qualities'.[164]

[164] Wiseman, *History of the British Pig*, chapter 6; Wright (ed.), *Standard Cyclopedia*, vol. x, p. 39; F. Hams, *Old Poultry Breeds* (Princes Risborough, 1978); M. Thompson, 'The evolution of poultry', *The Ark*, 16, no. 8, August 1989, p. 277; E. Brown, *Races of Domestic Poultry* (1906, reprinted Liss, Hants., 1985), p. 24.

Farm horse breeds

The heavy breeds of working farm horses, in contrast, were virtually fixed by the end of the eighteenth century, and remained so throughout the nineteenth. The Suffolk Punch in East Anglia, the Clydesdale in Scotland and northern England, and the Shire (also known as the English Cart Horse or the Heavy Black Horse until the middle of the nineteenth century) in the rest of the country, accounted for most of the farm horses, although the Cleveland Bay might sometimes be used in parts of north-eastern England. Whilst these basic breed types were recognised, there was much variation within them, to the point where some argued that most farm horses were mongrels up to the end of the nineteenth century. Less organised effort seems to have been put into the breeding of Shire horses, compared with cattle, sheep and pigs, until the 1870s: the Earl of Ellesmere began his stud farm, with a thousand acres and a hundred horse boxes, in 1869; stallion-buying companies or associations were established in the Fylde district of Lancashire, Cornwall, south Devon and Kent; and stallion shows with associated hiring arrangements were set up in Montgomeryshire, Staffordshire and Norfolk. All this culminated in the formation of the English Cart Horse Society of Great Britain and Ireland in 1878 (it was renamed the Shire Horse Society in 1884). Prizes were offered at the Royal Show the following year. The Suffolk Stud Book began in 1880, although the activities of the Suffolk Agricultural Society from the 1850s had done much to improve the breed: in the early 1860s veterinary inspections at shows were instituted, and no prize could be awarded to a horse with any major hereditary defect. A similar Board of Agriculture scheme for all heavy horse stallions was not instituted until 1911. Thus the improvement of horse breeding lagged behind that of cattle and sheep. At least part of the reason for this lay in the fact that most farmers had only a few horses, and therefore only a few to select from. Moreover, prize money for farm horses at shows was often less than that for cattle and sheep, although, since many farmers considered that show horses were over-fat and under-worked, this may not have been very significant. Paradoxically, depressed prices for other agricultural products at the end of the century probably gave an impetus to heavy horse breeding: the demand for heavy horses for town work increased until the rise of the internal combustion engine in the first decade of the twentieth century, and prices rose. Few other farm products were in a similar position, and so farmers had some incentive to increase the quantity and quality of the horses they had to sell.[165]

[165] Fream, *Elements of Agriculture*, p. 364; Hall and Clutton-Brock, *British Farm Livestock*, pp. 321, 233; K. Chivers, *The Shire Horse* (London, 1976) pp. 70–3, 85, 111–26, 273–7.

The value of breeds and breeding

It is thus apparent that the large number of breeds which were identified with various regions of the country in the middle of the nineteenth century was not significantly reduced by the beginning of the twentieth. But by then some breeds were much more important than others, as Table 7.6 demonstrates. The Shorthorns accounted for two-thirds of all cattle, three hill breeds for more than a third of all sheep and the white breeds for more than a half of all pigs. Morton, writing in 1878 of the 'surprising permanence' of the various dairy breeds in one small island, attributed it to '. . . the isolation and seclusion in which our agriculturalists have been content to dwell'. The effects of the railways, the greater distance from which the food for the urban population would be drawn, and agricultural exhibitions, would be seen, he argued, in the 'extending supremacy' of the Shorthorn over other breeds, and already '. . . the great bulk of the cattle in our English dairy districts are year by year exhibiting a constantly increasing Shorthorn character'. Yet, he estimated, probably no more than 20,000 cows would qualify for registration in the Shorthorn herdbook. At the same time Clarke, after an exhaustive discussion of the points of the various breeds of sheep, admitted that '. . . over large portions of many counties the breeding flocks consist of old local races, improved by generations of crossing . . .' When the Board of Agriculture conducted its survey of breeds in 1908, respondents were asked to state whether their stock were pure-bred or not, pure-bred being defined as registered or eligible for registration, or stock for which pedigrees were kept. 'In the large majority of instances the replies were placed under the heading "not pure-bred" . . .' Moreover, many animals were simply described as 'cart horses', or 'Irish' cattle, 'Scotch' or 'Down' sheep or 'white' pigs. The figures were presented so that 'The numbers given for each breed represent not only the pure-bred animals of that breed, but also those which, though returned as cross-bred, were mainly of the type of that breed.' It was pointed out that this implied that those breeds which were extensively used for crossing would tend, if anything, to be over-represented. The extent to which pure-bred animals were in a minority can be gauged from the results of a census of pedigree stock carried out by the Ministry of Agriculture in 1919: only 7.4 per cent of the bulls used for service and 3 per cent of the cows and heifers in calf and milk were pedigree animals. The *Standard Cyclopedia of Agriculture* noted that 'Cross bred sheep are . . . universal favourites both with farmers and butchers', so that it was '. . . impossible to give a full list of all the crosses which are locally esteemed'. Half-breds, mules and Mashams were common and popular crosses, but there were many others, such as the Radnor ewes crossed with Shropshire tups, and Shropshire

Table 7.6. *Numbers of livestock of various breeds on agricultural holdings exceeding one acre in Great Britain, 1908. (NB 'The breeds or descriptions are as stated in the returns. Where the description is not that of a definite breed the name is put in italics in the table. Animals of the type or general character of a breed are included in that breed.')*

1. Horses	
Shire	369,567
Clydesdale	203,256
Suffolk Punch	12,032
Carthorse	765,444
Draught Horse	14,721
Hackney	77,086
Pony, Cob, Nag, Roadster	63,101
Welsh	10,880
Highland	7,090
Shetland	6,529
Other breeds or descriptions	15,965
Total	1,545,671
2. Cattle	
Shorthorn	4,413,040
Devon	454,694
Ayrshire	440,000
Hereford	384,877
Welsh	248,401
Aberdeen-Angus	193,960
Irish	188,023
Lincoln Red Shorthorn	168,790
Highland, Kyloes	99,804
South Devon	96,991
Channel Island	101,233
Galloway	31,265
Red Polled or Norfolk	27,232
Sussex	19,660
Other breeds or descriptions	37,164
Total	6,905,134
3. Pigs	
Large White	620,789
Berkshire	459,118
White	440,258
Middle White	399,088
Large Black	300,374

Table 7.6 (*cont.*)

	Black	85,792
	Small Black	50,946
	Tamworth	44,487
	Other breeds or descriptions	157,208
	Total	2,823,482
	(of which breeding sows	369,476)
4.	Sheep	
	Black faced Mountain	5,579,182
	Cheviot	2,650,817
	Welsh Mountain	2,600,131
	Lincoln	1,850,074
	Hampshire Down	1,672,340
	Shropshire	1,603,874
	Scotch	1,173,663
	Oxford Down	1,082,737
	Kent or Romney Marsh	1,044,569
	Suffolk	918,034
	South Down	755,389
	Devon Longwool	750,688
	Leicester	676,556
	Radnor	654,547
	Herdwick	531,457
	South Devon	353,826
	Kerry	331,948
	North or North Country	302,599
	Wensleydale	259,450
	Border Leicester	231,786
	Dartmoor	199,475
	Dorset or Somerset Horned	179,598
	Mashams	173,005
	Exmoor	172,347
	Downs	145,920
	Clun Forest	119,285
	Lonk	113,613
	Dorset Down	99,853
	Shetland	79,756
	Ryeland	28,936
	Cotswold	26,966
	Limestone	12,199
	Other breeds or descriptions	745,105
	Total	27,119,725
	(of which breeding ewes	10,569,089)

Downs crossed with Oxford Downs, found by Rider Haggard in Herefordshire at the turn of the century.[166]

It is possible that the working farmer's usual unwillingness to become involved with pedigree breeding might simply be a reflection of what has been described as 'the reactionary and suspicious nature of the impecunious small farmer'. This phrase was used in explaining the lack of improvement of the native stock in upland areas of Wales. Yet, its author points out, these unimproved animals were readily bought by graziers in the English midlands. The superiority of pedigree animals was far from universally accepted. There was much contemporary criticism of the animals in shows. 'Show condition' was translated as 'a hopeless obesity . . .', breeders seeming to prefer to concentrate on producing fat at the expense of milk or meat. Worse still, much attention was given to even more commercially irrelevant characteristics such as the shapes of horns or the colours of coats. Animals were selected on the basis of appearance and pedigree, not performance, while at the same time the selection pressure – the number of animals from which the breeding animals were selected – was not very great, and numbers of animals entered in each class at the leading shows never very high. This was perhaps understandable in the earlier nineteenth century. When Thomas Bates took his Shorthorns to the first Oxford show in 1839, the journey, by sea and the Grand Junction Canal, took three weeks. The extension of the railway network overcame this problem, but nevertheless the numbers exhibited remained low. At the Royal Show in 1904 one of the largest classes was for Shorthorn bulls calved in 1903: of the thirty-six original entries, ten failed to turn up. But there were only seven entries in the class for Suffolk shearling rams and only three in the Dorset Horn shearling rams. It is perhaps unfair to criticise nineteenth-century breeders for their failure to use selection criteria based on twentieth-century technology and knowledge of genetics, but it may explain why the ordinary farmer was not over-impressed by highly bred stock.[167]

If the pedigree breeder was not working for the benefit of the commercial farmer, what then was the point of the expenditure of all the time, money and effort which undoubtedly went into pedigree breeding in the nineteenth century? It has been argued that the breeding and possession of pedigree cattle, in particular, as opposed to pigs or poultry, was a form of conspicuous consumption, serving to reflect the prestige of the

[166] J. C. Morton, 'Dairy farming', *JRASE*, 14, 1878, pp. 648–9; Clarke, 'Practical agriculture', p. 572; Board of Agriculture and Fisheries, *The Agricultural Output of Great Britain*, Cd. 6277 (1912), BPP, 1912–13, x, p. 529; J. R. Walton, 'Pedigree and the national cattle herd', *AHR*, 34, 1986, p. 156; Wright (ed.), *Standard Cyclopedia*, vol. x, p. 226; Rider Haggard, *Rural England*, vol. 1, pp. 304–7.

[167] R. J. Colyer, 'Some Welsh breeds of cattle in the nineteenth century', *AHR*, 22, 1974, pp. 11–12; Walton, 'Pedigree and the national cattle herd', pp. 164–7; Goddard, *Harvests of Change*,

breeder and distinguish him from the generality of farmers who could not afford to lose so much money. The £1,000 in prize money won by Prince Albert between 1843 and 1861 was much less than the running costs of the royal farms. A 'hierarchical interpretation' of the animal kingdom confirmed the ascendancy of the aristocracy in human affairs and thus reinforced the established social order. Leading breeders were leaders of society. Lord Berwick and Lord Coventry bred pedigree Herefords, the Duke of Portland Shire horses, while the Earl of Ellesmere took a leading part in the formation of the Shire Horse Society. Among the successful breeders at the Royal Show in 1904 were Albert Brassey MP, E. A. Hambro, the banker, Lord Henry Bentinck MP, the Duke of Richmond and Gordon, and the King himself. If anything, the dominance of the aristocracy in the lists of prizewinners seems to have increased towards the end of the nineteenth century. Dr Walton has demonstrated how the concentration of pedigree Shorthorn herds in the counties around London reflected the influence of metropolitan wealth, while the absence of pedigree herds in upland Wales shows the absence of 'those social groups likely to find pedigree attractive'. The mean holding size of pedigree Shorthorn breeders in Oxfordshire before 1880 was 1,527 acres, compared with a county mean holding size of 201 acres, their élite status demonstrated by their leadership of agricultural societies, farmers' clubs and other county organisations. At the end of the 1880s, 10 per cent of British Shorthorn breeders were responsible for breeding more than 40 per cent of all pedigree bulls. However, there is little evidence that their efforts resulted in significant genetic improvement in commercial herds. Some bulls sold for very high prices. Lord Wilton, a fashionable Hereford stock bull of the 1880s, was sold at the dispersal sale of the Carwardine herd in 1884 to an American, a Mr Vaughan, for £3,990. Mr Vaughan proved unable to complete the sale, however, and Lord Wilton had to be sold again the following day, when he was bought by a syndicate for £1,000. But such prices were paid by other breeders, not commercial farmers. This is perhaps one of the reasons why the requirements and objectives of breeders and farmers began to diverge: as long as there were enough pedigree breeders to form a market for each other's stock the whole business could be carried on in isolation from the requirements of the meat and milk producers. If pedigree breeding was a confidence trick, it is not always easy to see who was tricked and who were the tricksters.[168]

Nevertheless, there was one good hard commercial reason for the

[168] H. Ritvo, *The Animal Estate* (Cambridge, Mass., 1987), pp. 42, 55, 62, 81; E. Heath-Agnew, *A History of Hereford Cattle* (London, 1983), chapters 8 and 12, p. 89; Brigden, *Victorian Farms*, p. 118; Chivers, *The Shire Horse*, pp. 111–12; Walton, 'Pedigree and the national cattle herd', pp. 157–8, 160–1; the term 'confidence trick' was used in a review of Ritvo's book by J. Brown in

Table 7.7. *Expansion of sheep and cattle breed societies*

	Number of sheep breed societies formed in the decade	Number of cattle breedsocieties formed in the decade
1870s	–	8
1880s	3	3
1890s	11	3
1990s	9	1
1910s	–	1

Sources: Edith H. Whetham, 'The trade in pedigree livestock 1850–1910', *AHR*, 27, 1979, pp. 47–50. Miss Whetham's figures have been compared with the information given in S. J. G. Hall and J. Clutton-Brock, *Two Hundred Years of British Farm Livestock* (1989) and the *Directory of British Associations* (1986). It should be noted that in several cases the herdbook was published many years before the breed society was formed (e.g. The Shorthorn herdbook was published in 1822 and the breed society was formed in 1875; the Hereford herdbook began in 1846 and the breed society was formed in 1876).

emphasis on pedigree, and for the efforts expended on the compilation of flock and herdbooks and running breed societies: the export trade in breeding livestock. Between 1860 and 1880 exports of live cattle from Britain usually totalled about 500 head per year; between 1880 and 1910 they were never fewer than 2,000 and up to 4,800 head per year. Exports of live sheep, which were less than 4,000 head per year before 1870, were more than 7,000 head per year in most years after 1886. Shorthorns, Herefords and Aberdeen-Anguses became popular breeds in the United States and the dominant breeds in Argentina by 1890. In the early years of the twentieth century Argentinian breeders were major buyers of British pedigree stock. Lincoln, Romney Marsh and Leicester sheep were popular crossing breeds in Australia and New Zealand until the 1890s and after the development of refrigeration increased the ability of those countries to enter the meat market in Britain, the demand switched to meat sires, such as the Down breeds. The demands of the export trade in breeding livestock must therefore be one of the major reasons for the fact that many breed societies were formed in the period between 1870 and 1910, as Table 7.7 indicates.

As far as cattle, in particular, are concerned, pedigree breeders seem to have been very successful in satisfying the requirements of overseas farmers in these years; whether they did as good a job for the home producer is much more open to question. For sheep and pigs the position is even less clear. There is certainly evidence for the small proportion of animals which were pedigree, for the popularity of cross-bred animals among commercial farmers, and for the diverging standards and requirements of commercial farmers and pedigree breeders. On the other hand, the extent to which pig and sheep breeding was dominated by the social and agricultural élite might be questioned. The fact that Joseph Tuley, the name most closely associated with the development of Large White pigs, was a weaver, has often been mentioned, and Copus has demonstrated that in the development of Hampshire and Wiltshire Down sheep '. . . much of the work was done by small working farmers'. He also argues that over the long run, from the seventeenth century to the twentieth, sheep breeds evolved as '. . . rational responses to long term shifts in the relative prices of mutton, tallow and wool, and their relationship in turn with the price of cereals'. As with many other aspects of the development of agricultural technology in this period, the relationship between the élite and ordinary farmers needs further investigation.[169]

169 Copus, 'Changing markets and the development of sheep breeds in Southern England 1750–1900', p. 51.

I
ANIMAL NUTRITION

BY PAUL BRASSLEY

Any discussion of animal nutrition in the latter part of the nineteenth century must be dominated by F. M. L. Thompson's view that the major change was the increased use of purchased feedingstuffs. Accordingly, the following pages examine the use of feedingstuffs in agriculture as a whole, then on individual farms, and go on to attempt to explain the changes which occurred.[170]

Most farm animals were fed on a mixture of forage and root crops and concentrated foods. For ruminant livestock, grass was obviously the most widely used feed. The acreage of permanent grass rose progressively from the 1870s, while the acreage of temporary grass fluctuated between 2.8 and 3.2 million acres between 1870 and 1905, and then declined steadily, as Table 7.8 demonstrates:

These figures understate slightly the total area of crops which might be grazed or cut for hay, in that they exclude lucerne, vetches or tares, and sainfoin. In 1911 it was estimated that 53,000 acres of lucerne were grown, half of them in Essex, Kent and Suffolk. There were 110,000 acres of vetches, which were especially useful in dry summers, being 'soiled' (i.e. zero-grazed) to cows or folded by sheep. In Oxfordshire, in 1914, they were sown in autumn and spring, and were said to '. . . constitute the green food for the flocks in many parts from June until September'. Sometimes peas and rape were sown with them, and in other counties they were mixed with oats. The Royal Agricultural Society carried out trials on fodder maize, but since they were done in the cold, wet summers of the early 1880s they were not a success, although a few acres were grown in the east and south-east of England by the early twentieth century. Gorse was also used as fodder, being crushed or chopped in special mills. Between 5.5 and 7 million acres of grass were cut for hay every year. Yields varied considerably from year to year, averaging less than a ton per acre in the drought years of 1893, 1896, 1901 and 1911, and more than thirty hundredweights in 1889 and 1898.[171]

[170] Thompson, 'The second agricultural revolution, 1815–1880', pp. 62–77.

[171] J. Orr, *Agriculture in Oxfordshire: a survey* (Oxford, 1916), p. 209. The survey was made in the spring and summer of 1914; W. J. Malden, 'Additional crops for cows and sheep', *JRASE*, 72, 1911, pp. 144–6, 148, 150–1. See also *J. Bath & West*, 3, 1855, pp. 206–8, on gorse: MAF, *A Century of Agricultural Statistics* (1966), pp. 105 and 120; J. M. Stratton, *Agricultural Records AD 220–1968* (London, 1969), pp. 124–34.

Table 7.8. *Grass: ten-year average acreages (000 acres) in England and Wales, 1854–1915*

	Temporary grass	Permanent grass	Total grass
1854	2,820.1	12,392.1	15,212.2
1866–75	2,871.6	11,411.8	14,283.4
1876–85	2,995.0	13,319.9	16,314.9
1886–95	3,094.2	14,837.7	17,931.9
1896–1905	3,208.1	15,392.1	18,600.2
1906–15	2,695.8	15,957.7	18,653.5

Sources: The figures for 1854 are taken from G. E. Mingay (ed.), *AHEW*, vol. VI, 1989, p. 1043. 'Temporary grass' includes the acreage returned as 'clover, lucerne and other artificial grasses'. 'Permanent grass' includes the acreage returned as permanent pasture, irrigated meadows, and sheepwalks and downs. Figures for other years are from Ministry of Agriculture, Fisheries and Food, *A Century of Agricultural Statistics* (1966), pp. 96–7.

In the 1880s the practice of conserving grass as silage first began in Britain, although initially silage seems to have been seen more as a substitute for root crops than for hay. By 1890 James Caird was reporting that 'within recent years the system of storing in silos or stacks green grass or fodder of any kind has been successfully introduced'. It was especially useful, he found, on dairy farms. About this time Wrightson described it as '. . . favourably spoken of, and generally accepted, in almost every agricultural district'. In 1892 Fream's *Elements of Agriculture* devoted nearly as much space to ensilage as it did to hay.[172] Some of the impetus to develop the process presumably came from the difficulties of making hay in the wet years of the early 1880s. Moreover, scientists and journalists were clearly fascinated by the idea that bacterial fermentation might produce an acid to pickle grass, and did a lot of work on it. But ordinary farmers were not so excited: a speaker at the 1884 Cartmel Show in the Furness district of Lancashire raised a laugh from his audience by suggesting that '. . . if they got a few more dry seasons silos and ensilage would die a natural death and there would not even be a *post mortem*'. Although some landowners and a few book farmers persisted with experiments, the general view, echoed in the early twentieth-century textbooks, was that 'it cannot be said that in Great Britain the system has generally been adopted – the root crop is of such cultural and

[172] H. M. Jenkins, 'Report on the practice of ensilage, at home and abroad', *JRASE*, 2nd ser., 20, 1884, pp. 126–245; Caird, 'Fifty years progress of British agriculture', p. 33; J. Wrightson, 'The agricultural lessons of "The Eighties"', *JRASE*, 3rd ser., 1, 1890, p. 286; Fream, *Elements of Agriculture*, pp. 227–31.

Table 7.9. *Root crops: ten-year average acreages (000 acres) in England and Wales, 1854–1915*

	Acreage of turnips and swedes	Acreage of mangolds
1854	2,267.2	177.3
1866–75	1,655.9	305.1
1876–85	1,548.7	343.2
1886–95	1,468.1	366.8
1896–1905	1,236.6	385.3
1906–15	1,083.5	439.9

Sources: The figures for 1854 are taken from G. E. Mingay (ed.), *AHEW*, vol. VI, 1989, p. 1043. Figures for other years are from Ministry of Agriculture, Fisheries and Food, *A Century of Agricultural Statistics* (1966), pp. 96–7.

feeding importance, and as a rule a comparatively certain crop, that succulent winter feed is generally obtainable, and it is not often that the conditions are such that a reasonable quality of hay crop cannot be secured'. The advantages of silage, perhaps, were outweighed by the difficulty of making and handling it; silage became popular when these difficulties were overcome by mechanisation in the second half of the twentieth century.[173]

The root crops, principally turnips and swedes, probably reached the peak of their popularity in the middle of the nineteenth century, as shown in Table 7.9.

The decrease in the acreage of turnips and swedes was associated with the general decline in the arable after the 1870s: 'Labour and expenses on the root-crop, with the prospect of £13 per acre gross return on the succeeding corn crop, was one thing. Labour on the root crop, with a wretched prospect of £7 or £8 per acre from the next corn crop, is another and less encouraging result', asserted Wrightson in 1890.[174] To some extent the decline in the turnip and swede crop was offset by the increase in mangolds, especially on heavier soils in the south of the country. Deeper rooting than turnips and immune to attacks of club root and turnip fly, they were also more resistant to drought and more reliable. Moreover they produced, on average, about seven tons more per acre of

[173] The work of the scientists is outlined in H. E. Annett and E. J. Russell, 'The composition of green maize and of the silage produced therefrom', *Journ. of Agric. Science*, 2, 1907–8, pp. 382–3; Mutch, 'Rural society in Lancashire', p. 271; Wright (ed.), *The Standard Cyclopedia*, vol. v (n.d., c. 1910), p. 59; P. Brassley, 'Silage in Britain, 1880–1990: the delayed adoption of an innovation', *AHR*, 44, 1996, pp. 63–87.

[174] Wrightson, 'The agricultural lessons of "The Eighties"', pp. 282–3.

roots of good keeping quality.[175] Academic commentators complained that farmers were too slow in adopting them, but conceded that they demanded more cultivation, more manure, more labour, and needed to be clamped so as to mature before they could be fed. Other fodder crops, it was contended, could also be exploited to greater effect, but in the early twentieth century there were only 65,000 acres of cabbage and kale, 13,000 acres of kohl-rabi, and 78,000 acres of rape grown. In 1911 'helianti', 'a tubering plant of the sunflower order' (presumably Jerusalem artichoke) had recently been introduced.[176]

The total acreage of grass, both permanent and temporary, increased with the number of grazing livestock, but the production of root crops did not (see Table 7.10). It follows that either the output of the grass, as grazing or hay, was increased, or the use of concentrate feeds increased to offset the decline in roots. There is no evidence of larger hay yields,[177] but while the consumption of concentrates increased, it is unclear as to the extent to which it did so (see Table 7.11). Thompson has argued that concentrate use doubled in the thirteen years between 1864 and 1878, and quadrupled between 1847 and 1891. Indeed, applying Thompson's method to the whole period between 1847 and 1913 suggests a sixfold increase, while an alternative calculation, based on Ojala's figures, implies a mere threefold. Moreover, it is important to remember that livestock numbers were rising in this period, so that, as Table 7.11 demonstrates, consumption *per head* rose by less than total consumption: by five times using Thompson's data, and doubling using Ojala's.[178] Whatever the precise figure may have been, there was clearly a significant upward trend.

In some areas the use of concentrate feeds was well established by 1850; in others it was much less common. The overwhelming impression of livestock rations is one of enormous variety. Some combination of grass in summer and hay, straw and roots in winter was the basis of most ruminant rations, but on this theme there were many variations. This diversity is illustrated by Caird's personal observations on the feeding of fattening cattle. In Devon, they were given cut turnips and 4 or 5 lb of cake per day. In Staffordshire, on Lord Hatherton's estate near Cannock Chase, in addition to turnips, swedes, mangolds or cut grass, according

[175] This refers to an average mangold yield for England of 19.51 tons per acre over the period 1904–13, as reported in Orr, *Agriculture in Oxfordshire*, p. 206. However, some dairy farmers on the London clay were reported to produce up to 50 or 60 tons per acre with the aid of London dung. A. D. Hall and E. J. Russell, *A Report on the Agriculture and Soils of Kent, Surrey and Sussex* (London, 1911), p. 84.

[176] Orr, *Agriculture in Oxfordshire*, pp. 206–7; Webb, *Advanced Agriculture*, p. 314; Malden, 'Additional crops for cows and sheep', pp. 141–52.

[177] See data in MAF, *A Century of Agricultural Statistics*, table 62.

[178] For the detailed figures and calculations, see Tables 7.10 and 7.11.

Table 7.10. *Fodder supplies and livestock numbers, 1854–1915*

	Total livestock units (000)	Livestock units per acre of grass	Tonnage of roots per livestock unit
1854	7,137	0.47	4.47
1866–70	8,651	0.63	3.03
1871–5	9,025	0.61	2.96
1876–80	9,295	0.59	2.80
1881–5	9,060	0.54	2.82
1886–90	9,596	0.54	2.59
1891–5	9,763	0.54	2.60
1896–1900	10,080	0.55	2.08
1901–5	10,028	0.54	2.21
1906–10	10,154	0.54	2.48
1911–15	9,954	0.54	1.96

Sources: The figures for livestock units have been based on the grazing livestock unit coefficients in John Nix, *Farm Management Pocketbook* (9th edn, 1979) p. 45, except that for the 1854 data (from G. E. Mingay (ed.), *AHEW*, vol. VI, 1989, p. 1043), calves and cattle are aggregated and multiplied by 0.65, and 'other sheep' are multiplied by 0.2. All other animal numbers, except for horses, have been taken from MAF, *A Century of Agricultural Statistics* (1966), pp. 96–7. These data show that approximately 85 per cent of farm horses in Great Britain were in England and Wales, so the figures for all horses (i.e. on farms and not on farms) given for Great Britain in F. M. L. Thompson, 'Nineteenth century horse sense', *EcHR*, 29, 1976, Table 2, have been multiplied by 0.85. For grass acreages and root tonnages, the figures for 1854 are taken from G. E. Mingay, *AHEW*, vol. VI, and for other years from MAF, *A Century of Agricultural Statistics*, pp. 104, 118–19, 122–9. The total tonnage of turnips and swedes is reported from 1886 onwards. An arithmetical average of the reported production between then and 1915 gives an average yield of 12.67 tons per acre. This figure is then used to convert the acreages of turnips and swedes for earlier years to total production in tons. Mangold production is not reported, but the mangold acreage is. Thus, taking a reasonably conservative figure of 18 tons per acre as the average mangold yield (cf. 20 tons per acre in P. McConnell, *The Agricultural Notebook*, (9th edn, 1919), p. 230) it is possible to convert these acreage figures into average annual production figures. To allow for the effects of weather on root growing conditions, it is assumed that a good year for turnips and swedes would also be a good year for mangolds, and vice versa, and so from 1886 the mangold production figure is adjusted by the percentage variation of the turnip and swede production from the long-run average.

Table 7.11. *Concentrate feedstuff supplies, 1854–1913 (tons per grazing livestock unit)*

Thompson's estimates		Ojala's estimates	
1854–8	0.07	1854–8	0.31
1864–71	0.11	1867–9	0.35
1872–6	0.19	1870–6	0.40
1877–81	0.26	1877–85	0.48
1882–6	0.23		
1887–91	0.25	1886–93	0.48
1894–1903	0.37	1894–1903	0.58
1904–10	0.32	1904–10	0.60
1911–13	0.34	1911–13	0.65

Sources: The figures for grazing livestock units are the same as those used for Table 7.10. The data for feedstuff supplies are those in F. M. L. Thompson, 'The second agricultural revolution 1815–1880', *EcHR*, 2nd ser., 21, 1968, pp. 73–7, and E. M. Ojala, *Agriculture and Economic Progress* (Oxford, 1952), pp. 210–15. The two sets of figures differ because they include different products. Thompson's includes only oil-cakes, maize and maize-meal; Ojala's, wheat, wheat offals, barley, brewer's offals, pulses and molasses in addition. Of these, only wheat offals and brewers' offals were used in quantities greater than 100,000 tons in most years. Thompson's original series ends in 1891: the figures for subsequent years listed above have been calculated from Ojala's data for oil-cake and maize. Ojala's original series does not begin until 1867; figures for the previous period have been produced by assuming a constant rate of growth in the use of cereal offals, and adding the resultant figure to Thompson's estimates. It should also be remembered that both sets of data will overestimate the feedstuffs available per head of livestock, because they refer to the United Kingdom, whereas the livestock unit data is for England and Wales only. In addition, some of these feedingstuffs will have been eaten by pigs and poultry, which are omitted from the livestock unit calculation. Very roughly, 2.5 million pigs, each consuming half a ton of meal per year, and 20 million head of poultry, each accounting for perhaps half a hundredweight of grain per year, would require between one-quarter and one-third of the concentrate feeds consumed, and the figures in this table must therefore be reduced in proportion.

to the time of year, they received corn or oil-cake, beginning with 3 lb per head per day and increasing to 6 or 7 lb. On one farm in Oxfordshire Caird found cattle being stall-fed on 18 lb per day of bean and barley meal, mixed with hay and chaff, but no turnips or other green food: 'This obviously cannot pay', he wrote. He described at length the Dorset farm of the Reverend Mr Huxtable, rector of Sutton Waldron, who fed his cattle on a mixture of ground roots and straw chaff, to which cake and corn were added. Not satisfied with this, Mr Huxtable was in the process of erecting a steaming chest in order to cook a mixture of straw chaff, roots, meal, oil-cake or bran, and cut furze. On Philip Pusey's farm in Berkshire cattle were fattened on 7 lb of oil-cake and a peck of barley meal per day, mixed with hay chaff. Mr Hudson at Castle Acre in Norfolk fed his bullocks on 10 lb of cake per day, besides roots, but generally 4 lb of oil-cake per day was a more common ration.[179]

A similar lack of uniformity is apparent in the feeding of dairy cows. On a farm near Whitehaven in Cumberland, in addition to 56 lb of turnips per head per day, cows were given a cooked mixture of oats, tares and chaff, together with hay and oat straw. Here they were grazed in summer, but on farms at Halewood in Lancashire and Seacombe in the Wirral they were 'house-fed' (zero-grazed) in summer on a mixture of cut clover, Italian ryegrass and vetches four times a day at regular intervals. In other parts of Cheshire, however, Caird found 'nothing particularly good' to report: cows were poorly wintered on straw until after Christmas, 'when they get a few turnips . . . and hay till March or April, when they drop their calves. From that time till the grass is ready the best farmers give them a little bruised oats or oilcake, which is discontinued as soon as they are turned out to pasture.' His most disparaging remarks were reserved for the 'starving system of the dairy farmers of Gloucestershire', who fed their cows on hay alone during the winter, with the result 'that the annual produce of a dairy cow, on the average, does not exceed three and a half hundredweight of cheese, and that fully three acres of land are required for the annual support of each cow'. Stocking rates were similar in Buckinghamshire and in Wiltshire, where he found the cows standing 'shivering at the old-fashioned racks where their scanty provender is supplied'.[180]

In many of the arable areas sheep were mainly fed on crops grown especially for them. At Eynsham in Oxfordshire in 1850 they went on to turnips in October, switched to swedes in December or January and to mangolds in March. In April they were moved on to rye and vetches, in May to trefolium, vetches and trefoil, and in June and July to vetches and clover before going into rape for August and September. In both Northamptonshire and the West Riding of Yorkshire it was said that an acre of turnips would feed eight young sheep for twenty weeks. In some areas turnips and swedes were fed on the ground, but in others they were lifted and sometimes cut before being fed to the sheep. Even on light land in Nottinghamshire turnips were lifted, and the sheep were also given

[179] Caird, *English Agriculture*, pp. 54, 242, 23, 68, 109, 168, 189, 204, 376, 413, 428; Morton, *A Cyclopedia of Agriculture*, vol. II (1856), p. 529; Trow-Smith, *History of British Livestock Husbandry*, p. 311. [180] Caird, *English Agriculture*, pp. 365, 271, 260, 258, 44, 5, 77.

about half a pound of cake per day. In Buckinghamshire, in contrast, Caird found ewes living on grass in both winter and summer, with corn given only in bad weather and around lambing time. On the Lincolnshire wolds cake was only given to ewes with twin lambs. Again, the picture is one of great variation between different parts of the country, and even within small districts, from one farm to another. Horses, in contrast, were generally fed on a mixture of hay, and straw, often chaffed, with oats and bean meal, and sometimes boiled linseed or linseed cake, although Mr Hudson of Castle Acre fed his teams on 12 lb per day of sprouted barley with their fodder.[181]

The non-ruminant livestock of the farm, the pigs and poultry, had traditionally been scavengers. Thus Morton wrote: 'It is an undisputed fact that store pigs do not pay any profit upon purchased food of the usual kinds, namely offal, bran, etc.; but that they must in fact be left, in a great measure, to shift for themselves, so that they pick up the refuse of the farm, the garden and the kitchen; the refuse of the barn, and the stray grains of the fold yards.' This system worked perfectly well when they were kept in small numbers, but increasingly they were being kept in larger herds: Caird found a farmer in Hampshire who kept between 40 and 50 breeding sows and another in Staffordshire who fed 200 pigs. In these circumstances they could no longer survive on what they could pick up, but had to have food provided for them. Another implication of their scavenging origin was that they were kept to what would now seem to be a great age: after weaning at eight weeks they would become store pigs at four or five months. They would then be kept as stores to fifteen or twenty months, living on turnips, mangolds or potatoes during the winter and clover, tares and grass during the summer: 'they should not be less than fifteen months old for first-rate feeders', wrote Morton. Then they might be fattened. The best fattening diet, Morton recommended, was barley meal and water, but it was expensive, so that oat, maize, bean, and pea meal, and coarse flour (middlings) were often substituted, sometimes mixed with skim-milk or whey. Linseed was thought to produce rank flesh and oily fat. Brewer's grains and distiller's wash were also used, and often breweries, distilleries and dairies kept their own herds of fattening pigs.[182]

The mixture of fodder, roots and, sometimes, concentrates was therefore well established as the basis of ruminant nutrition by the middle of the nineteenth century. An examination of the evidence on the feedingstuffs used and recommended suggests that over the next sixty years the most important changes were a widening of the range of concentrated feedstuffs

[181] Morgan, 'The root crop,' p. 388; Caird, *English Agriculture*, pp. 3, 22, 54, 101, 168, 189, 204, 241, 293, 312, 395, 412, 425, 168, 293, 383, 448; Morton, *Cyclopedia of Agriculture*, vol. I, pp. 74–5.

[182] Morton, *Cyclopedia of Agriculture*, vol. ii, pp. 946–9; Caird, *English Agriculture*, pp. 69, 93, 105, 234, 293.

available, an increase in the extent to which they were used, and a corresponding reduction in the reliance placed on roots.

Clarke's account of 'Practical agriculture' in the later 1870s contained several examples of high feeding of sheep and cattle, similar, in many ways, to those described by Caird, a quarter-century earlier. He also mentioned the use of rape cake and decorticated cotton cake. Webb's textbook of *Advanced Agriculture* (1894) recommended the use of palm-nut cake, and of Bibby's Calf Meal and Waterloo Mixed Cake for calves. It also had an interesting discussion on the merits of fattening cattle at fourteen to twenty-four months, instead of the traditional three years. In order to achieve earlier fattening it was necessary to increase the use of cake and meal, up to 4 lb per day in the first year and 7 lb per day in the second. Cattle which were ready for the butcher at three years old would receive 1 lb per day in the first year, 2 lb in the second year, and up to 8 lb just prior to finishing. Webb concluded that there was little difference between the profitability of the two systems, and that early fattening might be better in arable areas and later in grassland areas.[183]

The Farm Prize competitions organised by the Royal Agricultural Society in the late nineteenth and early twentieth centuries provide an insight into the best practice of the time. In 1911, for example, Mr Sherwood, of Playfold near Ipswich, won first prize in class 1 of the competition. He used proprietary concentrates such as Brantom's calf meal and Thorley's cake, but otherwise his animals fed on rations which would not have been unfamiliar to an advanced farmer of the 1870s. Cattle in the later stages of fattening were given 2 lb per day of Thorley's cake and 2 lb of a meal consisting of peas, beans and maize. In winter, milking cows had pulped mangolds, chaff and hay, with 3 or 4 lb of cotton cake and 2 lb of bean meal or cottonseed meal per day, but in summer they were kept on the meadows all day and had no corn. Then in autumn they were given green maize and drum-head cabbage. His flock of pedigree Suffolk sheep lived on grass, kale, mustard and stubbles from June to November, and were given no corn. From November the ewes had ¾ lb per day of linseed cake, crushed oats and bran, increasing to 1 lb per day after lambing. Lambs were given linseed cake, crushed oats, lamb food and split peas or beans *ad libitum*. The tegs were fattened on kale, cabbage, kohl-rabi and swedes, with up to 1 lb per head of cake and corn. The composition of concentrated feeds seems to have become more complicated over time, one textbook going so far as to argue that '... the best results can only be obtained from a mixture of feedingstuffs, and the more complex the mixture the better'.[184]

[183] Clarke, 'Practical agriculture', pp. 503–10; Webb, *Advanced Agriculture*, pp. 474, 486–9.

[184] J. Bainbridge, 'Farm prize competition, 1911: report of judges', *JRASE*, 72, 1911; Wright,

By the early twentieth century the work of agricultural scientists, and especially Kellner (see Chapter 8), had progressed to the stage where a textbook writer felt able to give typical rations which would comply with Kellner's standards. For fattening cattle (per day, per 1,000 lb liveweight) these prescribed 70 lb swedes or mangolds, 7 lb meadow hay, 14 lb oat straw, 4 lb crushed oats, 2 lb undecorticated cotton cake and 2 lb linseed cake. For store cattle a simpler ration of 56 lb swedes or mangolds, 14 lb oat straw and 3–4 lb undecorticated cotton cake was recommended, although the same textbook also asserted that 'The need for "storing" a bullock, in which there is about as much economy as carrying first-class passengers upon a sailing ship . . . has been abolished.' Nevertheless, the author admitted, 'The bulk of British cattle are "stored" for a shorter or longer period', and cattle might be fattened at all ages from eighteen months to three years, although the majority would be fat at between two and two and a half years. It is also interesting to note that it was not until the early twentieth century that soya beans and meal became available as a feed.[185]

The use of proprietary compound feedstuffs, if not universal, was at least a common practice by the early twentieth century. The idea of combining sources of energy and protein was not a completely new one: several firms had begun to produce compound feeds in the 1850s and 1860s. One of the more successful of them was Joseph Thorley, who first produced 'Thorley's Food for Cattle' in Hull in 1856 before moving to London the following year. Other pioneer producers were The Kingston Cattle Food Co. of Hull, and Matthews, Sons & Co. of Driffield in Yorkshire, who in 1864 made cakes of various sorts of finely ground corn mixed with locust beans and spices. Compounds were convenient for farmers, saving the necessity of mixing small quantities of several different ingredients. For oilseed crushers and millers they were a means of diversification into new markets. Thus it is not surprising to find that some of the first firms to enter the market were located in Hull, the centre of the linseed crushing industry. The Waterloo mixed cake, mentioned above, for example, was made by the Waterloo Mills Cake and Warehousing Co. Ltd, which began as Ayre, Chambers and Ayre, and in 1873 took out a patent for producing a compound cake 'according to the recommendations of Dr Voelcker'. (Dr Voelcker was the consulting chemist to the Royal Agricultural Society.) British Oil and Cake Mills (BOCM) and Ranks were also based on Hull. Bibbys began as corn millers near Lancaster. Joseph Bibby was quick to recognise the significance of American competition in the flour trade, and began the production of Rapid Fattening Meal, Dairy Cow Meal and Excelsior calf

[185] Wright, *Standard Cyclopedia*, vol. III, pp. 141–2; J. B. Bibby and C. L. Bibby, *A Miller's Tale*

meal in 1878 in an attempt to diversify his business. The firm's move to Liverpool in 1885 reflects the increasing importance of cottonseed cake, and other successful firms followed them: Silcocks, who began to produce compounds in 1871, in 1898, and Calthrops (later to merge with Crosfields) was founded there in 1893.[186]

The mixtures of ingredients used in the production of compound feeds were often complex. A typical batch of fattening cake produced at the Phoenix Mill in Liverpool in 1907 would have contained, in hundredweights:

Rangoon Rice Meal (22), Bombay Cottonseed Cake (14), Ground Bombay Cottonseed (4), Dark Decorticated Meal (9), Hemp and Rape Cakes (14), Ravison [i.e. rapeseed] Meal (5), Maize Germ (4), Dried Grains (2), Locust Meal (2), Mixed Spices (2.5), Treacle (10).

This produced a 19 per cent protein cake. The same firm also produced a 16 per cent protein fattening meal, a 14 per cent protein feeding and dairy cake, and a calf meal. There were also products for non-ruminant livestock. Spillers and Bakers Ltd made a compound poultry feed from 1902, and George Rackham, who farmed at Hethel near Norwich and won first prize in the Royal Agricultural Society's farm prize competition in 1911, fed his bacon pigs on three parts foreign barley, one part gram (chickpea meal), one part middlings and one part 'Uveco'. Until the mid-1890s most compounds were supplied in the form of a cake or slab which the farmer broke up in the same sort of machine which he used to break up straight oil-cake. Thereafter, manufacturers began to offer ready-broken cakes, and by 1903 Bibbys were selling Cakettes, a compound formed, by a special machine, directly into nuts. Designed for feeding to cattle, they were complemented by Cakelettes, which were smaller and intended for calves and sheep. Although most farmers seem to have still been buying their concentrated feedingstuffs as straights in the early twentieth century, the use of branded proprietary compounds was clearly increasing. In 1885 Bibbys could produce 300 tons of compound per week. In 1895 they could produce ten times as much, although they would only do so at periods of peak demand in the winter. By 1902 their annual sales of compounds exceeded 100,000 tons, and by 1914 they claimed to be selling almost 200,000 tons. Their rivals, too, used the tactics of extensive advertising and discounts to distributors in order to increase sales, and not only for compounds: by 1914 R. & W. Paul of Ipswich achieved a national reputation for their 'Kositos', which was simply cooked, flaked maize.[187]

[186] H. W. Brace, *History of Seedcrushing in Great Britain* (London, 1960), chapter 7; Bibby and Bibby, *Miller's Tale*, chapters 1–3.

[187] Brace, *Seedcrushing*, chapter 7; Bibby and Bibby, *Miller's Tale*, chapters 1–3; Bainbridge, 'Farm

It seems likely, therefore, that the most significant change in feeding practices over the period 1850–1914 was the increasing part played by concentrated feedingstuffs. To take oil-cakes as an example: in 1850 home production and imports only amounted to about 180,000 tons, whereas by 1911–13 consumption had expanded to 1.25 million tons. To compare this figure with the tonnage which would have been consumed had every farmer fed according to best practice (or, at least, the practice of those who were written about in the textbooks and journals), is a very speculative exercise, requiring some heroic assumptions about the quantities fed per day and the number of days they were fed. If, despite these caveats, the exercise is carried out, it suggests that there was nowhere near enough oil-cake for all to be fed according to recommended standards in the mid-nineteenth century, but rather more in the early twentieth, although still falling short. These findings are consistent with Professor Thompson's conclusion that in 1880 sufficient oil-cake and maize was being used to feed half the British cattle herd (if it had been fed exclusively to them, which of course it was not); and consistent also with Dr Morgan's calculation which showed that roots provided over 40 per cent of the energy content of farm-produced foods in 1870. But, tentative as they are, they cast doubt on the extent of high feeding in the 1850s and 1860s.[188]

It is clear that by the 1850s the use of roots and concentrates was established practice in the feeding of livestock. But the fact that they were regularly and extensively used by some farmers does not necessarily mean that they were used by all. Neither the writers of the Prize Reports in the Royal Agricultural Society's Journal, nor Caird, appear to be reflecting the common standard of management. As Caird stated in his conclusions: 'In the preceding Letters the details of good farming are given much more at length than instances of the reverse, as it was from the first only that instruction could be drawn. This was from no want of examples of antiquated farming . . .', and, indeed, he did include some of these examples. His remarks upon the dairymen of Gloucestershire have been noted above. He described a farm in Buckinghamshire with only a few acres of turnips, none of the mangolds or other roots, and 'scarcely any purchased feeding stuffs'. On the chalk downs between Winchester and Basingstoke he found that 'A few use cake and corn extensively, in addition to roots and green food, both summer and winter; but the great proportion of occupiers cannot afford to do so, and continued to feed their flocks on the green crops produced by the land, without aiding them even by the use of the turnip cutter.' Of nine-tenths of the dairy farmers around

prize competition, 1911: report of judges', p. 310; Holderness, 'Agriculture and industrialization in the Victorian economy', Mingay (ed.), *The Victorian Countryside*, p. 192.

188 Thompson, 'Second agricultural revolution', p. 71; Morgan, 'The root crop', pp. 386–7.

Birmingham he wrote: 'having little means they keep their cows wretchedly'. The Prize Report on the farming of South Wales in 1849 made no mention of the use of oil-cakes, and indeed a report on Pembrokeshire in 1887 referred to 'ample room for the increased use' of them. Karkeek's report on Cornwall in 1846 referred to half-starved cattle and argued that 'oilcake had scarcely been seen by one farmer in a thousand'.[189]

This variation from one farm to another, and from one part of the country to another, was still apparent later in the century. 'To many graziers and stock-rearers in other counties the expenses of Devon and Cornwall farmers for purchased feeding-stuffs would, with but one or two exceptions, seem mere trifles', wrote one commentator in 1890. Conversely, the amount of oil-cake used on the farms of the Yorkshire Wolds was said to have doubled in the decade after 1850, to the point where the cake bill might equal the rent bill, resulting in great improvements. The same variability is attested to by the small amount of farm-account evidence which is available. Caird's table of cultivation costs on farms in Lincolnshire and Yorkshire in 1850 revealed a range of expenditures on bought-in feeds from 2.6 to 13 per cent of total costs. The evidence presented to the 1896 Royal Commission on Agriculture produced a similar picture: on two Cambridgeshire farms over the period 1874 to 1894 expenditure on feedingstuffs as a percentage of total costs varied between 2.5 per cent and 5.6 per cent; on an 800-acre farm in South Wiltshire it rose from an average of 8.6 per cent in 1869–73 to 20.1 per cent in 1889–93; and on a similar-sized farm in south Dorset from 9.5 per cent in 1876–9 to 18.25 per cent in 1890–3. On the South Wiltshire farm the labour bill always exceeded the feedingstuffs bill until 1878; after 1883 it was always the other way round. On the other farms the labour bill was always the greater of the two. In 1890 Caird wrote, 'From the new starting point in 1851, when the best farming was exceptional, there has been little advance from the best practice then reached . . . The use of purchased manure and linseed cake, in addition to the manure of the farm and its green produce, was spreading slowly in the better-farmed districts.' Later, and more succinctly, Trow-Smith agreed: 'Good mid-twentieth century practice had already arrived, here and there, in 1860.' For feedingstuffs in the late nineteenth century, it seems, it was one thing to pioneer a new method, ingredient or practice, and quite another to get it widely adopted.[190]

[189] Caird, *English Agriculture*, pp. 9, 14, 93, 228; C. S. Read, 'On the farming of South Wales', *JRASE*, 10, 1849, p. 154; Barrow Wall, 'The agriculture of Pembrokeshire', p. 95; Karkeek's remark is quoted in F. Punchard, 'Farming in Devon and Cornwall', *JRASE*, 3rd ser., 1, 1890, p. 515.

[190] Punchard, 'Farming in Devon and Cornwall', p. 521; Adams, 'Agricultural change in the East

There were several reasons why many mid-nineteenth-century farmers were reluctant to use bought-in feeds. Some of their contemporaries felt that it was a matter of ignorance or inertia. Caird, referring to the middle of the century, wrote that '. . . the investigations of the Royal Agricultural Society showed that the cost of feeding farm horses varied immensely, as much as 50 per cent within a few miles, from want of knowledge, economy and care'. His criticisms were repeated by C. S. Orwin, reviewing the Royal Agricultural Society's 1913 farm prize competition, covering the counties of Gloucestershire, Somerset and Dorset: on some farms, he wrote, '. . . the vaguest notions frequently prevailed as to the nature and quantity of the various feeding rations'. On the other hand, what appeared to some as blind prejudice might be more soundly based: '. . . it is generally agreed that pig-feeding does not yield a profit except in the shape of the resulting manure', wrote Clarke in 1878, and thirty years later tortuous calculations could be found in textbooks addressing the same question in relation to cattle fattening. The question of whether high feeding was profitable in itself, or whether it could only be justified as a way of producing manure, was one which rumbled on throughout the whole of this period.[191] The fact that it did so presumably means that the answer never became so clear-cut that the majority of farmers moved in one direction or the other. It would depend upon the individual farm and the preferences and circumstances of the individual farmer. And if cereals and oil-cakes were expensive in comparison with hay, straw and roots, compound feedstuffs might be more expensive still. In 1858 a pig-feeding experiment was carried out at Rothamsted which demonstrated no advantage in using compounds, or 'manufactured foods' as they were called. Lawes subsequently pointed out that a mixture of barley meal at 8s. 4d. per hundredweight, beans at 9s. 4d. and oil-cake, at 10s. 0d. per hundredweight would work as well as heavily advertised manufactured foods which would cost from 40s. to 50s. per hundredweight. The only extra ingredients in manufactured foods were turmeric for colouring and cumin and anise for flavouring. 'The virtues which they really do possess over and above those which could be secured at one-fifth the price, are confined, therefore, to the action on the health and digestion of the animals, of the small amount of stimulating and carminative seeds which they contain. In fact, so far, they are sauce or medicine, rather than food.'[192]

of Expenditures and Outgoings on Certain Estates in Great Britain and Farm Accounts reprinted from the Reports of the Assistant Commissioners, BPP, 1896, XVI (c.1825), appendix 1; Caird, 'Fifty years of progress', Trow-Smith, *History of British Livestock Husbandry*, p. 303.

191 Caird, 'Fifty years of progress', p. 22; C. S. Orwin, 'Farm prize competition, 1910', *JRASE*, 74, 1913, p. 324; Clarke, 'Practical agriculture', p. 532; Webb, *Advanced Agriculture*, pp. 485–509; Wright, *Standard Cyclopedia*, vol. III, p. 145. See also *supra*, pp. 72–137, *passim*.

192 J. B. Lawes, 'Observations on the recently-introduced manufactured foods for agricultural stock',

Another reason why farmers might be suspicious of bought-in feeds was fear of adulteration. The 1892 report on the adulteration of fertilisers and feeding stuffs concluded that adulteration of oil-cakes was 'particularly prevalent'. The adulterants of linseed cake, for example, known in the trade as 'buffum', included corn-flour extract, saccharum meal, bran, rice-meal fannings, ground nut cake, niger cake, ground and dried olive refuse, the husks of various kinds of grain, and cocoa-nut fibre. Castor oilseed, which was poisonous, and sand, might also be added.[193]

Despite all these problems more animals were being fed to higher standards in 1914 than in 1850. They were being fed on roughly the same amount of grass and rather fewer roots per head, and were probably fattened more quickly and yielded more milk. They must, therefore, have been eating more concentrated foodstuffs, as either straights or compounds (see above). There are several reasons for this increase. One of the least quantifiable is the demonstration effect. The ordinary farmer, particularly if he attended agricultural shows, meetings of the local agricultural society, the 'farmers' ordinaries', or from time to time read an agricultural newspaper, would know of the exploits of the progressive farmers, and eventually might decide to imitate them. The direction of the effect is clear; to measure it is much more difficult. As the price of purchased feeds fell, so farmers should have been more willing to buy them. The cost of grain feeds fell with the rise in imports after 1875 and the lowering of internal transport costs due to the extension of the rail network. Oil-cake prices fell too, from a peak of £11.45 per ton in 1874 to a minimum of £5.73 in 1896, after which they rose again, reaching £9.12 in 1912. The price per ton of grain offals exhibits the same pattern, reaching its maximum of £8.83 in 1875 before declining to £4.35 in 1896 and then rising to £6.93 in 1912.[194] If these prices are corrected to a constant price basis to take account of changes in the value of money, the basic pattern remains but the amplitude of the variation is reduced. The increasing importance of the corn mills at the ports, where they could process imported grain, meant that the country mills, if they were to survive, had to find alternative products, and many of them went over to provender milling. Joseph Rank, head of one of the major port milling firms, visited Wiltshire in 1907 and found that 'round about that county there are mills which just grind pig's food and cattle food'. Hard times for the country millers enhanced the supply of concentrates to the farmer.[195]

[193] *Report of the Departmental Committee appointed by the Board of Agriculture to Inquire into the Adulteration of Artificial Manures, and Fertilizers, and Feedingstuffs used in Agriculture*, C.6742, 1892, p. ix.

[194] These figures are taken from the unpublished working papers of J. R. Bellerby, kept at the Rural History Centre, University of Reading.

[195] R. G. Burnett, *Through the Mill: the Life of Joseph Rank* (London, 1945), p. 159.

Thus market forces increased the likelihood of farmers using concentrates. So, too, did legal and institutional factors. The problems of adulteration identified by the 1892 Committee were addressed by the 1893 Fertilisers and Feedingstuffs Act, which enabled farmers to have samples tested by the District Analyst. By so doing the Act extended to all the option previously open to a relatively few farmers, such as members of the Royal Agricultural Society, who had been able to send samples to the Society's analyst since 1865. However, the analysis still had to be paid for, so even here the opportunity was not always taken up. Accordingly, in 1904, Lindsey County Council appointed two inspectors to take samples on its behalf, and at its expense, where an offence was suspected. The Board of Agriculture was so impressed by the results of this initiative that it recommended the practice to other councils. The 1904 Fertilisers and Feedingstuffs Act required manufacturers to give a guarantee of the chemical analysis of their products, at least as far as their major constituents were concerned, albeit subject to fairly wide margins of error. Another piece of legislation which encouraged the use of purchased feedingstuffs was the Agricultural Holdings Act of 1875, which allowed outgoing tenants to be paid compensation for their unexhausted manurial residues. However, the impact of the first Act was reduced because landlords were allowed to contract out of its provisions, and many of those in Wales did so. The 1875 Act, and subsequent Acts, were an attempt to extend to the whole country by legislative means a practice which was already widely adopted in some counties by 1850. It was particularly associated with Lincolnshire, and was often known as 'The Lincolnshire Custom', but it was found in other counties too. Sir Tatton Sykes, and other landowners on the Yorkshire Wolds, gave tenant-right on oil-cakes from the early 1840s. One agreement made then for a farm at Sewerby allowed for the recovery of one-sixth of the cost of cake used in the penultimate year of a tenancy, and one-third of the cost in the last year. Leading agricultural commentators were split as to the effectiveness of the system: Philip Pusey supported it to the extent that he tried to get it brought into law, but James Caird was opposed to it, on the grounds that it led to fraud, perpetuated bad husbandry, and absorbed the capital of the incoming tenant. He had the better of the argument in the 1850s, but it was Pusey's policy which prevailed in the end. The increase in knowledge brought about by scientific research on feedingstuffs was considerable (it is discussed in Chapter 9), but how far it encouraged the greater use of bought-in feeds is uncertain.[196]

[196] Haresign, 'Agricultural change and rural society on the Lincolnshire Fenlands', p. 362; Brace, *History of Seed Crushing*, p. 61; Adams, 'Agriculture in the East Riding of Yorkshire', pp. 317–20; Orwin and Whetham, *History of British Agriculture* (2nd edn, 1971), pp. 170–2; Caird, *English Agriculture*, p. 507.

To summarise: in the years between 1850 and 1914 grass, forage and root crops remained important in the feeding of both ruminant and non-ruminant livestock. Bought-in feeds were used more in the later part of the period, but not to the point where they became dominant: even a textbook published just before the First World War could conclude that 'the base from which the farmer starts to earn a profit in fattening cattle is the economical production of turnips and straw'.[197]

[197] Wright (ed.), *Standard Cyclopedia*, vol. III (n.d., *c.* 1909–14), p. 145.

J
ANIMAL HEALTH AND VETERINARY MEDICINE

BY PAUL BRASSLEY

The story of veterinary medicine in the late nineteenth century comprises three interwoven strands: the development of veterinary knowledge; the development of legislation and the state veterinary service; and the development of the veterinary profession. None can properly be understood in isolation from the others.[198]

Even in the 1860s the theories of Galen, that disease arose as a result of the corruption of decaying matter to form a 'miasma' which was carried by the atmosphere to susceptible animals, were widely accepted. H. Thompson, a member of the Royal College of Veterinary Surgeons, in a standard agricultural textbook of 1894, observed that pit ponies rarely suffered from tetanus, and concluded that 'This shows that the atmosphere has something to do with producing tetanus.' Alternatively, it was held that disease was spontaneously generated within an animal itself. There was also widespread acceptance of the belief in animal disease, especially when it reached plague proportions, as a form of divine retribution. Consequently methods of treatment often involved bleeding, purgatives and drugs of dubious efficacy. Advertisements for patent veterinary medicines can be found in the *Journal of the Royal Agricultural Society* from the 1860s onwards. Elliman's Royal Embrocation was promoted as a cure for any number of conditions, from sore throats and chapped heels to wind galls and foot and mouth disease (1875). Messrs Day, Son, and Hewitt of London and Wantage recommended their Gaseous Fluid for colic and gripes in horses and oxen, and their Red Drench for cleansing after calving and lambing and all inflammatory disorders (1865). Many advertisements printed letters from satisfied customers, such as Capt. H. Barton of Rock Ferry, who told Francis Cupiss MRCVS, the maker of Cupiss's Constitution Balls ('For Neat Cattle they are a most valuable medicine in case of Hove or Blown, Hide Bound, Loss of Appetite, Distemper or Influenza . . .') that 'In the Epidemic that visited my Cattle, your Balls prevented my slaughtering several.'[199]

[198] Much of the material for this section is taken from Iain Patisson, *The British Veterinary Profession 1791–1948* (London, 1983) and Ministry of Agriculture, Fisheries and Food, *Animal Health: a Centenary, 1865–1965* (London, 1965).

[199] MAF, *Animal Health*, p. 127; J. R. Fisher. 'Animal health and the Royal Agricultural Society in its early years', *JRASE*, 143, 1982, p. 107; Webb, *Advanced Agriculture*, p. 254; Patisson, *British*

Nevertheless, it would be unfair to suggest that veterinary medicine was totally bound by tradition in the later nineteenth century, for some significant advances had been made. In 1865, for example, Professor Gamgee reported that the onset of cattle plague was signified by an increase in the victim's temperature, and by the end of the decade it was clear that the clinical thermometer would soon become established as an aid to diagnosis. In 1865 the classical report and description of swine fever appeared in the *Journal of the Royal Agricultural Society*. Cooper's dips for the control of scab in sheep, based on arsenic and sulphur, had been available from the 1840s, and cresol-based dips from the mid-1870s. In 1881 an Army vet produced the first description of a trypanosome, in 1884 the link was made between rickets and defective diet, and in 1885 there were reports of the use of cocaine as a local anaesthetic. In 1896 X-rays were first used for a veterinary purpose, to locate a piece of metal in the leg of a cat. However, the two factors which most influenced veterinary practice in this period were developments in microbiology and the increasing attention paid by government to the problem of animal disease.[200]

In the early 1860s *The Veterinarian* carried an article on Pasteur's work on fermentation and putrefaction and another on the observations of Casimir Davaine, a French physician who observed bacteria in the blood of a sheep which had died of anthrax. In 1876 the German physician Robert Koch proved the connection between bacteria and anthrax and effectively demolished the spontaneous generation or miasma theories of disease. In 1881 he developed a technique for producing pure cultures of bacteria, which enabled him to identify the tubercle bacillus. In the same year Pasteur discovered the principle of attenuation of microorganisms, which led to immunisation. By 1890 Koch had produced tuberculin, which enabled cattle to be tested for the presence of tuberculosis. Mallein, working on the same principle, could be used to test for glanders. From the early 1880s onwards the work of Koch and others enabled an ever-widening range of diseases, including tuberculosis, glanders, anthrax and tetanus, to be linked to their causal organisms which were visible under the microscope. Other diseases, such as foot and mouth and cattle plague, did not respond to this technique. Then in 1898 the Germans Loffler and Frosch demonstrated that fluid from foot and mouth disease vesicles, passed through a porcelain filter with pores too small to allow the passage of bacteria, could still produce foot and mouth disease when injected into cattle. They had discovered viruses. The following year John McFadyean demonstrated that African horse-sickness was also a virus disease.

Several diseases attracted the attention of government. Following the

200 Patisson, *British Veterinary Profession*, pp. 72, 96, 114; MAF, *Animal Health*, pp. 166. 171.

removal of duty on imported animals in 1846 increasing numbers of foreign cattle and sheep began to enter the country, and with the sheep, in 1847, came sheep pox. It proved relatively easy to control through the provisions of an Act of 1848 which provided for the control of sheep importation and the inspection at the ports of cargoes of sheep. Cattle plague (rinderpest), which had been endemic in continental Europe for many years, was much more difficult to control. At the end of May 1865 a cargo of cattle and sheep originating from the Baltic port of Reval was put ashore at Hull. The animals were dispersed to Manchester and London. Towards the end of June 1865 Mr Priestman, a veterinary surgeon, was called to see some sick cows in two London dairies. Within five days twenty of them had died. On 4 July Priestman consulted Professor J. B. Simonds of the Royal Veterinary College, who conducted a post-mortem examination. On 10 July Simonds reported verbally, and four days later in writing, to the Clerk of the Privy Council, that cattle were dying. Acting under the terms of the 1848 Act designed to prevent the spread of sheep pox, the Privy Council issued an Order on 24 July that all suspicious cases should be reported to it. By then there were eighty-two centres of infection. Soon it was apparent that the cargo from Reval was the source of infection.[201] In August an Order in Council was issued conferring the power of slaughter on local authorities. It was up to farmers to report the disease in their herds, and they received no compensation. In September a Form of Prayer was ordered for use in every church. By then the disease had reached Scotland. On 29 September a Royal Commission was appointed. It issued an interim report recommending the discontinuation of the slaughter policy. By the end of the year it recommended that slaughter should be recommenced. In January 1866 the Archbishop of Canterbury wrote to the Home Secretary suggesting that 'The continuance of the Cattle Plague with unabated severity appears to call for the appointment of a Day of National Humiliation.' The government decided to continue with the Form of Prayer issued in September. On 12 February it introduced the Cattle Diseases Prevention Bill, which, receiving the Royal Assent on 20 February, provided for the appointment of local authority inspectors with power to enter premises and to order the slaughter of animals which they believed to be infected

[201] The question of when the disease was diagnosed as cattle plague, and by whom, is still a matter of controversy. R. Perren, in *The Meat Trade in Britain, 1840–1914* (London, 1978) p. 108, follows MAF, *Animal Health*, p. 17 in stating that it was Professor John Gamgee who made the first diagnosis, on or shortly after 29 July. Patisson's *British Veterinary Profession* (p. 59) argues that it was Simonds, and implies that he made the diagnosis by about the middle of the month. Gamgee, argues Patisson (p. 62), had business reasons – his Albert Veterinary College in Bayswater was in financial difficulties and failed two years later – for attempting to claim the credit for the diagnosis.

by plague. The owner was to be paid half of the value of the animal, up to £20, in compensation. Animals which had been in contact with the disease might also, at the discretion of the local authority, be slaughtered, at a higher rate of compensation. The movement and importation of cattle were severely restricted. The Act was an immediate success. In the week in which it was passed 17,875 fresh cases of plague were reported. A month later the corresponding figure was 9,388, and a month after that 4,963. In the third week in November only eight fresh cases were reported and in September 1867 the country was officially declared free from plague. The official estimate put the number of cattle attacked by plague at 278,943, which, according to the Earl Cathcart, was an underestimate due to misreporting and panic slaughtering. The real figure, he thought, should be nearer to 420,000. In the worst affected areas, such as Cheshire, more than half of all cattle may have been affected.[202]

Cattle plague was an extremely infectious disease with a high mortality rate, which spread rapidly through the national cattle herd. But it is worth retelling the story of its spread and control for two other reasons: the successful efforts to control it brought about the acceptance of the principles of slaughter with compensation and import control; and it led to the formation of the state Veterinary Service.

To the layman, slaughter appeared to be a policy of callous despair. If disease in humans could be treated, or prevented by vaccination, argued the letter writers in the press, why not disease in animals? Numerous drugs were tried, but none worked. Even if vaccines had been available, their use would simply have concealed the presence of the disease. Gamgee and Simonds may have had their differences over the initial diagnosis of the plague, but they were united in their recommendations for its treatment: slaughter and movement restrictions. By early February 1866 a conference of farmers' organisations agreed with them. Slaughter was introduced. Subsequent outbreaks of cattle plague in 1872 and 1877 were easily controlled.[203]

The success of the policy had implications for the treatment of other diseases, the functions and status of vets, and government involvement in animal welfare. In 1865 the Cattle Plague Department was set up in the Home Office. The following year it was transferred to the Privy Council, and in 1870 it became known as the Veterinary Department. On taking over the publication of the annual agricultural statistics in 1883 it became the Agricultural Department of the Privy Council, before reverting to

[202] MAF, *Animal Health*, pp. 22, 128–34; J. R. Fisher, 'The economic effects of cattle disease in Britain and its containment, 1850–1900', *Agric. Hist.*, 54, no. 2, 1980, p. 294; Earl Cathcart, 'The present state of the cattle plague', *JRASE*, 2nd ser., 2, 1866, p. 498.

[203] Patisson, *British Veterinary Profession*, pp. 59–60; Fisher, 'The economic effects of cattle disease', p. 281.

the title of Veterinary Department when it was transferred to the new Board of Agriculture in 1889. Its staff were responsible for administering the controls over the importation of animals and the legislation for the control of animal diseases. A series of Contagious Diseases (Animals) Acts, in 1869, 1878, 1884, 1886, 1890, 1892 and 1893, were all eventually subsumed into the Diseases of Animals Act 1894. As the legislation developed, the principle of notifiability, slaughter of infected animals and those in contact with them, and control of the movement and importation of animals, which had originally been developed to deal with Cattle Plague, were gradually extended to deal with more and more diseases: the 1878 Act dealt with pleuro-pneumonia, swine fever and glanders, and subsequent Acts with foot and mouth disease, rabies and anthrax. Sheep scab was made a notifiable disease in 1870, but it was not until 1907 that compulsory dipping of all sheep was instituted. In an era of free trade, it is perhaps remarkable that such exclusionist policies could be introduced. Indeed, one commentator has described them as '. . . the one major political achievement of the British Agricultural interest in the late 19th century'. One explanation for this must be their success. In the period 1855–60 contemporary estimates put the losses from disease at more than 2,250,000 cattle worth nearly £26 million. Between 1884 and 1900 there were no major outbreaks of disease.[204]

The practice of veterinary medicine was therefore changed by advances in scientific knowledge and by the intervention of the state. If the veterinary surgeon was popularly perceived as a professional at all in the mid-nineteenth century it was primarily in association with the treatment of horses. Although the Royal Veterinary College had been founded in the eighteenth century it was not until 1842 that J. B. Simonds was appointed as the first Professor of Cattle Pathology, his chair financed by the Royal Agricultural Society. The Royal College of Veterinary Surgeons (the RCVS, the professional organisation, as opposed to the Royal Veterinary College, the teaching organisation) received its first Charter in 1844, but the enquiries which were made in the course of compiling the first register of veterinary surgeons in 1852 revealed the existence of 1,733 graduate vets and about 6,000 others, variously described as horse-doctors, cowleeches, farriers, gelders and so on, who also made a living out of the treatment of animals. In 1862–3 there were 1,018 members of the RCVS, 1,244 qualified people calling themselves veterinary surgeons and 1,189 other people in some form of veterinary practice. Not until the Veterinary Surgeons Act of 1881 was it possible to prevent those who were not registered with the RCVS from calling

[204] Patisson, *British Veterinary Profession*, p. 61; Foreman, *Loaves and Fishes*, pp. 61–2; MAF *Animal Health*, pp. 66–7, 165–7; Fisher, 'The economic effects of cattle disease', p. 292.

themselves veterinary surgeons, although there were even ways round this: in 1896 the RCVS found it necessary to forbid the practice of 'covering', in which a qualified vet used an unqualified assistant to carry out treatment which properly required professional skill.[205]

The education of vets was gradually improved. More journals became available. *The Veterinarian* had been published monthly from 1828. In 1875 *The Veterinary Journal* was launched, to be joined in 1888 by *The Veterinary Record* and *The Journal of Comparative Pathology and Therapeutics*. In the 1830s it was possible to gain a qualification after a course lasting only one year. By the 1880s this had been extended to three years. Between 1881 and 1900 the annual output of qualified men averaged 118, '. . . and if that had gone on there would have been quite a decided superfluity of veterinary surgeons in the country, far more than were required', according to Sir John McFadyean, Principal of the Royal Veterinary College. Accordingly the RCVS made the entrance examinations for veterinary students harder, and added a year to the curriculum from 1895, which reduced the number qualifying each year to about eighty in the first decade of the twentieth century. The examiners noticed an improvement in standards, which was probably necessary: in the early 1890s *The Veterinary Record* felt it necessary to print some of the less competent and literate efforts produced by students in the final examinations, declaring them 'a disgrace to the profession'. In the following decade more universities mounted veterinary courses, so that by 1905 it was possible to take degrees at London, Liverpool, Edinburgh and Dublin, a diploma in Veterinary State Medicine at Manchester, and a long-vacation course at Cambridge Medical School. Nevertheless, when the Register of the RCVS was brought up to date in 1908 it was found to contain about 3,400 names, only about twice the number practising in 1852, since when life had been made much more difficult for unqualified practitioners. Even in 1921 there were only five full-time veterinary research workers in the whole country. It was not surprising that the Board of Agriculture, in 1912, found it necessary to set up a departmental committee to look into the supply of qualified veterinary surgeons for the public service. It found that the supply was 'inadequate', and recommended the provision of grants and scholarships, and more money for the veterinary colleges, although it accepted that the supply of newly qualified vets was adequate for the demands of general practice. Indeed, there is some evidence of over-supply. In 1887 *The Veterinary Journal* published a letter from 'Veritas' attacking the 'disgraceful' salaries paid to veterinary assistants: 'There are scores of cases where men . . . are earning some hundreds a year for their masters, who receive the magnificent sum of about 30s. a week. This

[205] Patisson, *British Veterinary Profession*, pp. 18, 44, 133.

should not be the case. A good assistant should receive at the rate of £120 to £150 a year.'[206]

Thus the veterinary profession was still beset by difficulties at the beginning of the twentieth century. But it had also overcome some major problems. It was no longer so dependent on the horse, which was fortunate for its future survival and well-being: *The Veterinary Record* in 1911 reported that the London General Omnibus Company was selling one hundred horses per week; shortly afterwards it carried a letter from a vet describing the motor car as 'a necessary adjunct to a veterinary practice'. It was gradually becoming a better organised and educated profession, increasingly employed by the state. Perhaps most important, it had become better scientifically informed by a series of fundamental discoveries about the nature and origin of animal disease.[207]

[206] Patisson, *British Veterinary Profession*, pp. 110, 125, 136; Anon., 'The supply of qualified veterinary surgeons for the public services', *Journ. of the Board of Agric.*, 19, no. 11, Feb. 1913, pp. 931–5; *Report of the Departmental Committee on the Public Veterinary Service*, Cd.6757, BPP, 1912/13, XLVIII, p. 251; letter on 'Assistantships', *The Veterinary Journal*, 25, 1887, pp. 146–7. Women were not allowed to encounter the problem of low pay for assistantships. Aleen Cust successfully completed her studies at Edinburgh, but the RCVS would not allow her to sit their professional examinations. It was not until 1922, after the passage of the Sex Disqualification (Removal) Act, that she was allowed to sit the examination and become the first female British veterinary surgeon.

[207] Patisson, *British Veterinary Profession*, p. 136.

CHAPTER 8

AGRICULTURAL SCIENCE AND EDUCATION

BY PAUL BRASSLEY

A. THE SCIENTIFIC REVOLUTION

By 1914 many of the new inputs and techniques used in agriculture – plant varieties, fertilisers, feedingstuffs, veterinary and pest-control products – were being developed by or tested by scientists and, in this respect at least, agriculture was typical of many other areas of Victorian and Edwardian industry.

The second half of the nineteenth century was a time in which the impact of science and scientists increased dramatically. To some, this appeared as a new development: in 1830 Charles Babbage, Lucasian Professor of Mathematics at Cambridge, argued that other European countries were excelling England in scientific discoveries and the education of scientists. The blame for this, he maintained, lay with the Royal Society and the neglect of science in the ancient universities. German universities, in contrast, combined research and teaching based on practical laboratory work. The laboratory run by the agricultural chemist, Justus von Liebig, at Giessen, attracted students from France, Switzerland, Britain, Russia and the USA between 1830 and 1852, and when Perkin, working in Britain, invented aniline dyes in 1856, he found that only in Germany was it possible to employ enough trained chemists to staff the factories, with the result that the dyestuffs industry came to be dominated by German firms. Thus there was some substance to Babbage's criticisms, although others have argued that they did not mean that English science was entirely moribund in the middle of the nineteenth century. If Oxford and Cambridge supported few scientists, there were other institutions, such as the Royal Institution, where Humphrey Davy and Michael Faraday worked, and the provincial Literary and Philosophical Societies, such as the one at Manchester, which supported John Dalton. Manufacturing industry was beginning to use scientific services, such as chemical analysis, and many of the literate middle classes were amateurs of botany, zoology or geology. In response to the inadequacies of the Royal Society, the British Association for the Advancement of Science

was founded in 1831, and the Royal Society itself was reformed in 1847. By 1869 there were nearly 12,000 members of specialist scientific societies, suggesting that scientists had acquired a sense of identity; what they had not acquired was professional status. That was what they appeared to want, and between about 1870 and 1914 it was what they got.[1]

There were several reasons for this increasing impact and increasing professionalism. Paradoxically, perhaps, one of the more important in the middle of the century was the popular appeal of science. Lectures and public exhibitions were held, museums opened, and a wide range of periodicals read, from the popular to the specialist journals of the Astronomical, Geological, Chemical and Botanical Societies, all of which existed by 1860, and *Nature*, founded in 1869, Mid-century science was accessible. In the 1850s it was still possible for major scientific discoveries to be announced in the *Edinburgh Review*. (Equally, *Nature* carried reviews of Royal Academy exhibitions as late as 1887.) Science was also fashionable, insofar as that is indicated by Prince Albert's involvement with it: he joined the Geological Society in 1849, despite the religious implications of the subject, and was President of the British Association in 1859. Increasingly, leading men of science – Darwin, Whewell, Murchison, Hooker and Huxley, for example – had a public as well as a professional life. Science was an important part of Victorian life, which was presumably why it became part of contemporary literature, with writers such as Eliot and Hardy using scientific images and ideas.[2]

Popular interest in science was matched by the rapid pace of scientific change and discovery. Some of the most significant developments in chemistry came in the 1850s and 1860s, with the work of Cannizaro on atomic weights and Kekule on the structure of organic compounds, and, perhaps most significant, Mendeleeff's periodic table of the elements in 1869. In physics, whereas Maxwell was elucidating the relationship between electricity and magnetism in the 1860s, by the 1890s Rontgen had described X-rays and the Curies had discovered radioactivity and isolated radium. On a more prosaic level, that basic tool of the chemical laboratory, the Bunsen burner, was invented in the 1850s and common in English laboratories by the 1870s. Pasteur effectively began a new science of microbiology when he demonstrated putrefaction by

[1] T. W. Heyck, *The Transformation of Intellectual Life in Victorian England* (London, 1982), pp. 50–62, 82, 88; H. Rose and S. Rose, *Science and Society* (Harmondsworth, 1970), p. 28; J. D. Bernal, *Science in History*, vol. II (Harmondsworth, 1969), p. 569; M. W. Rossiter, *The Emergence of Agricultural Science: Justus Liebig and the Americans 1840–80* (New Haven and London, 1975), Appendix 2; K. Robbins, *Nineteenth Century Britain: England, Scotland and Wales* (Oxford, 1989), chapter 5.

[2] J. Paradis and T. Postlewait (eds.), *Victorian Science and Victorian Values: literary perspectives* (New Brunswick, N.J., 1985), introduction, and pp. 121, 159, 161, 172, 299.

micro-organisms in 1861. Subsequently, viruses were named in 1897, hormones in 1902 and vitamins in 1912. In 1866 Mendel published his work on genetics in the *Journal* of the Brno Natural History Society, where it attracted no further attention until 1900. And these are only some of the high points in decades of solid scientific achievement. Many of the basic ideas of the physical and biological sciences were first formulated in the second half of the nineteenth century.[3]

A third reason for the increasing impact of science, in addition to its popular appeal and the pace of scientific change, was the controversy it generated. Perhaps the prime example of this was the conflict between science and religion generated by the publication, in 1859, of Darwin's book *On the Origin of Species by Means of Natural Selection.* At the British Association meeting in Oxford in 1860, T. H. Huxley defended Darwin from the attacks of Bishop Wilberforce; in 1871 he suggested, in print, that one could be a scientist (the term had been coined by Whewell in 1834, but did not come into common use until the 1870s or later) or a clergyman, but not both. In the same year religious tests for entry into the universities of Oxford and Cambridge were abandoned. Also in the early 1870s a Royal Commission on Scientific Instruction and the Advancement of Science under the chairmanship of the Duke of Devonshire recommended that more government money should be spent on science, and that state science laboratories should be established. There was little response from the government, but the Duke himself endowed the Cavendish Laboratory in Cambridge in 1874. The Clarendon Laboratory at Oxford was started in 1872, the Physical Society was founded in 1876 and the Institute of Chemistry a year later.[4] It is developments such as these which have led some commentators to speak of 'the triumph of science over theology' and victory for the scientific outlook by the 1880s.[5] It was not so much that the laboratories at Oxford and Cambridge were the first opportunity for undergraduates to obtain a scientific education, for they were not. Some of the profits of the Great Exhibition of 1851 were used to found the Royal School of Science, the City and Guilds Technical College and the Royal School of Mines (which all finally came together in 1907 as the Imperial College of Science and

[3] I. Asimov, *Guide to Science*, vol. I (Harmondsworth, 1975), pp. 137, 240–1, 323, 367; R. C. K. Ensor, *England 1870–1914* (Oxford, 1936), p. 551; Bernal, *Science in History*, vol. II, pp. 568, 633; H. T. Pledge, *Science since 1500* (1966), pp. 165, 218, 220, 241, 245.

[4] D. R. Dean, '"Through science to despair": geology and the Victorians', in J. Paradis and T. Postlewait (eds.), *Victorian Science and Victorian Values*, pp. 125–6; D. A. Roos, 'The aims and intentions of *Nature*' in Paradis and Postlewait (eds.), *Victorian Science and Victorian Values*, p. 161; Rose and Rose, *Science and Society*, pp. 26–7; H. Perkin, *The Rise of Professional Society: England since 1880* (London, 1989), p. 86.

[5] See especially Heyck, *Transformation of Intellectual Life*, p. 82, and Dean in Paradis and Postlewait (eds.), *Victorian Science and Victorian Values*, p. 128.

Technology), and the redbrick universities (such as Owens College in Manchester, founded in 1851) replaced the old Literary and Philosophical Societies as the centres of science and scientists in the provinces in the second half of the century. While the number of science professors at Oxford and Cambridge increased from 13 in 1850 to 26 in 1900, the number of university positions in science and technology in the whole country increased from 60 in 1850 to more than 400 in 1900. But the significance of the scientific penetration of the older universities lay in their ability to confer status on the scientists as professionals, and that is why the years after 1870 were seen as the ones in which science became important.[6]

Science was also increasingly important in industry. Many of the new industries, not just in Britain but in Europe as a whole, were science-based: chemicals, fertilisers and, towards the end of the nineteenth century, the electrical industry, are obvious examples. By 1914 telephones and wireless, typewriters, gramophones and the cinema, electric lighting in houses, motor cars and aeroplanes, were all becoming more or less widely available. Science was also applied to existing staple industries, as with the development of the Bessemer converter (1854) and the Gilchrist Thomas open-hearth furnace (1879) in steel-making. The larger firms began to set up their own laboratories, such as those of Lever Brothers at Port Sunlight in 1889 and of the United Alkali Company in 1892. Whereas in 1880 there were only 1,170 male workers in 'scientific pursuits', by 1911 their numbers had risen to 6,171, a rate of increase twice as fast as in any other profession. Whether this was enough is another question, and several commentators have argued that English industry was not as good as its competitors between 1870 and 1900 in integrating research and production, perhaps because scientists were more enthusiastic supporters of technical education than were businessmen. The increase in the number of scientific workers may have been impressive, but it is set in context by the corresponding figures from Germany, where there were 9,000 chemists alone by 1914.[7]

From the viewpoint of agriculture, however, the important point is that between 1850 and 1914 science changed from being a solitary, often self-financed pursuit, into a largely state- or industry-financed effort carried out by teams of professionals with their own professional organisations and

[6] Rose and Rose, *Science and Society*, pp. 31–6; Heyck, *Transformation of Intellectual Life*, pp. 89, 96, 113–14.

[7] H. C. G. Matthew, 'The liberal age (1851–1914)', in K. O. Morgan (ed.), *The Oxford Illustrated History of Britain* (Oxford, 1984), p. 515; Rose and Rose, *Science and Society*, pp. 26–36; Bernal, *Science in History*, pp. 548, 562; J. Bowle, *The English Experience* (London, 1971), p. 419; Perkin, *The Rise of Professional Society*, p. 80; Heyck, *Transformation of Intellectual Life* p. 93; P. Alter, *The Reluctant Patron: Science and the State in Britain, 1850–1920 (Oxford, 1987)*, p. 225.

journals. This was the environment within which agricultural research and education was carried out.

B. AGRICULTURAL SCIENTIFIC RESEARCH

'It is to the great German chemist Liebig that modern agriculture owes the origin of its most striking development', wrote R. E. Prothero (later Lord Ernle) in 1901. He was referring to Liebig's work on the relationship between plant nutrition and soil chemistry. But Liebig was not the first to apply scientific methods to problems relevant to agriculture. Lavoisier, the French chemist, set up a model farm in 1776. In Germany Thaer worked on soil fertility in the early nineteenth century, concluding that humus was the all-important factor. The Swiss de Saussure, who examined the effects of oxygen, carbon dioxide, water, light and mineral salts on plant growth, also took this view.[8] In early nineteenth-century Britain the most influential of these men of science was Sir Humphrey Davy. His *Elements of Agricultural Chemistry*, published in 1813, sold well in both England and the United States. It attempted to bring together the work of de Saussure, Thaer, Gay-Lussac and others on the role of the soil, humus, and mineral manures in plant growth. In particular, there were questions of whether plant growth was completely chemical or involved some 'vital' process, and of the function of minerals. In part Davy appeared to argue that the function of the soil was simply to support the plant so that its roots could absorb the dissolved organic matter, which was its food (all of which explained the effect of farmyard manure); but he also pointed out that plants contain silica, which they could only obtain from the soil, and consequently the soil must have a chemical role, which perhaps explained the effect of minerals and lime. Karl Sprengel, a little later than Davy, worked extensively on soil minerals, but remained a vitalist, convinced that organic substances such as humus were basic to plant nutrition. Then in 1828 Wohler synthesised a typical organic compound, urea, by purely inorganic methods independent of any vital force. By the 1830s there was an increasingly inescapable feeling that nobody could explain how manures worked.[9]

In 1837 Justus von Liebig, Professor of Chemistry at the University of Giessen, and one of the most prominent chemists of his time, read a paper at the Liverpool meeting of the recently formed British Association for the Advancement of Science, urging British scientists to study organic chemistry. They responded by asking him to prepare a report on the state

[8] R. E. Prothero, 'English agriculture in the reign of Queen Victoria', *JRASE*, 62, 901, p. 24; E. J. Russell, *A History of Agricultural Science in Great Britain* (London, 1966), p. 64. This is still the principal source for this subject and is referred to hereafter as *History*.

[9] Rossiter, *The Emergence of Agricultural Science*, pp. 9–19; Russell, *History*, p. 97.

of the subject. What appeared, in 1840, was the seminal *Organic Chemistry in Its Application to Agriculture and Physiology*. It was dedicated to the British Association, and was translated by Lyon Playfair, one of Liebig's pupils.[10] It attacked the humus theory, examined the way in which plants obtained nitrogen, and explained the role of minerals. The carbon in the plant was derived from atmospheric carbon dioxide and hydrogen and oxygen from soil water, according to Liebig. Nitrogen, he said, was derived from the ammonia in the air. (In the first edition of his book he concluded that the amount so produced was not sufficient for agricultural purposes; by the time the third edition was produced only three years later he took exactly the opposite view.) The mineral constituents which chemists had found in the ashes of plants, such as potassium and phosphate, came from the soil as it was slowly broken down by the process of weathering. Therefore, he argued, when a crop was harvested, the nitrogen and the minerals incorporated into it were taken away, and if the soil were to remain fertile they would have to be replaced. Inorganic fertilisers would be perfectly adequate for this. The precise amount required could be calculated by comparing the mineral contents of the plant and the soil. Within a few years Liebig's patent manure was being made and distributed by Muspratts of Liverpool.[11]

Liebig's views were questioned by several workers, but principally by Lawes and Gilbert. By 1855 they had established that most crops (except legumes) require more nitrogen than they can obtain from the atmosphere, and that analysis of the ash of a plant does not necessarily provide a guide to the amount of mineral fertilisers it requires. Moreover, although artificial manures were quite adequate to maintain soil fertility for several years, soil organic matter, such as might be provided by farmyard manure, did affect soil structure and the availability of nutrients in the soil. So began a long-running controversy.[12] And in practice, Liebig's fertiliser was a failure. Although it contained the necessary potash and phosphate it had been made insoluble so that it should not disappear in the drainage water. This, of course, made its nutrients unavailable to plant roots. When the problem was eventually worked out, Liebig accepted

[10] Russell, *History*, pp. 97, 114–15. From 1843 to 1845 Playfair was consulting chemist to the Royal Agricultural Society of England.

[11] Russell, *History*, pp. 97–100; Rossiter, *Emergence of Agricultural Science*, pp. 19–29; E. W. Russell, *Soil Conditions and Plant Growth* (10th edn, London, 1973) p. 12; N. Goddard, *Harvests of Change* (London, 1988) p. 88.

[12] J. D. Sykes, 'Agriculture and science', in G. E. Mingay (ed.), *The Victorian Countryside* vol. 1 (London, 1981) pp. 263–4. As late as 1892 Sir Thomas Dyke Acland could write (in *An Introduction to the Chemistry of Farming* (London, 1892) p. 91): 'At the present day, after forty years of research in England, France and Germany, the power of plants to gain nitrogen directly from the air is an undecided question.' (In fact, although Acland did not know, it had just been decided. See below, p. 601.)

that he was in error, but by then, it seemed to Philip Pusey, 'The mineral theory . . . [had] received its death-blow from the experiments of Mr Lawes.' Insofar as Liebig was right he cleared away a great deal of confusion on plant nutrition and disposed of the humus theory; in going wrong he served to make agricultural chemistry a matter of popular concern and brought the work of Lawes and Gilbert to popular attention. It was an important contribution to agricultural science.[13]

Lawes and Gilbert worked together at Rothamsted from 1843 to 1900, when Lawes died. In that time they produced 174 scientific papers and about 300 other publications. Much of their work was concerned with crop nutrition. Perhaps the most famous experiment was the one on the continuous growth of wheat, which began on Broadbalk field in 1843 and continues still. The field was divided into nineteen narrow plots of about half an acre each. Each year plot 3 was left unmanured, plot 2 was given 14 tons of farmyard manure per acre, plot 19 was dressed with rape cake, and the others were given various combinations of sodium nitrate, ammonium salts, superphosphate, and sulphates of sodium, potassium and magnesium. Each year the production of grain and straw was measured. It was soon possible to demonstrate a response to nitrogenous fertilisers, and it was this that enabled Lawes and Gilbert to disprove Liebig's assertion that plants obtained their nitrogen from the air, and produced Pusey's remark quoted above. But this was only the beginning. The experiment was continued, year after year. An immense amount of data was accumulated. With the results of thirty or forty years available, it was possible to overcome the problems caused by short-term fluctuations in weather or disease. The effects of more or less rain at different times in the growing season became clear. There were also experiments to examine the effects of different levels and timing of nitrogen applications on the nitrate content of the drainage water. Eventually it was possible to produce precise recommendations on fertiliser applications: wheat gave a good response to nitrogen top-dressings of one hundredweight per acre (i.e. 100 units of N) after a wet autumn and winter, and after two or three wheat crops in succession two hundredweights of superphosphate should be incorporated in the seedbed. Experiments on the lighter soils at Woburn demonstrated that potash applications only gave a significant response on light land. These were just the results for wheat. Other experiments were laid down for other crops. In Hoosfield, from 1852, a similar trial for barley was conducted, which demonstrated that barley would respond better to potash than would wheat. The Geescroft field oat trial began in 1869 and a rotation trial was started in Agdell field in 1848. The Barnfield turnip trial started in 1843, and was switched to

[13] Russell, *Soil Conditions and Plant Growth*, pp. 13–14.

mangolds in 1876. From 1856 seven acres of the park close to the house, which had been in grass for several centuries, were set aside for work on the effects of fertilisers and manures on the hay crop. All of these experiments produced large quantities of reliable basic data such as nobody had ever produced before.[14]

This collection of basic data was perhaps the major contribution made by Lawes and Gilbert to agricultural science. Apart from working out how the plant obtained its nitrogen (and perhaps, as an extension of this, the idea of nutrient balances for both soils and animals) they made no other great theoretical breakthrough. They could not, for example, explain why their conclusions on nitrates did not apply to leguminous crops. One of their fellow-workers at Rothamsted, Robert Warington, worked extensively on the problem, but it was the Germans Hellriegel and Wilfarth who demonstrated the presence of nitrogen-fixing bacteria in nodules on the roots of legumes in 1886. On the other hand, Lawes and Gilbert also worked on scientific problems referred to them by the government, such as bread reform, the effect of malting on the nutritional value of barley as a livestock feed, the chemical and economic effects of sewage disposal on farm land, and the question of compensation for unexhausted improvements, which eventually resulted in the foundation of a sub-station at Woburn. Lawes campaigned for the installation of weighbridges in cattle markets and produced tables for estimating the dead weight of cattle from the liveweight, in pocketbook form. It is perhaps possible to wonder if Lawes and Gilbert had so many practical problems to solve that they had no time to give to the great theoretical questions. Nevertheless, by the later nineteenth century Rothamsted was established as a centre for research in soils and plant nutrition, and others extended the range of work carried on there. Hall and Russell produced one of the first regional soil surveys, of the counties of Kent, Surrey and Sussex, and Russell led a team which by 1914 had demonstrated the enormous complexity of the soil fauna.[15]

So prolific was the Lawes and Gilbert partnership, and so long-lasting, that it might sometimes seem that they were the only agricultural scientists, and Rothamsted the only experimental station, in late nineteenth-

[14] G. V. Dyke, *John Bennet Lawes: the Record of his Genius* (Taunton, 1991), p. x. The results were collected together by A. D. Hall as his first task when he became Director of Rothamsted in 1905, and clearly summarised in his *The Book of the Rothamsted Experiments* (London, 1905), on which this paragraph is based. See also R. Brigden, *Victorian Farms* (Marlborough, 1986), pp. 198–201.

[15] Russell, *Soil Conditions and Plant Growth*, pp. 17–20; Russell, *History* pp. 159, 171–2, 238–43. The Woburn station, which was funded initially by the Duke of Bedford, was on light land, and so enabled useful comparisons to be made with results obtained on the heavier land at Rothamsted; Dyke, *John Bennet Lawes* p. 388. I am grateful to Dr Dyke for much help and discussion on this topic.

century England. They were not, of course; they were not even the only agricultural chemists. James Johnston, Reader in chemistry and mineralogy at the University of Durham until his death in 1855, was involved in the experimental work of the Highland and Agricultural Society, although probably his greatest achievements were as a writer on agricultural chemistry: his *Catechism of Agricultural Chemistry and Geology*, published in Edinburgh in 1844, was translated into many European languages, used as a textbook in Continental and American schools, and went through thirty-three editions in his lifetime. Charles Daubeny (1795–1867), who at various times held chairs of chemistry, botany and agriculture in the University of Oxford, worked on the uptake of nutrients by plant roots, and consequently, in 1845, proposed the distinction between available and unavailable nutrients which subsequently became so important to the development of soil analysis. Lawes was one of his pupils.[16]

In the latter part of the century two other experimental sites, unconnected to Rothamsted, came into being. The Suffolk Education Committee ran a long-term rotation trial with several manurial treatments at the Saxmundham experimental field from 1899. The work at Cockle Park, the experimental farm near Morpeth in Northumberland, run by the department of Agriculture at Newcastle, was perhaps better known. From the early 1890s William Somerville, the professor of agriculture, had been running manurial experiments at various demonstration centres. When, in 1896, the department took on Cockle Park farm, which was largely poor grass on boulder clay, he decided to try to improve it. John Wrightson had demonstrated the effect of basic slag, a by-product of steel-making which was rich in calcium phosphate, in some experiments in Durham in the 1880s. His work had attracted little attention, but Somerville knew about it, and made it a central feature of the Tree field experimental plots which were laid out in 1896 and continued until 1955. The nutrients in basic slag were insoluble in water, but on the kind of acid land found at Cockle Park they became available, and so basic slag was revealed as a cheap and effective way of improving thousands of acres of upland grassland. Even in the late 1960s agricultural students at Newcastle, in their lighter moments, sang 'Hark the Herald angels sing,/ Basic slag is just the thing.' Grassland improvement was carried further by the work of one of Somerville's successors at Cockle Park, D. A. Gilchrist, who was appointed director in 1902. He was best known for his work on wild white clover and the development of the Cockle Park seeds mixture for long leys, which consisted of three clovers

[16] Russell, *History*, pp. 86–8, 130–1, 138–41; G. E. and K. R. Fussell, 'James Finlay Weir Johnston, 1796–1855'. *Agricultural Progress*, 57, 1982, pp. 35–40.

– wild white, late flowering red and trefoil – and three grasses – perennial ryegrass, cocksfoot and timothy – and so was much simpler than currently popular mixtures of ten or more species. And in 1912, R. G. Stapledon, who was to do much of the basic work on grassland ecology, was appointed to the Department of Agriculture at Aberystwyth.[17]

Botanists, such as Stapledon, and zoologists, with agricultural interests, were rarer than agricultural chemists for much of the nineteenth century. Indeed, one standard textbook argued that agricultural botany had no clearly defined boundary, its scope being largely prescribed by Percival's book *Agricultural Botany*, which first appeared in 1900, and ranged over the anatomy, physiology and classification of plants, weeds, seeds, and plant diseases. By the middle of the century many of the fungal pests which attacked crops had been described, but no major changes occurred in methods of control. On the other hand, the increasing economic importance of grassland towards the end of the nineteenth century was reflected in increasing interest in grassland ecology. William Fream had carried out an experiment in 1888 and 1890 in which turves from old grassland were grown together and compared, and, soon after his appointment at Aberystwyth, Stapledon began the surveys which were to result in the publication of the first grassland survey of Wales in 1936. Winifred Brenchley, the first botanist to be appointed to the staff at Rothamsted (in 1906), also adopted an ecological approach in a series of pot experiments which examined the effects of competition for food, water and light between crop and weed species. The application of zoology to agriculture was also mainly confined to the description of pest species and the elucidation of their life cycles. John Curtis published *Farm Insects* in 1860, and Eleanor Ormerod her *Manual of Injurious Insects* in 1881. By the end of the century zoologists were familiar with the problem species, but, again, there was no great breakthrough in methods of controlling them.[18]

Many of the other changes in crop production were not so much the product of science but of the practical experience of the practitioners. One example of this is drainage, in which acknowledged experts such as Josiah Parkes were trained through estate management rather than science. Although the journals of the agricultural societies contained many papers on drainage they were largely written from practical experience rather than experimental results. The same is true of developments

[17] Russell, *History*, pp. 244–6, 250, 392–4.

[18] N. T. Gill and K. C. Vear, *Agricultural Botany* (2nd edn, London, 1966) p. v; W. Fream, 'The herbage of pastures', *JRASE*, 3rd ser., 1, 1890, pp. 359–92; J. Sheail, *Seventy-five Years in Ecology: the British Ecological Society* (Oxford, 1987), pp. 54–5; Russell, *History*, p. 219; G. Ordish, *The Constant Pest* (London, 1976) p. 153. I am grateful to David Iley for discussing this subject with me.

in farm mechanisation. In the nineteenth century it also applied to plant breeding, 'a game of chance played between men and plants . . . [with] . . . the chances . . . in favour of the plants'. New varieties were produced by seedsmen either by selection of superficially good-looking plants or, later, by hybridisation followed by selection. This was the method used by Gartons (see the section above on crop varieties) and by E. S. Beaven, an amateur whose methods were far from amateurish. Beaven was a maltster, with a sufficient income to indulge his interest in barley. He began his experiments in 1895, using his considerable powers of recognising a good barley to select from established varieties. Eventually he was operating on a considerable scale, with experimental plots covering four acres, and with some success: the best of his varieties, Plumage and Archer, were widely grown. But he realised that this method would not allow the introduction of new characteristics, and he began to hybridise different varieties. At about this time he came into contact with R. H. Biffen, who had been appointed lecturer in botany in the department of agriculture at Cambridge in 1899 and was working on wheat. The first announcement of Mendel's discoveries in genetics had not been made in England until 1900, and Biffen rapidly grasped their significance. In his first major scientific paper, published in 1905, he argued that ear, leaf and stem morphology, grain colour and baking quality, were all Mendelian characteristics, exhibiting dominance or recessiveness, as was susceptibility to yellow rust. The practical result of this theoretical breakthrough came soon after, when a new wheat variety bred by Biffen, Little Joss, was put on the market in 1910.[19]

Another member of the Cambridge department, T. B. Wood, began to investigate the application of Mendel's laws to animals and, in particular, the inheritance of commercial characteristics in sheep, such as wool and meat quality, but this work came to an end with the outbreak of war. The physiological aspects of animal breeding were investigated by F. H. A. Marshall from 1908 onwards. For his work on the functions of the male organs he used hedgehogs. Wood's main field of work was animal nutrition, and his co-director at the animal nutrition research institute was Frederick Gowland Hopkins, who had just discovered vitamins. Although agricultural research may have taken a long time to reach Cambridge, it had already produced some impressive results by the time of the Great War. But Wood was not the first to work on animal nutrition. Insofar as it was a branch of chemistry, it is not surprising to find that Lawes and Gilbert had become involved quite early. In 1848 they began work on the relationship between food consumption and conse-

[19] A. D. M. Phillips, *The Underdraining of Farmland in England and Wales during the Nineteenth Century* (Cambridge, 1989), pp. 158–60; Russell, *History*, pp. 209–13, 260–3.

quent weight increase; their last paper on the subject, summarising their work, was published in 1895. In between they had worked on nitrogen metabolism, demonstrated that carbohydrate feeds could be the precursor of fat in the animal, examined carcase composition, and carried out the first complete chemical analysis of animal bodies. They worked out that each ton of linseed cake consumed would add 101 lb of nitrogen, 42 lb of phosphoric acid and 31 lb of potash to the manure of the farm, and this sort of material enabled them to produce compensation tables for the purposes of tenant-right valuations. In fact, these tables were too complex to be used in practice, although a modified version produced by Voelcker and Hall in 1902 was eventually accepted. After that little further work on animal nutrition was done at Rothamsted. Cambridge, where T. B. Wood worked on energy metabolism, became the main centre. And it might be argued that Wood was more influenced by the ideas of Armsby in America or Kellner, who worked at the Mockern experimental station in Germany, than by those of Lawes and Gilbert. Many feeding trials were carried out at the various German experimental stations throughout the nineteenth century, from the work of Thaer in the early part of the century, to Wolff, who introduced the idea of digestibility of foodstuffs in the 1870s, and Kuhn, who distinguished between maintenance and production rations in the 1880s. Kellner was perhaps the most influential. His book on *The Scientific Feeding of Animals* was translated into English in 1910, and explained his 'starch equivalent' system of rationing livestock, which was widely used in the United Kingdom until the 1960s.[20]

Scientists also worked in the processing industries which converted the raw materials produced by the farmer into food. Indeed, it has been argued that in the dairy trade their impact may have been greater in the processing and retailing than in the production sectors.[21] In the early 1890s, for example, cheesemaking at the Bath and West Society's cheese school at Frome was carefully observed by Miss Cannon, the instructress, and F. J. Lloyd, a consulting chemist with a London practice. They made detailed observations of weights, temperatures, acidities, milk composition and

20 Russell, *History*, pp. 283–5; Board of Agriculture, *Annual Report of the Education Branch on the Distribution of Grants for Agricultural Education and Research 1913–14*, Cd.7450, BPP, 1914, XI, p. 717; Hall, *Book of Rothamsted Experiments*, pp. 256–9; P. McDonald, R. A. Edwards and J. F. D. Greenhalgh, *Animal Nutrition* (3rd edn, Edinburgh, 1981), pp. 228–9; B. H. Schneider and W. P. Flatt, *The Evaluation of Feeds through Digestibility Experiments* (Athens, Ga., 1975), p. 6; Russell, *History*, pp. 283–5; E. T. Halnan and F. H. Garner, *The Principles and Practice of Feeding Farm Animals* (2nd edn, London, 1944), pp. 52–7; T. B. Mepham, 'The emergence of dairy science in England' (paper presented to a conference on the history of Agricultural Science and Education held at Rothamsted Experimental Station on 12 May 1990). I am most grateful to Dr Mepham for providing me with a copy of his paper.

21 This is the view put forward by Mepham in 'The emergence of dairy science in England'.

bacteria present, and produced a series of reports which were among the first to explain the process in scientific terms.[22] The reason for this greater scientific interest in the dairy trade can be attributed to three factors: the increase in the liquid milk trade; increasing centralisation of the milk products trade with the development of, for example, cheese factories; and, consequent upon these two, increasing scientific and legal interest in adulteration, spoilage, and milk as a vector of pathogenic disease. Under the terms of the Sale of Food and Drugs Act of 1875 (amended in 1879 and 1899) decisions had to be made about what constituted genuine milk, and this led dairy chemists to develop and use methods of determining the fat content of milk, such as the Gerber butyrometer, developed in the 1890s. By the beginning of the First World War relatively sophisticated techniques such as polarimetry and refractometry were being used in the laboratories associated with the dairy industry and the public health service. There were also disagreements between the dairy trade and the medical profession, especially over the issue of pasteurisation of milk. The doctors were for it, and the dairymen against, and F. J. Lloyd was prepared to put their case, arguing that centrifuging to remove cellular material was sufficient to render milk marketable. With arguments such as these, and new analytical techniques, it is not surprising to find that the number of scientific papers written on dairying topics increased over the period 1875–1900. Perhaps more significant is the fact that French and German scientists produced more work than British scientists, and the number of papers produced by American scientists increased more quickly.[23]

In the social sciences, too, England and Wales lagged behind continental Europe and the United States. In Denmark agricultural societies and creameries promoted record keeping and there was a network of farm accounting societies from 1910. In Germany studies were made in both simple farm accounting methods and the political economy of agriculture. In the United States in the early 1890s a survey of wheat growing costs was undertaken which involved 25,000 farmers. By 1910 agricultural economists in the United States had developed analytical methods which enabled them to give practical business advice to farmers, and they were sufficiently well established to form their own society and publish a learned journal. Even after the war, the extensive (twenty-one-page) bibliography in Orwin's *Farming Costs* was largely made up of material published in the USA. In England and Wales, in contrast, there were few agricultural economists as such. Some, such as Sir Henry Rew, worked on agriculture as a whole. Rew was in charge of the agricultural census

[22] E. J. Cannon and F. J. Lloyd, 'The manufacture of Cheddar cheese', *J. Bath and West*, 4th series, 2, 1891–2, pp. 136–44; F. J. Lloyd, Observations on Cheddar cheese-making', *J. Bath and West*, 4th ser., 2, 1891–2, pp. 144–93; K. Hudson, *Patriotism with Profit* (London, 1972), p. 119.

[23] Mepham, 'Emergence of Dairy Science', *passim*.

at the Board of Agriculture in the early twentieth century, and also made estimates of the value and volume of national agricultural output. It was perhaps his influence which led to the extension of the Census of Production to agriculture in 1908. Rather more work was done on farm management. In the nineteenth century, book-keeping, for agricultural purposes, followed normal commercial practice, and consequently the Royal Commissions which investigated agricultural problems at the end of the nineteenth century had few reliable costings available to them. Sir Daniel Hall, in 1906, devised a system of full-cost accounting in connection with his work on the hop farm run by the Guinness brewing firm. It produced detailed information, but was probably too complex to be used by the ordinary farmer. Perhaps Hall's greatest contribution to the progress of agricultural economics arose from his work with the Development Commission, which in 1913 financed the Agricultural Economics Research Institute at Oxford, under the direction of C. S. Orwin. Thus agricultural economics, in this period, insofar as it existed at all, was largely concerned with the individual farm.[24]

This review of the state of agricultural science in the period 1850–1914 seems in some ways to lead to the conclusion that the terms agricultural science and agricultural chemistry were synonymous, at least until the early twentieth century. When R. E. Prothero (Lord Ernle) wrote, in 1901, that '. . . the science has not done all that was expected from it in the "Fifties"', he was referring to work on fertilisers. Admittedly, later in the same article he praised the work of the veterinary profession and the entomologists in the struggle against pests and diseases of plants and animals, but, with those exceptions, when he wrote of the major developments in this period he did so in terms of the work of seedsmen in plant breeding, farmers and landowners in animal breeding, and agricultural engineers in producing new types of farm machinery. The development of the milk separator, he argued, '. . . ranks with the reaper and binder as one of the triumphs of mechanical invention in the last quarter of the nineteenth century'. Not a triumph of science, but one of 'mechanical invention'. To that extent he concurred with the synonymity of agricultural science and chemistry.[25]

This perhaps raises the question: 'what is science?' Clearly the answer involves explanations of the way the world works. Agricultural science is thus concerned with the way in which agriculture works. But also, perhaps, these explanations are produced by the application of skills not ordinarily available within the farming community, or, in the case of farm machinery, within the engineering industry. Moreover, those who, by their possession of these skills, were recognised as professionals, were

[24] E. H. Whetham, *Agricultural Economists in Britain 1900–1940* (Oxford, 1981), pp. 1–40.

[25] Prothero, 'English agriculture in the reign of Queen Victoria', pp. 24–38.

exposed, in the second half of the nineteenth century at least, to the view that their work should be disinterested, and justified by service to society rather than the acquisition of personal wealth.[26] And professional scientists are likely to be more productive if they can communicate easily with others working on the same problems: this requires an institutional framework of training, laboratories, libraries, and learned journals and societies. In short, the answer to the question is that science (as opposed, to some degree, to technology) is explanatory, professional, disinterested and institutionalised. It therefore follows that a simple outline of what scientists knew at a particular point in time is only a part of the history of their science; to explain why they knew more or less at other points in time it is necessary to examine the extent to which their work was explanatory and they were professional, disinterested and institutionalised.[27]

If these tests are permissible, some interesting points emerge. One concerns the work of the model farms and demonstration farms. Perhaps the best known of these was run by John Joseph Mechi at Tiptree in Essex. After making his fortune from a patent razor strop he bought a 130 acre farm in 1841. Between then and the 1870s he used it to demonstrate how investment in drainage, buildings, equipment and the provision of manure could raise fertility and output. Moreover, he was brave enough to publish his accounts. John Morton, the agent on the Earl of Ducie's estate at Totworth in Gloucestershire, ran an example farm in the early 1840s. The Prince Consort had model farms at Windsor, Lord Bateman built one at Uphampton in Herefordshire in 1861, and there were numerous others, from Dorset to Cumbria. Some represented serious attempts to explain new techniques; others were, '. . . like other estate follies, designed to be admired from afar and had nothing to do with farming'. But even the best of them could not be properly scientific because they failed the test of explanation: their function was to demonstrate what could or might produce improvements, not *why* the improvement worked. Similarly, when the 'club of practical farmers' met at Harleston in Suffolk in 1840 to discuss what Philip Pusey called 'doubtful points of agricultural science', they were, not surprisingly, concerned with such practical questions as the best method of keeping farm accounts, or improving neat-cattle in the district, or the use of saltpetre as manure.[28]

[26] Perkin, *Rise of Professional Society*, p. 123; Heyck, *The Transformation of Intellectual Life*, p. 97.

[27] G. Grantham, 'The shifting locus of agricultural innovation in nineteenth-century Europe: the case of agricultural experiment stations', in *Technique, Spirit and Form in the Making of the Modern Economies: Essays in Honor of William N. Parker*, Research in Economic History Suppl. 3, 1984, pp. 191–214.

[28] Brigden, *Victorian Farms*, pp. 190–5; S. Macdonald, 'Model farms', in Mingay (ed.), *The Victorian Countryside*, vol. 1, pp. 218–21; P. Pusey, 'Some introductory remarks on the present state of agriculture as a science in England', *JRASE*, 1, 1840, pp. 18–19.

Many of the articles in the early volumes of the *Journal* of the Royal Agricultural Society are the result of observation, and even where they demonstrate understanding they may fail to pass the test of professionalism, in the scientific sense. They were often written by landowners, agents or larger farmers. Indeed, it is interesting to see how those with professional qualifications increased their contribution to the *Journal* over time. In the first volume, none of the authors listed academic qualifications or other evidence of professional status. In 1851 17 per cent of the authors had such qualifications, in 1860 more than a third, and of the thirty-four articles in the 1880 issue, seventeen were written by men with some claim to professional status, although thirteen of these were by the consultants to the Society. Thereafter the figures decreased, although the comparison is difficult to make because the format of the journal changed. Although Lawes and Gilbert wrote numerous articles for it, many of their conclusions were also published in the *Philosophical Transactions* of the Royal Society. On the other hand, even if the *Journal* of the Royal cannot be classed as a learned, scientific, or professional journal, it was still important. Grantham has made the point that 'A fruitful science requires a lengthy gestation period for gathering, verifying and classifying the facts of plant and animal growth', and it made a significant contribution to that process.[29]

Consultancy was an important aspect of agricultural science, not least because it brought farmers and landowners into contact with scientists. It certainly lay within the boundaries of science if the tests of professionalism and institutionalisation are applied. Whether the work of the consultant was disinterested is another matter. It was in part, in that some consultants worked on questions which interested them without looking for any immediate financial return. Augustus Voelcker, for example, consultant chemist to the Bath and West Society from 1855 and the Royal Agricultural Society between 1857 and 1884, worked on various problems concerned with potash fertilisers, and also on the analysis of drainage water. But much of his time was spent on consultancy. Between 1867 and 1875 the number of cases referred to him by members of the Royal Agricultural Society increased from 341 to 704. About half of the cases dealt with in 1875 were concerned with fertilisers, and about another quarter with the feeding value of concentrated feedingstuffs, which were all analysed for moisture, oil, albuminous compounds, mucilage, sugars and digestible fibre, woody fibre (cellulose) and mineral matter (ash). The remainder involved soil analysis, the purity of well water, and examinations for poisoning of livestock. The Society had appointed its first consultants

[29] Hall, *Book of Rothamsted Experiments*, Appendix 1; Grantham, 'The shifting locus of agricultural innovation', p. 195.

in the 1840s, when Lyon Playfair (the translator of Liebig, who later had a prominent role in the Great Exhibition of 1851 and became a considerable figure in science politics) was the consulting chemist and Josiah Parkes the consulting engineer. Playfair was followed in 1847 by J. T. Way, the Professor of Agricultural Chemistry at the Agricultural College at Cirencester, who in turn was succeeded by Voelcker, who was also teaching at Cirencester at the time of his appointment. He left in 1863 to set up in London as a consulting chemist with his laboratory in Salisbury Square, Fleet Street. After his death in 1884 the Society appointed his son John Augustus, who held the position until 1936, when another Voelcker, Eric, took over the job until 1976.[30]

The Royal Agricultural Society retained the services of consultant chemists because they could help farmers to overcome problems of adulteration in fertilisers and feedingstuffs. Sharp practice in the seed trade led to the appointment of a consultant botanist. William Carruthers was appointed in 1871 and held the position until 1909. His report for 1875 shows that he also worked on the causes of potato disease, and examined other crops for diseases, in addition to testing the germinating power of seeds. There was also a consultant entomologist (Miss Ormerod) from 1882 and a consultant veterinary surgeon from the 1840s. Members of the Society had 'privileges', which meant cheap rates for consultations. In 1912, for example, a full analysis of any compound fertiliser or feedingstuff cost 10s. 0d. (which was half the price of the similar service in 1856), a post-mortem report on an animal could be had for a guinea, and fungal diseases and injurious insects could be identified for a shilling, with suggestions for the treatment of the problem included.[31] Thus the influence of the Society was at least partly responsible for establishing the professional scientific consultant. The other influence was legal. Under the terms of the various fertilisers and feedingstuffs acts each county and county borough had to appoint a public analyst, and several of the men who wrote on scientific topics in agricultural journals appear in the lists of these analysts in 1900: J. A. Voelcker, his brother Edward, who shared his professional address in London, Bernard Dyer, a pupil of Augustus Voelcker's, F. J. Lloyd, who worked on the chemistry of cheesemaking, and M. J. R. Dunstan of the Midland Agricultural and Dairy Institute, and later Principal of Wye College. There were thirty-six analysts in all, and several of them were responsible for more than one county. J. A. Voelcker had six, Dyer

[30] A. Voelcker, 'Annual Report of the consulting chemist for 1875', *JRASE*, 2nd ser., 12, 1876, pp. 293–304; Goddard, *Harvests of Change*, pp. 95–8; Russell, *History*, pp. 173–5.

[31] W. Carruthers, 'Annual report of the consulting botanist for 1875', *JRASE*, 2nd ser., 12, 1876, pp. 304–5; Goddard, *Harvests of Change*, p. 127; the privileges and their costs were listed at the end of each volume of the *Journal*.

had nine, and J. A. Murray looked after six Welsh counties from the University College at Aberystwyth.[32]

It is therefore apparent that professional, disinterested, scientific work which sought to explain the workings of plants and animals was not carried on at the model farms, either by farmers' clubs and societies, by seedsmen or agricultural engineers, or, in the main, by consultants. It happened in the research institutes and the universities.

The first, and for many years the only, agricultural research institute in England and Wales was at Rothamsted, near Harpenden in Hertfordshire. For the entire second half of the nineteenth century it was inextricably linked with the names of Lawes and Gilbert, who, by virtue of longevity and productivity, became the most prominent agricultural scientists of this period. John Bennet Lawes was born in 1814. In 1832 he went up to Brasenose College, Oxford, where he attended Daubeny's lectures, but left in 1834 without taking a degree. He went to live at Mamhead in Devon, and then in London for about three years, before returning to live with his widowed mother on the family estate at Rothamsted. The home farm of 250 acres was vacant and he began to manage it. He also maintained his interest in chemistry, making experiments on medicinal plants. At some point in the 1830s he appears to have been discussing agricultural topics with one of his neighbours, Lord Dacre of Kimpton Hoo, who raised the question of bones, and why they were an effective manure on light lands but not on heavy soils. Lawes was interested in chemistry, suggested Dacre; should he not try to find out the answer to this question?[33] This conversation was the beginning of Rothamsted as a scientific institution, for not only did it kindle Lawes's interest in the application of chemistry to agriculture, it also gave him the means to finance his interest. By 1841 Lawes knew that treatment with acid would overcome the inertness of bones on heavy soils. In 1842 he obtained a patent for the manufacture of fertilisers by the treatment of bones and other phosphatic materials with sulphuric acid. The product was called superphosphate. In 1843 he had a factory at Deptford Creek in London producing superphosphate for sale at £7 per ton. Other manufacturers subsequently tried to produce the same product, but Lawes successfully defended his patent, and forced them to pay a royalty of 10s. 0d. on every ton of their output. These royalties, and the profits of his own factory, provided the money for Lawes to pay for the scientific work at Rothamsted.[34]

[32] Board of Agriculture (Intelligence Division), *Annual Report of Proceedings under the Fertilisers and Feedingstuffs Act 1893 ... for the year 1900*, Cd. 654, p. 40, BPP, 1901, XVII, p. 165.

[33] Russell, *History*, pp. 88–92. Russell's evidence for this story was a conversation he had in 1913 with a neighbouring landowner who had known both men.

[34] Russell, *History*, pp. 88–95, 143–5.

Joseph Henry Gilbert was a chemist by training, and had spent the summer of 1840 studying (together with Lyon Playfair) under Liebig at Giessen, for which he was awarded his PhD. Lawes needed a trained chemist for his work at Rothamsted, and invited Gilbert to join him in 1843. They worked together until the end of the century. When Lawes was at home, Gilbert spent about an hour of each day with him, planning experiments and discussing results and reports. Lawes was in charge of the agricultural work in the experimental fields, and the rest of the work was directed by Gilbert. Surviving photographs, taken in old age, show them both as white-bearded patriarchal figures, but written accounts emphasise their differences. Lawes was the man of the world, vigorous, practical and pragmatic. He was a responsible country gentleman who enjoyed his stalking and salmon-fishing holidays in Scotland, a provider of allotments for the labourers of Harpenden, concerned for the welfare of the workers in his factories, and interested in agricultural questions in the widest sense. As a scientist he was concerned with the broad outlines of a problem, and was satisfied when an answer had been found; the details did not interest him. Gilbert was the opposite. He was a dull lecturer, devoted to detail, methodical, and meticulously accurate, and so resistant to change that he persisted in using thousandths of a gallon and fractions of a grain in his scientific work when all other chemists were using the metric system. Once he had begun a series of measurements they were never discontinued, which meant that enormous amounts of consistent data were compiled, but the work was so tedious that no trained scientist would stay for long. He overcame this problem by training boys taken straight from the village school to become competent in one single process of each of the analytical techniques. In any case he was intolerant and suspicious of young scientists. At one point he accused Robert Warington of 'trying to get known out of my hard work'. When Lawes, without consulting Gilbert, invited Warington to work at Rothamsted in 1876, Gilbert was furious, and Lawes had to appoint Warington as his personal assistant. Warington had the last word. He was asked to write the obituaries of both men for the Royal Society. His account of Lawes portrays not only a great man but also a warm human being; his account of Gilbert contains not a word of criticism, and meticulously catalogues Gilbert's achievements, yet still leaves the faint impression that he was cold, unimaginative, small-minded and vindictive. If this portrait is accurate, it may be one reason why Rothamsted did not expand much in the nineteenth century, or produce many offspring in other parts of the country. Woburn, which was under the control of J. A. Voelcker, with some help at the beginning from Lawes, was the only one until the 1890s.[35]

[35] Russell, *History*, pp. 102–4, 162; the obituary notices are reprinted at the beginning of Hall, *Book*

It was in the 1890s that most of the university agricultural departments were set up, for reasons which were more concerned with education than with scientific research (see below pp. 629–32). They were not, initially, given any clear instruction to carry out research, although they were certainly not prevented from doing so. Again, the question of what may be defined as research raises itself at this point. William Somerville, who held the chair of agriculture in the College of Science at Newcastle, had to give extension lectures to farmers as a normal part of his duties. He believed that the best way to get their attention was through practical demonstrations, and by 1896 he had demonstration plots scattered all over the north-east. He eventually persuaded Northumberland County Council to acquire an entire farm, and they rented Cockle Park farm on the Duke of Portland's estate, with the objective of setting up 'demonstrations of improved processes in the practice of the manuring, tillage, and cropping of land . . .' and 'feeding experiments to demonstrate the relative value of foodstuffs and systems of feeding for farm stock'. The initial purpose was quite clearly educational, yet what developed was the experimental work on basic slag, and later wild white clover. At Cambridge, on the other hand, Biffen's work on plant breeding seems to have been stimulated more by the idea of applying Mendelian concepts to a practical problem. Thus, as Russell has pointed out, there was an implicit conflict in agricultural research in Britain at the beginning of the twentieth century: should it be trying to develop a science of lasting value which would reveal the basic laws controlling the growth of plants and animals, or should it search for the solution to the problems being faced by farmers at the time; the theoretical approach or the practical?[36]

When Daniel Hall was appointed Director of Rothamsted in 1902 he realised that this conflict existed, and decided in favour of elucidating the basic scientific laws. This was one of the reasons why Russell, his successor in the job, described his appointment as 'a turning point in the history of agricultural science in Great Britain'. The other was concerned with money. Lawes had died in 1900, and Gilbert the following year. The effective ownership of the laboratory was then in the hands of trustees, who appointed Hall, then Principal of Wye College, as Director. Hall discovered that Rothamsted was desperately short of money. He went to the Board of Agriculture for assistance and was turned down. In the event, he proved capable of raising the necessary money from private charitable sources, and indeed expanded the staff. Other scientists were not such effective fundraisers, and this was recognised by the Reay Committee, which reported in 1908, recommending, among other things, increased spending on research in agriculture. Whether this would have had any effect is dubious, had it not been for the establishment of the Development Fund in 1910. It was designed to promote the economic development of the country by means of a number of schemes, several of them agricultural. As Director of Rothamsted, Hall was one of the most prominent agricultural scientists in the country, and presumably this was one of the reasons why he was appointed as one of the Development Commissioners. He also knew T. H. Middleton, a former professor of agriculture who was then Assistant Secretary in charge of education and research at the Board of Agriculture. The Commission soon decided to spend its money in three ways: to promote agricultural co-operation, to experiment on new crops and industries, and to improve agricultural education and research. So the money necessary to put the Reay Committee's recommendations into effect became available.[37]

The research funds were used to create research institutes, each specialising in a particular field of enquiry. Those established or planned by 1914 are listed below:

Imperial College, London	Plant physiology
Cambridge	Plant breeding
Cambridge	Animal nutrition
Long Ashton (Bristol)	Cider and fruit
East Malling/Wye College	Fruit
Rothamsted	Soil and plant nutrition
Reading	Dairying
Birmingham	Zoology (helminthology)
Manchester	Zoology (entomology)
Oxford	Agricultural economics
Royal Veterinary College	Animal pathology
Kew	Plant pathology

Kew, Rothamsted and Long Ashton (which had been founded in 1903) were the only institutes not to be associated with a university department, although Long Ashton was later associated with the University of Bristol. The agricultural department at Cambridge acquired two of the institutes, reflecting the strength of the work there: Biffen was the director of the Plant Breeding Institute, and Wood and Hopkins were joint directors of the animal nutrition institute. Rothamsted was by far the biggest, with twenty-one staff. Most of the rest had between five and eight academic staff, and the total number in all the research institutes was sixty-seven. Woburn remained outside the scheme (it was eventually taken over by Rothamsted), although it received some grant aid from the Board of

[37] The effects on education are described below (pp. 643–4). H. E. Dale, *Daniel Hall: Pioneer in Scientific Agriculture* (London, 1956) pp. 75–100; R. Olby, 'Scientists and bureaucrats in the establishment of the John Innes Horticultural Institution under William Bateson', *Annals of Science*, 46, 1989, p. 497.

Agriculture, as did the Norfolk Agricultural Station, which had been set up in 1908 by a group of Norfolk Farmers. With a few modifications this was the scheme which lasted until after the Second World War.[38]

So by 1914 the system of laboratories and the funding to pay for them was in place. But this was only one part of the organisational framework required to ensure productive agricultural science. Another part, equally vital, was the human resource: the scientists themselves. By 1914 the university departments of agriculture were producing their own postgraduate students, several of whom became prominent in scientific research (see below p. 637) prior to which most agricultural scientists came from a pure science background. Lawes and Gilbert were chemists, and Gilbert was working as consultant chemist to a calico printer in Manchester when Lawes recruited him for Rothamsted. Warington, who also worked at Rothamsted, was a chemist and the son of a chemist. Playfair, Way, the Voelckers, Johnston and Daniel Hall were all trained as chemists. E. J. Russell was a Demonstrator in the chemistry department at Owens College, Manchester, when he applied for the lectureship in agricultural chemistry at Wye in 1900. His professor told him that 'good men did not go to agricultural colleges', and 'there was no career in agriculture'. Wood, Biffen and Percival all took the Natural Science Tripos at Cambridge. The main exceptions to this pattern were men like Somerville, Middleton and Gilbert who had degrees in agriculture from Edinburgh.[39]

The increasing numbers of agricultural scientists also needed to communicate with each other. For much of the nineteenth century the journals of the Royal Agricultural Society of England and the Bath and West Society had, in part at least, done the work of learned journals, although Lawes and Gilbert, and others, also published elsewhere, in, for example, the *Journal of the Chemical Society*, the *Journal of the Society of Arts*, and the *Proceedings* of the Royal Society.[40] The expansion of agricultural colleges and peripatetic lecturers in the 1890s resulted in the publication of much research material in college journals and county council reports, some of it perforce written in non-technical language or mixed up with material of local or temporary interest. It was too 'applied' for the pure science journals, and insufficiently popular for the journals of the agricultural societies or the Board of Agriculture. By the beginning of the twentieth century

[38] Russell, *History*, p. 282; Board of Agriculture and Fisheries, *Annual Report of the Education Branch on the Distribution of Grants for Agricultural Education and Research, 1913–14*, Cd.7450, p. 7; BPP, 1914, XI, p. 717.

[39] Russell, *History*, pp. 103, 115–16, 122, 130, 160, 190, 200, 204, 209, 216, 244, 248; Sir E. John Russell, *The Land Called Me* (London, 1956), p. 93.

[40] M. Harcourt Williams, *Rothamsted Archives: a Catalogue of the Records in the Library* (Rothamsted, 1987).

science to agriculture, and was widely influential. In 1881 an agricultural chemist and a soil scientist from Germany were working at the Komaba Agricultural School in Japan, and some of the early American agricultural scientists were trained in Germany. Liebig's work became well known in the United States in the 1840s, and attracted several American students to Giessen. When they returned home such men attempted to set up university laboratories, with mixed success. The establishment of the Land Grant colleges in 1862 appeared to open up further opportunities, but their impact was limited. What really made the difference was the Hatch Act of 1887 which established State Agricultural Experiment Stations. University laboratories expanded too, and from then on the opportunities for agricultural scientists increased. In the Netherlands the experimental station at Wageningen was established in 1877, and in France Lavoisier experimented on his own estate and Boussingault established an experimental station in 1834.[45]

Grantham argues that economic trends provide an incomplete explanation of this expansion in Europe and the United States, and the same is probably true in England and Wales. To be flippant, it might be argued that before 1875 the agricultural industry felt that it did not need science; after that it could not afford it. Rather less flippant, but equally incapable of proof, is the idea that if Gilbert had been less suspicious of young scientists Rothamsted might have had imitators in the way that Mockern did, although this leaves aside the problem of how they would have been funded. Part of the problem also lies in the definition of science, as discussed above: the scientists employed by the farmers of England and Wales, insofar as the leading agricultural societies were representative of farmers, were employed as consultants, asked to determine whether or not farmers had been sold poor samples of feed or fertiliser or seeds which would not germinate. They fulfilled some of the functions of a public analyst. Indeed, some of them were public analysts. Some of the work done by the Voelckers was similar to that done in experimental stations, but clearly they could have done much more had they not had their consultancy businesses to run. Moreover, to be fair to agriculture, it might be argued that this indifference to science was by no means confined to agriculture alone, but was shared by many other industries. If, in the years before 1870, there was not enough science in England, there was thereafter an increasing divorce between science and general culture, in part because the scientists wanted to isolate themselves from the economic and

[45] Grantham, 'The shifting locus of agricultural innovation', pp. 196–8; V. W. Ruttan, *Agricultural Research Policy* (Minneapolis, 1982), pp. 71, 74, 84; J. R. Kloppenburg, *First the Seed: the Political Economy of Plant Biotechnology, 1492–2000* (Cambridge, 1988), pp. 58–60; Rossiter, *The Emergence of Agricultural Science*, pp. 172–5; I. Arnon, *Agricultural Research and Technology Transfer* (London, 1989) p. 22, 40.

social demands of the public and be seen as disinterested investigators. Initially, therefore, there were not many scientists in total, and later there were not many in industry. Moreover, they were expensive. At the end of the century scientists at the start of their career could command a salary of 1200 marks in Germany, but their salary in England was equivalent to 2000 marks. British governments were against public support for scientific research in general until about 1900, although after that the relationship between the state and science was strengthened. The Royal Commissions which sat in the 1880s made no strong case for state support for measures to increase agricultural productivity, although the Departmental Committee on Agricultural and Dairy Schools which reported in 1888 commended the work going on at Rothamsted and Woburn, and argued that further scientific investigations were necessary, that more experimental stations were wanted, and that the state might reasonably be asked to contribute to the cost. Little came of these recommendations until the case was made again by the Reay Committee in 1908, and the money made available by the Development Commission in 1910.[46] In 1902, in fact, when Hall was trying to raise funds for Rothamsted, he was told unofficially by Sir Thomas Elliott, Secretary to the Board, that British agriculture was dead and the Board's business was to bury it decently.[47]

The attitude of the agricultural community to science was more ambivalent. There are examples of great interest, and of dismissal. When (presumably in the 1840s) Philip Pusey took Liebig, Daubeny and Playfair on tour to speak to farmers on science, 'considerable interest in the subject was excited throughout the country'. Many farmers visited Rothamsted to see the field experiments. Not only were the results interesting, but the experiments themselves were simple in design and consequently easy to understand. Sometimes a cold collation was prepared in a marquee on the lawn at the end of the proceedings.[48] But understanding was one thing; adoption was another. Part of the blame for this, according to one commentator in the 1850s, lay with Liebig, 'for the failure of his patent manure caused a reaction in the minds of farmers

[46] Heyck, *Transformation of Intellectual Life* p. 114; Alter, *The Reluctant Patron*, pp. 247–50; Grantham, 'The shifting locus of agricultural innovation', pp. 202, 208; *Final Report of the Departmental Committee on Agricultural and Dairy Schools* (the Paget Committee), C.5313, p. 10, BPP, 1888, XXXII, p. 11.

[47] This story is told in both *The Land Called Me* (p. 117), the autobiography of Sir John Russell, who worked with Hall, and in Dale, *Daniel Hall* (p. 56 n.1). Since both books were published in 1956, and neither gives a source for the story, it is impossible to be precise about its origin, although presumably it came from Hall himself. Since the Board was at that point distributing grants for agricultural education *and research*, it perhaps suggests some inconsistency in the Board's policy or some exaggeration in the story. See Board of Agriculture, *Annual Report on the Distribution of Grants for Agricultural Education and Research, 1899–1900*, Cd. 310, BPP, 1900, LXVIII, p. 9.

[48] E. Clarke, 'Philip Pusey (1799–1855)', *JRASE*, 3rd ser., 11, 1900, p. 7; Russell, *History*, p. 150.

against the teachings of chemistry . . .' John Prout of Sawbridgeworth achieved fame (or, more often, notoriety) by following the teachings of the scientists, dispensing with his livestock, and using only inorganic manures from the 1870s onwards. A little later, George Baylis, who farmed around Newbury (Berkshire), adopted a system of continuous corn interspersed with fallows, and he also kept no grazing livestock. Both were successful, and the system enabled Baylis to expand his land holding from 3,440 acres in 1896 to 12,140 in 1917, but few followed their example. Prout attributed this to the lack of legal security for the necessary investment required from the tenant. He himself was an owner-occupier and so had no such problem nor any restrictive clauses in his lease. Simply acquiring the necessary capital would also have been a problem for many tenants and, interestingly, both Lawes and Voelcker considered that Prout's methods would eventually exhaust the soil. They also mentioned, perhaps more rationally, that continuous corn growing would lead to the build up of disease.[49]

To summarise, therefore, it seems that agricultural science's failure to expand in England and Wales before 1890 was partly something which was common to all forms of science, partly a result of the attitude of government, and partly a result of the attitude of the farming community. Other factors were also present which promoted the expansion of research in other countries but were absent in England and Wales. In Germany, for example, Grantham has argued for the importance of a scientifically literate bureaucracy in raising the expected marginal return from expenditure on agricultural research. If this were the case, it would emphasise the importance of men like T. H. Middleton, who was professor of agriculture at Cambridge before he moved to the Board of Agriculture in 1906, and Daniel Hall, a chemist, principal of Wye College, and Director of Rothamsted at the time of his appointment to the Development Commission in 1910. Not until men such as these attained positions of power were significant state funds allocated to the establishment and running of agricultural research institutes. A cynic might observe that they were serving the interests of their own kind in much the same way as the Kentish farmer who sat on the government body of Wye College and argued that it should be 'a place from which we can get a really good ploughman or shepherd'. On the other hand, the effect of their actions might benefit both the food producer and consumer if agricultural science could be shown to increase agricultural output and productivity.[50]

[49] E. T. Hemming, 'On the neglect of chemistry by practical farmers: its causes and remedies', *JRASE*, 13, 1852, p. 409; J. R. Fisher, 'Public opinion and agriculture, 1875–1900', PhD thesis, University of Hull, 1972, pp. 72–3.

[50] Grantham, 'The shifting locus of agricultural research', pp. 204–5; Russell, *History*, p. 205; Dale, *Daniel Hall*, pp. 44, 73.

Unfortunately, it is not clear whether or not science did indeed improve the lot of the food producer or consumer in this period. As far as dairying is concerned, Mepham has argued persuasively that developments in quality control techniques increased public confidence in the safety and palatability of dairy products by the end of the nineteenth century, and milk yields were increased too. However, the contemporary views of prominent agricultural scientists and commentators, while agreeing that there had been improvements in dairying, suggested that it might have been an exception. Lawes, in 1881, told a Royal Commission that science had yet to reach the standard of perfection required to teach everything about agriculture, although it might probably help another generation. In the meantime, it was no substitute for a 'good thorough business-like knowledge' of farming. In 1885 Voelcker considered that the main problem was to increase the relevance of science to agriculture rather than to encourage farmers to be scientific. Even J. C. Morton and H. M. Jenkins, two of the leading advocates of agricultural science and education in the 1880s, conceded that the best practice of the time owed little to science and had little to learn from it. Later, in 1896, Malden thought that farmers had been right to be cautious about the claims of scientists, although he approved of their recent increasing interest. At about the same time Professor Wrightson, although an advocate of the benefits of agricultural science, agreed with those who argued that these had accrued more to the overseas competitor than to the home farmer. On the other hand, R. E. Prothero, looking back on 'English Agriculture in the Reign of Queen Victoria' in 1901, wrote of the 'incalculable debt' then owed by farmers to Lawes and Gilbert.[51] The major problem, in assessing the impact of agricultural science, is that the discovery or invention is only a part of the process; it must also be adopted, and on a significant scale, often in conjunction with improved cultivation practices, for any advances to occur. So the success of science cannot be measured by increases in output or productivity, for those increases are not simply the result of successful science, but of science plus adoption. The rate of adoption is determined by a range of variables, from changing input prices to the age of the farmer. Consequently, disaggregation of all the factors involved is not easy, and measuring the impact of scientific research in agriculture is very difficult.[52] Any conclusion must therefore be impressionistic, and those of contemporaries seem to be as valuable as those arrived at a century later. The main benefit of hindsight is that it

[51] Mepham, *Emergence of Dairy Science*, p. 12; Fisher, 'Public opinion and agriculture', pp. 81–90; Prothero, 'English agriculture in the reign of Queen Victoria', p. 24.

[52] Even with the data available to agricultural economists in the late twentieth century it remains difficult. See D. R. Harvey, 'Research priorities in agriculture', *Journ. Agric. Economics*, 39, no. 1, 1988, pp. 81–97.

demonstrates the importance of the Development Commission. Many of the research institutes which it established remained in existence through the dramatic agricultural changes of the later twentieth century, and indeed helped to bring them about.

C. AGRICULTURAL EDUCATION.

Since much agricultural education in the late twentieth century is carried out in educational establishments of one kind or another, it might at first seem obvious that the history of agricultural education is the history of those institutions. Much of what follows will indeed be concerned with the development of farm institutes, agricultural colleges and university departments of agriculture, but it is important to remember that, throughout this period, almost all farm workers, and all but a small minority of farmers and landowners, received what training they had 'on the job', as part of their working routine. As far as farm workers were concerned, Dr Fream summarised current thinking quite simply, if not brutally: 'It would be unnecessary to offer the labourer's child the same technical education as the son of the occupier of a large farm, for possessing no capital, he does not need such education.' Farm workers would be shown what to do by other farm workers, and fathers would pass on their skills to their sons. Fred Kitchen started work on a farm in Yorkshire in March 1904, 'being three months turned of my thirteenth birthday'. The following autumn he was 'given a pair of horses and taught to plough' by two of his fellow-workers. When things went wrong 'over would go the plough, with me clinging on and ready to cry with vexation. George and Arthur would laugh at my distress before coming to my assistance.' He was taught to do other jobs in the same way, and saw

> nothing unusual in their method of teaching; they had been taught the selfsame way, and were only carrying on in the same tradition – that the only way to learn is to find out. A lad was never shown how to do a thing; to show him how was to spoil him. The only way to learn either ploughing, thatching, stacking, or any other skilled work, was to watch how other people did it, and then earn your skill by trial and error.

Similarly, Robert Savage of Blaxhall in Suffolk was trained as a shepherd by working as a shepherd's 'page'.[53]

Many farmers would train their own sons. Often the process was so informal as to be unrecognisable as training. The process was simply to

[53] C. Tyler, 'The history of the Agricultural Education Association, 1894–1914', *Agricultural Progress*, 48, 1973, p. 2; Alun Howkins, 'In the sweat of thy face: the labourer and work', in Mingay (ed.), *The Victorian Countryside*, vol. II, p. 508; Fred Kitchen, *Brother to the Ox* (London, 1943 edn) pp. 27–32; G. E. Evans, *Ask the Fellows who Cut the Hay* (2nd edn, London, 1965), p. 27.

give the boy more and more responsibility as he got older. A. G. Street was a Wiltshire tenant-farmer's son. He left school in 1907 at the age of sixteen and returned home to work on his father's farm. He had been sent to a boarding school (Dauntsey's, near Devizes) where agriculture was part of the syllabus, but he clearly felt that he learned most of what he knew about farming from the men who worked on the farm and from his father:

I did not do much actual laborious work, but my father made me do every job on the farm at some time or another in order that I might, from personal knowledge, be able to estimate whether a man was working well or ill at any particular job. I was much older before I realised how much I did learn in those first years after leaving school. It is curious that one doesn't know the exact moment when one felt qualified to say that the sheep were doing well or not, whether a certain horse or cow were a good or bad one, or what precise cultivation was needed for a particular crop or field. One only knows that suddenly one does know. You don't learn by going round and asking why, but by growing up with the whole business. One assimilates knowledge unknowingly.[54]

A rather more formal system was for the new entrant to farming to be sent as a pupil or apprentice to 'farms run by distinguished farmers in the most progressive districts. There the professional taught not agriculture as a diversion for gentlemen, but farming as a business for farmers.'[55] Stephens wrote his *Book of the Farm* on the assumption that the reader would be a farm pupil.[56] John Simpson Calvertt, for example, in 1847, at the age of eighteen, went as a farm pupil to Mr Adams of Collow Grange, Lincolnshire, for two years. He then lived and worked with another farmer at Claythorpe for nearly three years until he obtained a tenancy of his own near Alford in Lincolnshire. William Carter Swan was a farm apprentice at Dial Post Farm in Sussex for two years from January 1909 until he obtained a tenancy of his own in January 1911. His father paid a premium of £50 for this apprenticeship, and a further £1 per week for his board and lodging. He received 2s. 6d. per week as pocket money, had his own room in the farmhouse, and lived with the family. As J. C. Morton wrote in 1865, '. . . the present generation of practitioners has been bred and educated by the last, and is engaged in the education of the next.' H. M. Jenkins, the Secretary of the Royal Agricultural Society, who produced a voluminous report on agricultural education for the Royal Commission on Technical Education and Instruction, took the

54 A. G. Street, *Farmer's Glory* (London, 1959 edn), p. 40; P. Street, *My Father, A. G. Street* (London, 1969) p. 31.

55 Macdonald, 'Model Farms', in Mingay (ed.), *The Victorian Countryside*, vol. I, p. 223.

56 'The only object I have in view in entering into all these particulars, is the preparation of the mind of the agricultural student, to enable him, when he becomes a pupil on a farm . . .' H. Stephens, *The Book of the Farm* (London, 1851), vol. I, p. 129.

view that this system might be institutionalised by sending students to leading farms in each county where best practice could be observed, while theoretical instruction was provided by a lecturer attached to the farm.[57]

Thus it appears that by the middle of the nineteenth century, under the farm pupil or apprentice system, a method of training new farmers was followed which, with its emphasis on practice, met with the approval of existing farmers, as far as their preferences are known. In short, there was little demand for academic training in agriculture; and at mid-century, in England and Wales, not much was supplied. In continental Europe, in contrast, colleges had existed for some time: there was one in Hungary and several in Switzerland; one had been established near Versailles in 1826; Germany had one near Frankfort-on-Oder, and another with an estate of 1,000 acres had been established near Stuttgart in 1817. Stephens described several of them in detail, and concluded that 'as a means of imparting practical knowledge to pupils, they are inferior to the mode usually adopted in this country, of boarding with farmers'.[58] In Scotland, a chair of agriculture had been established in the University of Edinburgh in 1790, although it was not possible for students to take a degree in the subject. In Ireland the Albert Agricultural College at Glasnevin near Dublin was founded in 1838 for training farmers, bailiffs and 'estate agriculturalists', and also primary-school teachers, who were supposed to pass on improved methods to their pupils. Chairs in agriculture were also established at the new Queen's Colleges at Belfast, Cork and Galway shortly after their foundation in the 1840s, although those at Cork and Galway were discontinued after the 1860s.[59] But in England, virtually no interest was shown in agriculture in the universities. J. F. W. Johnston taught a course in agricultural chemistry at Durham University from 1848 to 1852, although he probably had more influence through his authorship of a number of clearly written textbooks. The only university chair was at Oxford. There the Sibthorpian Chair of Rural Economy had been founded in 1796, although no funds were available to fill it until 1840, and it was held jointly with the chair of Botany until 1877. In any

[57] C. Miller (ed.), *Rain and Ruin: the Diary of an Oxfordshire Farmer* (Gloucester, 1983), p. 7; E. E. Swan (ed.), *The Diary of a Farm Apprentice: William Carter Swan, 1909–10* (Gloucester, 1984), pp. 1–9; see also S. Macdonald, 'The diary of an agricultural apprentice in Northumberland, 1842', *Local Historian*, 12, 1976, pp. 139–45; Morton's phrase is quoted in S. Richards, '"Masters of Arts and Batchelors of Barley": the struggle for agricultural education in mid-nineteenth-century Britain', *History of Education*, 12, no. 3, 1983, p. 165; Fisher, 'Public opinion and agriculture', p. 81.

[58] Stephens, *Book of the Farm*, vol. 1, pp. 121–3; Sykes, 'Agriculture and science', in Mingay (ed.), *The Victorian Countryside*, vol. 1, p. 267.

[59] S. Richards, 'Agricultural science in higher education: problems of identity in Britain's first chair of agriculture, Edinburgh, 1790–c. 1831', *AHR*, 33, 1985, pp. 62–4; Richards, 'Masters of Arts', pp. 171–4.

case it was not possible to take a degree in agriculture until the early twentieth century.[60]

It was against this background that the Royal Agricultural College was founded. It all happened with remarkable speed. In November 1842 Robert Jeffryes Brown read a paper to the Fairford and Cirencester Farmers' Club 'On the Advantages of a Specific Education for Agricultural Pursuits', arguing for a practical approach to agricultural education. In April 1844 a public meeting was held at Cirencester, with Earl Bathurst in the chair, at which a motion was carried to the effect that 'it is expedient to provide an Institution in which the rising generations of farmers may receive instruction, at a moderate expense, in those sciences, a knowledge of which is essential to successful cultivation, and that a farm form part of such Institution'. A committee was formed to put this motion into effect, and on 1 July 1844 Earl Bathurst was elected President, with Brown as Secretary. Bathurst offered a 400-acre farm on a 99-year lease, and also provided some money towards the building of a College. Philip Pusey chaired a meeting at the Royal Show at Southampton three weeks later at which further funds were raised by a subscription scheme. Prince Albert was Patron and subscribed the first five shares of £30 each. 'The Agricultural College' (it did not become Royal until 1880) was incorporated by Royal Charter in March 1845. Building began the next month. The first students were admitted in September 1845, although they had to live in Cirencester until accommodation was ready in the College buildings in April 1846.[61]

The original capital raised for the College amounted to £12,000. When this proved inadequate provision was made to increase it to £24,000. The money was spent on building the College and modifying existing buildings, such as a barn which was converted into a chemical laboratory. Student fees, which had to cover board and lodging costs, tuition fees and capital repayments, were set at £30 per year. Unfortunately, the students proved capable of consuming £32 worth of food and drink per year. By 1848 the College had an overdraft of £10,000. The real possibility loomed that it might have to close, but it was saved by additional subscriptions from Mr Holland, the Earls Ducie and Bathurst, and various other gentlemen, to the extent of £30,000. Once the finances had been secured the College attracted some capable men to its staff, among whom John Wilson, J. T. Way, J. A. Voelcker, John

[60] Sykes, 'Agriculture and science', p. 268; S. A. Richards, 'Agricultural science in British higher education, 1790–1914', MSc thesis, University of Kent at Canterbury, 1982, p. 88; G. E. and K. R. Fussell, 'James Finlay Weir Johnston', p. 35; J. A. Scott Watson, 'The University of Oxford', *Agricultural Progress*, 14, 1937, pp. 95–6.

[61] R. Boutflour, 'The Royal Agricultural College, Cirencester', *Agricultural Progress*, 15, 1938, pp. 1–3; Richards, 'Masters of Arts', pp. 166–7.

Wrightson and William Fream were the best known. But it did not, at least at first, attract the sons of farmers. The sixty students on the books when Caird visited the College in 1850 were 'all the sons of solicitors, clergymen, officers, or landed proprietors'. However, most of them intended to become either land owners or occupiers, and Caird felt that some of them might yet 'prove very valuable to the community, as an educated and competent body of land agents and stewards, conversant with the details of agriculture'. By then the fees had risen to £50, perhaps twice the annual wage of a farm labourer. In the 1880s they had risen to £135 per annum, and student numbers had increased, but only to about ninety. Even in 1909 the college had only twelve members of academic staff.[62]

One of the criticisms most commonly made of the Royal Agricultural College was that it was too academic and scientific and insufficiently practical. An early prospectus listed the subjects to be studied as geometry, mechanics, hydraulics, designing and drawing implements and buildings, chemistry and physics, geology and mineralogy, botany, vegetable physiology and natural history, principles of the veterinary art and methods of farm accounts, which is perhaps evidence for this criticism. On the other hand, students were supposed to spend half of each day on the farm, and to undertake 'all the manual operations of husbandry'. Whether these early intentions were maintained is another matter. John Wrightson was a student at the college in the early 1860s, and in 1864, at the age of twenty-four, was appointed Professor of Agriculture there. He held this position until his resignation in 1877. In July 1878 he took over the tenancy of Charford Manor, near Downton on the borders of Wiltshire and Hampshire. The tenancy included a farm of 535 acres and his initial intention seems to have been to take a limited number of farm pupils, but in 1880 the house and farm became the Wilts. and Hants. Agricultural College, changing its name within a year to the Downton College of Agriculture. Wrightson's view of the teaching at the Royal may be inferred from the statement he made in 1880 that it was 'our object to make a farmer, not a chemist, of the youth, and to treat all the sciences connected with agriculture as subsidiary to this main object'. Nevertheless, he was quite clear that he saw his college 'as a school for landowners, land agents and colonists. I consider that, unless in the case of wealthy farmers, the agricultural education of farmers and farm bailiffs falls outside our province.' The fees were commensurate with these inten-

[62] C. Lawrence, 'The Royal Agricultural College of Cirencester', *JRASE*, new series, 1, 1865, pp. 2–5; Boutflour, 'The Royal Agricultural College, Cirencester', p. 4; Richards, 'Masters of Arts', pp. 167–8; James Caird, *English Agriculture in 1850–51* (2nd edn, London, 1968), p. 37; Richards, 'Agricultural science', pp. 74, 110; the 1909 figures are taken from an advertisement for the college in *JRASE*, 70, 1909, p. 12.

tions, and even higher than those at the Royal. They ranged from £50 per year for a non-residential student to £150 for a private sitting room and bedroom for a student not assisting with the farm work. It was never a very large college, generally having between thirty and forty students, with four staff (one of whom, for ten years, was William Fream), in addition to Wrightson. Another privately run college at Hollesley Bay in Suffolk was started in 1886 by Colonial College and Training Farms Ltd, and known as the Colonial College. As the name suggests, its purpose was to train 'young gentlemen intending to become colonists, in all the arts suitable for a colonial life, with all the practical details of farming'. It closed in 1905. Downton closed rather abruptly in 1906 when tighter controls over the provision of grant-aided technical education were introduced. By then Wrightson was sixty-six years old and in poor health, and his eldest son, who had been on the staff, did not wish to continue the college. Moreover, the provision of agricultural education in other colleges and the universities had increased significantly since Downton had been founded.[63]

In some ways this increase in the provision of agricultural education at the end of the nineteenth century can be traced back to the formation of the Education Committee of the Royal Agricultural Society in 1864. Initially it limited its activities to encouraging the study of science in middle-class schools by giving prizes for success in examinations. This had little impact except to provoke four members of the committee, including its chairman, Edward Holland MP, to protest that the society should be encouraging candidates in practical and scientific agriculture. In 1865 John Chalmers Morton addressed the Council of the Society, arguing that recent advances in agriculture could not be attributed to any improvement in the professional abilities of farmers. One of his main pieces of evidence was derived from a comparison of the sales of medical and agricultural textbooks. He found that the 15,000 doctors, surgeons and apothecaries in the country bought between them 14,000 copies (in total) of seven well-known medical books. Total sales of eight well-known books on agriculture amounted to 38,591 copies, and Morton estimated the potential readership to include 30,000 landowners and 60,000 farmers. The figures, he asserted, reflected unfavourably on their professional as against their general education. In agriculture, as in other areas of education, England and Wales lagged behind Scotland, where in

[63] Richards, 'Master of Arts', p. 169; G. E. Jones and B. K. Tattersfield, 'John Wrightson and the Downton College of Agriculture', *Agricultural Progress*, 1980; D. Hewish, 'Horses, Hollesley and the Home Office', *Ark*, 16, no. 5, May 1990, p. 166; Hollesley Bay is also mentioned in William Somerville's article on agricultural education in R. P. Wright (ed.), *The Standard Cyclopedia of Modern Agriculture and Rural Economy*, vol. v (n.d., *c.* 1913) p. 19, which gives its date of closure as 1903.

1856 the Highland and Agricultural Society had established a diploma in scientific and practical agriculture. Holland and Morton's efforts presumably had some effect, for in 1869 the Society established its own examination, in which candidates had to take at least four subjects – practical agriculture, chemistry, book-keeping, and either land surveying or agricultural mechanics – and might also offer one or more optional subjects such as anatomy, botany and geology. Agricultural entomology and veterinary science were later added to the list of optional subjects. Yet only 142 candidates were examined between 1869 and 1882, and of these only 32 per cent were successful. The questions were printed in the *Journal*, and illustrate why the science may not have been thought particularly practical ('Give an account of the preparation and properties of nitrogen, chlorine, and potassium'), nor the practical agriculture especially scientific ('Give particulars of the feeding and management, breeding, rearing, and breaking-in of farm horses').[64]

Between 1874 and 1895 a Junior examination was organised for twelve schools which taught agricultural science. Between twenty and forty candidates were examined each year, some of whom were subsequently awarded scholarships to enable them to spend a year at an agricultural college or as a farm pupil. From 1875 the Science and Arts Department began to pay fees to teachers in elementary schools whose pupils passed examinations in the principles of agriculture, and in 1881 the Normal School of Science in London began to give lectures in agriculture. Again, farmers argued that the course was mainly concerned with basic science, and was insufficiently practical or related to agriculture. H. M. Jenkins, in his 1884 report on agricultural education, concluded that the central government support given to the Normal School was justified, although he agreed with agricultural opinion on the need to revise the course to make it more practical. It produced the science teachers who would teach agriculture in the schools, but it was at this level that the biggest problem was located. The agricultural colleges had reached the point where they were self-supporting and required 'no propping from the state'. It was at the lower level, argued Jenkins, that the problem lay, in the education of farm labourers, bailiffs and small farmers. Unfortunately, 'At the present time there exists no machinery in Great Britain for the technical instruction of this class except that given by science teachers under the Science and Art Department.' A few schools had included agriculture in their ordinary teaching, and Jenkins mentioned those at Cranleigh in Surrey, Bedford, West Buckland in Devon, Dorchester, Elmham in Norfolk, and

[64] J. A. Scott Watson, *The History of the Royal Agricultural Society of England, 1839–1939* (London, 1939), pp. 136–8; Richards, 'Agricultural science', pp. 90–6; the superiority of Scottish education is discussed in Robbins, *Nineteenth-Century Britain*, chapter 5; 'Examination Papers, 1874', printed in *JRASE*, 2nd series, 10, 1874, pp. lxxxviii–xcv.

the Agricultural and Commercial School at Aspatria in Cumberland, where agriculture was the 'leading feature'. Clearly, these were insufficient to do the job which Jenkins thought was needed. In contrast, his report demonstrated that other European countries had made extensive provision for agricultural education. Agricultural academies had been established in most German states before 1850, and between 1863 and 1880 agricultural faculties were set up in seven universities. The Folk High Schools founded in Denmark between the 1840s and 1870s included agricultural subjects in their syllabuses and a Royal Veterinary and Agricultural College had been established in 1858. (By 1900 there were one thousand students in Danish agricultural colleges.) In France, the Institut National Agronomique in Paris and in Grignon, 'the Cirencester of France' according to Jenkins, were both supported by the state, and there were several agricultural colleges in Belgium and Holland. Educational enterprises, from agricultural colleges to evening meetings for farmers, had been expanding in the United States from the 1870s.[65]

By the middle of the 1880s, therefore, it could fairly be said that formal agricultural education in England and Wales had made little progress. There was only one university chair, and that part-time. There was only one major college, which, although it might be self-supporting, attracted few students, most of whom would not spend their lives in practical farming. The examinations set by the Royal Agricultural Society were commonly criticised as being excessively biased towards irrelevant science and insufficiently practical, which was perhaps why few people presented themselves as candidates. For the bulk of those who would do the farming and the farm labouring there was virtually no provision in basic agricultural education or training. It was not surprising that most young farmers and farm workers were trained by older farmers and farm workers. The allegations made by Morton in 1865 might almost have been repeated with equal justification twenty years later.

This gloomy picture was brightened considerably over the following thirty years, largely by throwing taxpayers' money at it. In 1888 county councils were established, and under the terms of the Technical Instruction Act of 1889 were required to use the proceeds of a penny rate to provide facilities for that purpose, including instruction in agriculture. Also in 1889 the Board of Agriculture was established, and was allowed to disburse a total of £5,000 on agricultural educational establishments.

65 Watson, *Royal Agricultural Society*, p. 138; Richards, 'Agricultural science', p. 98; H. J. Little, 'Report on agricultural education – a summary', *JRASE*, 2nd ser., 21, 1885, pp. 126–64, 526–7, 544–5; Ruttan, *Agricultural Research Policy*, pp. 73–4; M. Tracy, *Agriculture in Western Europe* (2nd edn, London, 1982), p. 116; F. A. Shannon, *The Farmer's Last Frontier: Agriculture, 1860–1897* (New York, 1963), pp. 272–9.

The real breakthrough occurred in 1890, with the passage of the Local Taxation (Customs and Excise) Act, the original purpose of which was to close down superfluous public houses. In order to compensate publicans who were to lose their licences it provided for a duty to be levied on beer and spirits. The legislation to raise the duty was passed without difficulty, but the temperance movement argued fiercely against using the money so raised in 'endowing the publicans'. During the debate in the Commons in June 1890 A. H. D. Acland (Liberal member for Rotherham and General Secretary of the National Association for the Promotion of Technical and Secondary Education) moved that the money should be used for technical education. He did not expect his motion to be carried, and indeed it was not. But the government was in difficulty, for it had already begun to raise the duties, and needed some uncontroversial purpose towards which they could be diverted. When Mr Goschen, the Chancellor of the Exchequer, returned to the House in July, he announced that the money would go to the county councils with the instruction that it should be used 'with reference to intermediate, technical or agricultural education'. Not surprisingly, it soon became known as the 'whisky money'. The precise amount raised every year depended upon the amount of alcohol consumed, but rose to about £1 million by the turn of the century. It was much more than had ever before been available for technical education, and seemed to result in the acceptance of the principle of state aid for such instruction. Each year about £80,000 of it was devoted to agricultural education, in the form of lectures, extension classes, dairy schools, and grants to agricultural colleges.[66]

At this point it is expedient to divide the story into two parts – higher and lower educational levels – since they evolved in different ways. Higher education was especially the concern of the Board of Agriculture. When the Board was formed and given its educational responsibilities, it was clear that it would have to do something, but not quite so easy to see what it would be. In 1887 a Departmental Committee on Agricultural and Dairy Schools under the chairmanship of Sir Richard Paget had recommended the establishment of a Central Normal School of Agriculture for training teachers of agriculture and dairying. The Farmers' Club and the Central Chamber of Agriculture agreed with this suggestion, but the Educational Committee of the Royal Agricultural Society, in 1890, argued for several different centres, on the grounds that they would better reflect the regional differences in English agriculture. Furthermore these

[66] S. Foreman, *Loaves and Fishes: an Illustrated History of the Ministry of Agriculture, Fisheries and Food 1889–1989* (London, 1989) p. 101; P. R. Sharp, 'The entry of County Councils into English Educational Administration', *Journ. Educational Administration and History*, 1, 1968, p. 19; W. Somerville, 'Education', in Wright (ed.), *Standard Cyclopedia*, vol. v, p. 20; Richards, 'Agricultural science', pp. 118–20.

centres should be in the universities, where they would have 'almost every brand of scientific teaching in immediate propinquity'. The Board of Agriculture, and its Educational Inspector, A. E. Brooke-Hunt, took the same view, and gave the first of their grants in 1889 to the University College of North Wales at Bangor.[67]

J. J. Dobbie, the professor of chemistry at Bangor, had been giving lectures to farmers, and carrying out field experiments on manuring, first in Anglesey, and later in other parts of North Wales, since 1885. He seems to have been impressed with the development of agricultural teaching in Denmark, where Folk High Schools and agricultural colleges had existed since the middle of the nineteenth century, and wished to develop something more than a purely academic department of agriculture. Thus extension work was important from the outset, and the county councils (which, of course, had access to the whisky money) soon became involved, and helped to finance the work of the new department. Bangor eventually took responsibility for the six northern counties of Wales. But it was the first grant of £200 from the Board of Agriculture which launched the scheme, and allowed the employment of D. A. Gilchrist as a full-time lecturer in 1889. The Board of Agriculture quickly realised that the way things had been done at Bangor might 'form a type on the lines of which it may be feasible to organise agricultural education throughout the Kingdom'.[68]

Within five years of the first grant to Bangor most other university departments of agriculture had been set up. Several farmers and landowners contributed £500 to supplement funds from the three Yorkshire county councils and the Board of Agriculture, and the department at Leeds was set up in 1890. The Northumberland County Council was instrumental in the endowment of a chair of agriculture in 1891 at the College of Science at Newcastle (which subsequently became Armstrong College, then King's College, Durham, and finally Newcastle University). The department at Aberystwyth was established in the same year. In 1892 Nottingham University College became involved, although from 1895 most of the work was done by the Midland Dairy Institute at Kingston, which separated from the University College in 1900. M. J. R. Dunstan, who had started the department at Nottingham, had originally been employed as one of the Extension lecturers of the Oxford Delegacy for Local Examination, which was also instrumental in the foundation of the University Extension College, which subsequently became Reading University. The agriculture department, one of the original departments

67 Richards, 'Agricultural science', pp. 117–22.

68 Tracy, *Agriculture in Western Europe*, pp. 115–16; R. G. White, 'The University College of North Wales, Bangor', *Agricultural Progress*, 16, 1939, p. 116.

of the university, was founded with the help of Suttons, the local seed firm, and the first lecturer in agriculture was appointed in 1894. In the same year the Kent and Surrey County Councils decided to use their whisky money to build the South-Eastern Agricultural College at Wye, and this became part of the University of London in 1900. By the middle of the 1890s, therefore, most of the university departments of agriculture had been brought into being. The only exceptions were Oxford, where the first full-time professor was not appointed until 1907, and Cambridge, which in 1890 rejected the Board of Agriculture's proposal to set up an agricultural department on the grounds that it was not the purpose of the university to provide technical instruction. This view was changed by the prospect of endowments, the first, in 1896, to establish the Gilbey lectureship in the history and economics of agriculture, and the second in 1898 to establish the Drapers' chair of agriculture. In contrast to all this expansion, agricultural activity at the Normal School in South Kensington was contracting. For many years it had only managed to attract about seven students each year onto its agriculture course, and by 1898 this number had fallen to one. After that the course was abandoned.[69]

Although some might view an agricultural degree as 'technical instruction', the syllabuses followed at the end of the nineteenth century seem academic enough to the modern eye. That followed at the College of Science, Newcastle, for the Durham BSc degree (see Table 8.1) is not untypical.[70] Half the time allocated to each subject was devoted to practical work. Nevertheless, it is easy to see why practical farmers might fail to see the relevance of a degree to practical farmwork.

Much of the work done by the universities was at diploma, rather than degree, level, as Table 8.2 demonstrates. Since the mid-nineteenth century both the Royal Agricultural Society of England and the Highland and Agricultural Society of Scotland had conducted examinations for the award of their diplomas. Many candidates prepared for these examinations at the Royal Agricultural College, and, as other colleges and university departments were founded, they too began to enter students

[69] N. M. Comber, 'The Department of Agriculture of Leeds University', *Agricultural Progress*, 24, 1949, pp. 7–13; H. C. Pawson, 'The Department of Agriculture, King's College, University of Durham', *Agricultural Progress*, 23, 1948, p. 7; C. Bryner Jones, 'The University College of Wales, Aberystwyth', *Agricultural Progress*, 24, 1949, p. 91; B. H. Tolley, 'M. J. R. Dunstan and the first Department of Agriculture at University College Nottingham, 1890–1900', *Trans. Thoroton Soc. of Nottinghamshire*, 87, 1983, pp. 71–9; G. H. J. Watkins, 'The Royal Agricultural College, Cirencester: its origins and development as a specialist institute of scientific learning 1844–1915', MEd thesis, University of Bristol, 1979, p. 86; Richards, 'Agricultural science', pp. 118, 129, 142, 149, 150, 155.

[70] Board of Agriculture, *Annual Report on the Distribution of Grants for Agricultural Education and Research 1899–1900*, Cd.310, p. 7, BPP, LXVIII, p. 19.

Table 8.1. *The Durham BSc syllabus, 1899–1900*

First year		Second year		Third year	
	hours		hours		hours
Maths	200	Agriculture	140	Agriculture	30
Physics	200	Agricultural chemistry	240	Forestry	30
Chemistry	200	Agricultural engineering	80	Entomology	30
Geology	200	Agricultural botany	160	Estate management	30
Natural history	160	Anatomy, physiology and pathology of farm animals	130	Botany	180
				Organic and agricultural chemistry	300
		Book-keeping	40	Anatomy, physiology, pathology and farm hygiene	130
		Land surveying	33		
		Agricultural geology	22	Engineering	60
				Geology	60
				Building construction (optional)	60

Table 8.2. *Student numbers in grant-aided educational establishments, 1899–1900 and 1912–13*

	1		2		3					
	Degree courses		Diploma courses		Other courses of one year or more		Total of columns 1–3		Short courses	
	1899–1900	1912–13	1899–1900	1912–13	1899–1900	1912–13	1899–1900	1912–13	1899–1900	1912–13
Aberystwyth	3	19	5	12	3	4	11	35	108	90
Bangor	5	11	3	7	6	–	14	18	16	33
Cambridge	–	–[a]	15	152[a]	–	–	15	152	15	15
Leeds	–	1	–	25	35	25	35	51	2	4
Manchester		6		–		–		6		–
Newcastle	6	22	–	9	2	–	8	31	168	45
Oxford		8		12		–		20		–
Reading	–	11	16	43	56	37	72	91	83	35
R.Ag.Coll.			–	58		37		95		19
Holmes Chapel		3		52		–		55		–
MADC[b]	–	–	–	48	10	–	10	48	17	110
Harper Adams		–		19		51		70		14
Swanley		–		–		76		76		–
Uckfield		–		–		46		46		–
Wye	–	21	46	103	–	63	46	187	12	17
B.D.Inst.		–		–		–		–		44
Harris Inst.		–		59		–		59		–
National Fruit and Cider Institute		–		–		2		2		–
RHS School		–		43		–		43		–
Totals	14	102	85	642	112	337	211	1081[c]	421	461

Notes:

[1] The Cambridge figure is the total of Diploma and Degree Students.

[2] MADC figures are those for the Midland Agricultural and Dairy College in 1912–13 and University College Nottingham in 1899–1900.

These totals are not the same as those in the original source because forestry and veterinary courses mentioned therein have been omitted from this table.

Sources:

The 1899–1900 figures are taken from Board of Agriculture, *Annual Report on the Distribution of Grants for Agricultural Education and Research 1899–1900*, Cd.310, pp. 4–12, BPP, 1900, LXVIII, p. 19.

The 1912–13 figures are taken from Board of Agriculture and Fisheries, *Annual Report of the Education Branch on the Distribution of Grants for Agricultural Education and Research 1913–14*, Cd.7450, pp. 124–7; BPP, 1914, XI, p. 717.

for this qualification. From 1896 the Royal Agricultural Society also offered a diploma in the science and practice of dairying. The following year it combined with the Scottish society to form a Joint Examining Board which set the first examination for the National Diploma in Dairying. In 1900 the two societies combined again to set the first examination for the National Diploma in Agriculture (the NDA). It was in two parts, the first involving agricultural botany, mensuration and land surveying, general chemistry, geology and agricultural zoology; and the second, taken a year later, with papers in practical agriculture, agricultural book-keeping, agricultural chemistry, agricultural engineering and veterinary science. This version of the NDA was criticised, especially by university teachers, on the grounds that it contained too much irrelevant science. Perhaps they simply disliked having their science teaching assessed by external examiners. On the other hand, faced with a question like, 'What is the most common ore of lead? How is lead prepared from it? How is (a) white lead and (b) red lead prepared from lead?', perhaps they were justified. Whatever their motives, they were effective. In 1912 the NDA examinations were changed to become more practical and so more clearly distinguished from an agricultural degree. Nevertheless, the universities continued to prepare candidates for the diploma: of the successful candidates in 1914, fifteen were from the universities and nineteen from colleges.[71]

The colleges were described by William Somerville as 'giving instruction suitable for the sons of farmers, taking part in extension and demonstrational work, but not equipped for the highest forms of research'. In this category he included the Royal Agricultural College, Harper Adams Agricultural College in Shropshire (founded in 1901 from the bequest of £45,000 from Thomas Harper Adams, a farmer of Newport in Shropshire), the College of Agriculture and Horticulture at Holmes Chapel in Cheshire (opened by the County Council in 1895), the Agricultural and Horticultural College at Uckfield in Sussex (1894), and the Harris Institute at Preston (1892). The Studley College provided two-year diploma and one-year certificate courses for women in horticulture, poultry and beekeeping, or dairy work, poultry and beekeeping. It also offered a one-year course in fruit preservation. The college had been started by the Countess of Warwick at Reading in 1898 and moved to Studley Castle in Warwickshire in 1903. Also in this group were the British Dairy Institute at Reading (1896), the Royal Horticultural Society's school at Wisley (1907) and the National Fruit and Cider

[71] The examination question is one of those set in 1901 and printed in the *JRASE*, 62, 1901, pp. clxxxiv–clxxxix; Reports on the results of the 13th, 14th and 15th examinations for the National Diploma in Agriculture, *JRASE*, 73, 74 and 75, 1912–14; Richards, 'Agricultural science', pp. 162–5.

Institute near Bristol (1903), all of which were subsequently to develop as research rather than teaching establishments. The colleges in this category did not normally award degrees (although Holmes Chapel College did so when it was associated with the University of Manchester), but prepared students for the diploma examinations and taught short courses.[72]

Thus the 1890s and the first decade of the twentieth century were a period of considerable institutional growth and activity in the higher levels of agricultural education. As Table 8.2 demonstrates, numbers increased dramatically, especially on diploma courses, although Table 8.2 exaggerates the increase, because it is confined to institutions grant-aided by the Board of Agriculture. Some institutions which were not grant-aided in 1900 still prepared candidates for the diploma examinations, although one of the main examples of this type, the Royal Agricultural College, was losing students to the grant-aided colleges. Student numbers there fell from 106 in 1885 to 70 in 1906, and still further in 1912 (Table 8.2).[73] Moreover, the Cambridge figure for 1912–13 includes both diploma and degree students, so the total for the degree should be increased and that for the diploma reduced. Despite these caveats, the overall trend is clear: numbers of institutions, courses and students all increased. Whether this was sufficient to have a significant impact on the agricultural industry is another question. Beside the figure of more than a million farm workers and a quarter of a million farmers in the 1901 and 1911 censuses, a total of just over a thousand students on courses of one year or more in 1912–13 looks small; yet it is interesting to compare it with those registered for degree and diploma courses in agriculture in the mid-1980s, which was 903.[74] The numbers of staff in the eight university departments also increased. In 1900, 60 were employed; by 1913 they numbered 128, with an additional 24 advisory staff. More postgraduate students were also recruited (some of whom, such as Hammond, Halnan, Engledow and Ashby, would become prominent academics after the

[72] Somerville, 'Education', in Wright (ed.), *Standard Cyclopedia*, vol. v; C. Crowther, 'The Harper Adams Agricultural College', *Agricultural Progress*, 27, 1952, p. 5; D. M. Garstang, 'Studley College', *Agricultural Progress*, 28, 1953, pp. 5–11; and see Table 8.2.

[73] Watkins, 'The Royal Agricultural College', p. 88.

[74] H. F. Marks and D. K. Britton, *A Hundred Years of British Food and Farming: a Statistical Survey* (London, 1989), p. 138; the mid-1980s figure for student numbers is taken from R. S. J. Bolter, *Farm Management Education Today* (Reading University, 1987), Table 2. The figure for degree students is taken from Bolter's figure for Agriculture degrees. There were also 149 students taking agriculturally-related courses. The diploma figures are for the Higher National Diploma, which replaced the NDA in the early 1970s. There were also 737 students taking agriculture at National Diploma level, but this is generally accepted as a lower level than the old NDA. The number of farmers in 1985 was 256,000, only a slight decrease from 1913, but not all of these were full-time farmers.

war), as the Board of Agriculture gave twelve research scholarships in each of the years before the First World War. So rapid was the expansion, it seemed that there were hardly enough academics to go round. Gilchrist stayed at Bangor for only five years before moving to the chair at Reading, and eight years later he moved to Newcastle. There he replaced T. H. Middleton, who had had three years at Aberystwyth, followed by another three at Newcastle, before he moved to Cambridge, where he replaced William Somerville, who had been the first resident professor at no fewer than three universities, Newcastle, Cambridge and Oxford. This growth could not have happened without the approval of the Board of Agriculture, and its Education Inspector, A. E. Brooke-Hunt, clearly had considerable influence. It was also largely on his initiative that the Agricultural Education Association was formed in 1894, for the purpose of bringing together those involved in the field, and, of course, arranging conferences. All of this cost more, and the Board of Agriculture's expenditure on colleges and universities rose to £12,300 in 1908–9 and further to £18,500 in 1913–14.[75]

As agricultural education was expanding, there was also a flurry of new textbooks. To modern eyes many of the works of agricultural writers of the mid-nineteenth century are fascinating and detailed sources of historical evidence, but they are written in a way which cannot have made them easy to use as student textbooks. Morton's *Cyclopedia of Agriculture* (1855), for example, largely consisted of a series of unrelated articles laid out in alphabetic order, so that the section on barn implements was followed by barrenness, bases, basil (wild), *bassus albosignatus*, bean, bedstraw and bee. Stephens' *Book of the Farm* was arranged according to the seasons, so that the article on mares foaling was followed by treatment of bulls in summer, and in turn by pasturing of sheep and cattle in summer. Neither book was cheap. Morton's was published by Blackie and Son in twenty-eight parts, price 2s. 6d. each. In 1852 Blackwoods advertised a new edition of Stephens in two volumes, 'handsomely bound in cloth', for £3. The first volume of the *Journal of the Royal Agricultural Society* carried an advertisement for the cheap edition of Liebig's classic *Chemistry in its Application to Agriculture* at 9s. 6d., and J. C. Loudon's *Encyclopaedia of Agriculture* at £2 10s. 0d. For comparison, the same volume also offered a superfine frock coat with silk facings for £2 10s. 0d. and shooting

75 Board of Agriculture, *Annual Report on the Distribution of Grants for Agricultural Education and Research 1899–1900*, Cd.310, BPP, 1900, LXVIII, p. 9; Board of Agriculture and Fisheries, *Annual Report on the Distribution of Grants for Agricultural Education and Research, 1913–14*, Cd.7450, BPP, 1914, XI, p. 717; Richards, 'Agricultural science', pp. 139–40; Tyler, 'The history of the Agricultural Education Association', pp. 1–3 (it is interesting to note that *Agricultural Progress*, the Association's journal, remains a major source for the history of agricultural education); A. D. Hall, 'The development of agricultural education in England and Wales', *JRASE*, 83, 1922, p. 17.

jackets at half a guinea to a guinea. Between half a guinea and fifteen shillings would have purchased the services of a farm labourer for a week in this period. Loudon's book remained in print for many years. It was published in 1825, and by 1865 about 9,000 copies had been sold. On the other hand, cheaper works such as Johnston's *Elements of Agricultural Chemistry and Geology*, a readable book, logically arranged, proved more popular: between 1842 and 1852 it sold 10,000 copies in five editions in Britain alone, and more in the United States and the colonies.[76] Then in the 1890s came the expansion of agricultural education. As student numbers increased so also did the demand for textbooks. More lectures meant presumably more authors, and existing books went into new editions. Warington's *Chemistry of the Farm* was originally published in 1881 as part of a series designed for use in schools. By 1919 it was aimed at the college market. It had doubled in size and reached its twenty-second edition and fourth revision. The real price of such books was clearly lower than that of their predecessors forty years earlier. Fream's *Elements of Agriculture* sold at 2s. 6d. in its third edition, of 430 pages, published in 1892. Ten years later an advertisement for the seventh edition, at 3s. 6d., boasted the sale of 30,000 copies. Some of the textbooks first published in the late nineteenth century went on and on. The sixteenth edition of what had long been known simply as 'Fream's' was published in 1983. The eighteenth edition of *The Agricultural Notebook*, which started off as a simple compilation of agricultural facts and figures in 1883, was published in 1988. Several of the first staff at Wye College produced books which lasted through the first half of the twentieth century: Percival's *Agricultural Botany*, for example, and Hall's *The Soil*.[77]

In the light of these developments it is not surprising that when the Departmental Committee on Agricultural Education in England and Wales (the Reay Committee) reported in 1908 it could conclude that most areas of the country, with the exception of parts of the midlands and the south-west, were adequately covered by institutions of higher agricultural education. Thus they felt that if the Royal Agricultural College became a public institution, and 'if an agricultural college were established in Devon under the Seale-Hayne bequest', these would be in areas of the country where there were no universities with full

[76] J. C. Morton, *A Cyclopedia of Agriculture, practical and scientific* (London, 1855), section 1, pp. 195–224; Stephens, *Book of the Farm*; *JRASE*, 1, 1840; J. F. W. Johnston, *Elements of Agricultural Chemistry and Geology* (6th edn, Edinburgh, 1852); J. C. Morton, 'Agricultural education', *JRASE*, 2nd ser., 1, pp. 455–7.

[77] R. Warington, *Chemistry of the Farm* (London, 1919), preface; W. Fream, *Elements of Agriculture* (3rd edn, London, 1892); *JRASE*, 64, 1903, advertisements, p. 12; R. J. Halley and R. J. Soffe (eds.), *The Agricultural Notebook* (18th edn, Oxford, 1988) preface; J. Percival, *Agricultural Botany* (London, 1900); A. D. Hall, *The Soil* (London, 1903).

agricultural departments.[78] Otherwise, there were enough colleges and university departments. Future expenditure, they felt, should be devoted to improving the quality of their facilities, and of their staff, who should 'attempt to combine investigation with teaching', since 'original work should not only be encouraged, but expected'. There was still a need to produce more agricultural teachers and researchers, they felt, but otherwise the previous twenty years had seen 'remarkable progress' in higher agricultural education.[79]

'On the other hand', stated the Reay report,

> there is in this country a marked need for some form of institution providing agricultural education of a suitable kind for those who have had little secondary education. The majority of those who became farmers leave school to begin practical work between the ages of 13 and 15, and until this large class has some suitable form of technical instruction within reach, it is clear that the system of agricultural education in this country cannot be regarded as satisfactory.[80]

At the time, in fact, several kinds of institution provided agricultural training or education at a non-advanced level. One of the first was the Aspatria Agricultural College in Cumberland, which was set up by local landowners in 1874 'to advance the science and teaching of agriculture'. Most of its students were the sons of local farmers, aged between twelve and twenty years old, organised into elementary, advanced and practical divisions. Aspatria was always beset by money worries, which, for example, prevented it having any proper chemistry laboratory for its first twelve years. The Reay Committee clearly approved of it, and recommended that it should be assisted by the Board of Agriculture; it was not, and closed in 1914. The Tamworth Agricultural College and Training Farm, set up by the Sillito brothers in 1886, was another private venture which also terminated in 1914. There were also several schools, such as Dauntsey (Wilts.), Bigods (Essex), Shepton Mallet, Brewood, Barnard Castle county school and Morpeth Grammar School, which combined a general education for boys of fourteen to seventeen with instruction in the science and practice of agriculture. Some of their pupils then went on to agricultural colleges but the majority finished their education at school. Although the Reay Committee approved of the work done by these hybrids, they felt that they were outside their term of reference and therefore made no recommendation about them.[81]

[78] Board of Agriculture, *Report of the Departmental Committee on Agricultural Education in England and Wales, 1908*, Cd.4206, (the Reay Committee) pp. 10–13, BPP, 1908, XXI, p. 377; The Royal never did develop in quite the way that Reay envisaged. The Seale-Hayne bequest of 1903 was indeed used to found an agricultural college, although it did not begin to take students until the early 1920s. See C. C. Cattermull, 'Seale-Hayne Agricultural College', *Agricultural Progress*, 26, 1951, p. 61. [79] The Reay Committee (see note 78 above), pp. 11, 32–6. [80] *Ibid.*, p. 15.

[81] *Report of the Departmental Committee on Agricultural and Dairy Schools*, Cd.5313, Minutes of

One of the first forms of instruction in manual skills was the travelling dairy school organised by the Bath and West of England Society. The first was held at Swindon in 1880, and later that year it was repeated at Shepton Mallet, Chippenham, Exeter and Oxford. The whole course lasted for ten days and cost £1. 1s. 0d. Alternatively, students could attend for one week for 15s. 0d. or one day for 5s. 0d. Classes were held from 10.45 a.m. to 12.30 p.m. and from 1.30 p.m. to 4.30 p.m. every day except Sundays. Local Committees were formed in each of the districts visited and were charged with providing a suitable building, the necessary milk and cream, suitable lodgings for those female students (and most of the students seem to have been female) who needed them, and a guarantee of at least ten students per entire course. The necessary equipment was taken from place to place on a horse-drawn dray. The instructors spent three weeks at each venue, and so could give two complete courses. They were paid a guinea a week each, plus expenses, and in the first two years visited 18 venues for a total of 342 days, teaching a total of 450 students. The scheme attracted support from the Privy Council, and subsequently the Board of Agriculture, from £100 in its first years rising to £300 in 1889. In 1890 cheese schools, conducted by champion Cheddar cheese-makers, were started at Wells and Frome. These various schools seem to have continued until at least the First World War, and by 1914 the Society was publishing a range of pamphlets, not only on cheese-, butter- and cider-making, but also on a range of subjects from permanent pastures and the construction of dairy herds to dairying in New Zealand and how stock breeding was aided in Germany.[82]

When county councils began to involve themselves in technical education in the 1890s the Society was frequently asked for advice, and its dairy schools served as a model for other regions. Dairy schools came into being at the Worleston (Cheshire) Dairy Institute (founded in 1886), the Lancashire County Council Dairy School and Farm at Hutton near Preston (founded before 1900), and the Gloucestershire County Dairy School, Lleweni Hall Dairy School (near Denbigh), Garforth (near Leeds), Monmouth and Warwick, (all founded by 1907). Some of these were known as 'fixed' dairy schools, to distinguish them from the travelling schools. When the British Dairy Farmers' Association was set up in 1886 it soon decided that there was a need to train specialist dairy instructors. Accordingly, in 1888, the British Dairy Institute opened at Aylesbury. In its first eight years of operation it trained 418 students. It became associated with what was to become the University College at Reading, and moved there in 1896, into buildings specially designed for

Evidence, qq. 357–389, BPP, 1888, XXXII, p. 11; Somerville, 'Education', pp. 19–21; The Reay Committee (note 78 above), p. 1[illegible] [82] [illegible] dairy teaching. As a result, Reading came to be seen as a centre for dairy teaching and research. The national diploma examinations were taken there, and when the National Institute for Research in Dairying was established in 1912 it was located nearby, at Shinfield. Although originally the emphasis at the Institute had been on short courses, by 1907 it was concentrating on the two-year national diploma course. At the Eastern Counties Dairy Institute near Ipswich, on the other hand, courses lasted from April to October, or November to March. The fees were £5 per month in 1907. Many dairying students were women. In the pass lists for the national diplomas in 1911, for example, no women appeared on the list for agriculture but seven of the fifteen on the dairying list were women. Horticulture, too, was attractive to women students. Studley College in Warwickshire provided instruction especially for women, as did Swanley Horticultural College in Kent. Swanley was started in 1889 as 'The Horticultural College and Produce Company' by Arthur Harper Bond. The first women were admitted in 1891 and from 1901 it catered for women only. By then it was associated with the Kent County Council and the Department of Science and Art at South Kensington.

Between 1902 and 1915 there was a special course to train women for work in the colonies. Several of the students went on to university to read for degrees: one of these was Winifred Brenchley, later the first botanist to be employed at Rothamsted. By 1910 the college had sixty-three full-course and thirteen short-course students, and was under the control of the Board of Agriculture.[83] Other agricultural societies also became involved in education. The Royal, in addition to administering the diploma examinations, also had a regular agricultural education exhibition at the annual show from 1903, published pamphlets and commissioned Dr William Fream to write *Elements of Agriculture*, as a standard textbook. More locally, the Berkeley Hunt Agricultural Society in Gloucestershire, for example, held classes and competitions for young farmers.[84]

The Reay Committee approved of these developments. They pointed out that the demand for instruction in dairying especially was increasing,

[83] *Ibid.*; Reay Committee (note 78 above), p. 6; Board of Agriculture and Fisheries, *Agricultural Education in England and Wales* (Leaflet no. 197, 1907), p. 16; B. Platt, *The Royal Association of British Dairy Farmers: 1876–1976* (Leamington Spa, 1976), pp. 55–8 (I owe this reference to the kindness of Mr S. A. Hands); Board of Agriculture, *Agricultural Education in England and Wales* (Leaflet No. 197, 1907), p. 11; Lord Moreton, 'Report on the results of the sixteenth examination for the National Diploma in Dairying, 1911', *JRASE*, 72, 1911, p. 343; Somerville, 'Education', p. 21; Elsa Morrow, *A History of Swanley Horticultural College* (Wye, 1984), pp. 63–102; Stanley was eventually incorporated into Wye College.

[84] E. H. Godfrey, 'The Society's Show of 1903', *JRASE*, 64, 1903, p. 171; The Reay Committee (note 78 above), p. 18; Fream, *Elements of Agriculture*.

presumably as the dairy trade expanded, and so they recommended that more money should be spent on it. But they did not feel that they were the complete answer. What was really needed, they felt, were winter schools for lads of between seventeen and twenty years old who already had some experience of farm work. And these could best be provided by the farm institutes.[85] Some farm institutes already existed. Those listed in the following table were set up by county councils in response to the changing legislation on technical instruction.

	Date of foundation
Essex Technical Laboratories, Chelmsford	1893
Uckfield Agricultural and Horticultural College, Sussex	1894
Holmes Chapel College of Agriculture, Cheshire	1895
Bedfordshire Agricultural Institute, Ridgmont	1895
Cumberland and Westmorland Farm School, Newton Rigg, Penrith	1896
Hampshire Farm School, Basing	1900

Uckfield and Holmes Chapel also provided advanced courses, so there were only four institutions entirely of the kind recommended by Reay. As they provided more practical instruction than that offered at the colleges, all had farms attached.[86]

The Reay Committee's approbation of the work done by the farm institutes led to the recommendation that many more of them, as many as fifty or sixty, should be established, and funded in part by the Board of Agriculture as well as the county councils. There was clearly a conflict within government during this period over the organisation and funding of agricultural education, advisory work and research. The Board of Agriculture seems to have favoured the centralisation of these services based on the universities and colleges, whereas the Board of Education favoured assistance to local centres run by county councils. Perhaps this explains why the Reay Committee's recommendations on farm institutes were not put into immediate effect, although they were in fact implemented in 1910. It was then that the Development Commission was set up and £325,000 set aside for assistance to farm institutes. In the event, therefore, neither Board won the argument outright. The county farm institutes favoured by the Board of Education began to be set up, but in 1912 responsibility for them was passed to the Board of Agriculture. As a result of the new money from the Development Commission, the Monmouthshire Institute of Agriculture and Horticulture at Usk and the Madryn Castle Farm School in Caernarvonshire were established in

[85] The Reay Committee (note 78 above), pp. 16–18.

[86] Somerville, 'Education', p. 21; the Reay Committee (note 78 above), p. 15; G. H. Purvis, 'Agricultural and horticultural institutes', *Agricultural Progress*, 24, 1949, pp. 102–5.

1913, and by then the Shropshire Technical School for Girls was providing short courses in agricultural subjects. The foundation of institutes in the English counties had to wait until after the War was over.[87]

By 1911–12 only 350 residential students in those farm institutes were grant-aided by the Board of Agriculture, being registered for courses varying in length from six months to thirty hours. But the institutes and colleges catered for more non-resident students. In that year 322 day-courses were held, which might last from as few as 5 to as many as 110 days, attracting a total of 3,093 students, and 200 evening schools and classes attracting 2,957 students. Over 4,000 individual lectures were also given, and there were 2,534 meetings for instruction in manual processes such as hedging, thatching, ploughing and milking. That year the county councils spent £80,362 on this work. And this was in addition to the work done by the universities and colleges. As Table 8.2 shows, a significant number of students were on short courses of less than one year in length. But the extension work reached even more people. In Wales, for example, the county agricultural education organisers and their staff were appointed by the colleges at Bangor and Aberystwyth, and regarded as part of the college staff. From their first foundation the departments at Bangor and Aberystwyth had been heavily involved in extension work. In 1899 Bangor offered a choice of lectures to farmers, either in English or in Welsh, on twelve subjects, including soils, manures and manuring, the chief farm crops: their cultivation and management, farm foods and feeding of stock, diseases of crops, insects injurious to crops, and pests of domestic animals. A choice of four or six of these lectures was given that year at five centres on Anglesey to an average audience of twenty, at ten centres in Caernarvonshire to an average audience of thirty-one, seven in Denbigh (average audience thirty-four), two in Flint (average audience forty), and nine in Montgomeryshire (average audience twenty-six). In addition, eighty-three students attended butter- and cheese-making courses. The average audience at the lectures given by Aberystwyth staff in Carmarthenshire and Brecon was ninety-eight. Each of the English university departments was also heavily involved in extra-mural activity, although none of them had quite such large audiences as were found in Wales. Multiplying the number of centres by the average audience for the whole of England and Wales for the year 1899–1900 gives a total of 7,779 students attending these courses, which were usually of four or five lectures. It is difficult to say how this figure compares with Somerville's estimate, which probably relates to the years around 1910, of a total audience

[87] Purvis, 'Agricultural and horticultural institutes', pp. 102–5; Foreman, *Loaves and Fishes*, p. 102; Richards, 'Agricultural science', p. 127; Board of Agriculture and Fisheries, *Annual Report of the Education Branch on the Distribution of Grants for Agricultural Education and Research, 1913–14*, Cd.7450, p. 128; BPP, 1914, XI, p. 717.

of 35,000 for extension lectures and local classes. His estimate of 1,500 for the number of full-time students is not very different from that which appears in Table 8.2, so it may be that a significant increase took place over the decade. On the other hand, the figures given at the beginning of this paragraph perhaps suggest otherwise.[88]

What is clear is that in comparison with 1850, when the formal provision of agricultural education was restricted to the Royal Agricultural College, there had been major changes. Most obviously, more people were being taught, or at least exposed to other people's ideas, and often scientists' ideas, about farming. This should not be exaggerated. Many new entrants to farming still learned their trade as farm pupils, and would continue to do so after the First World War.[89] Most of the colleges and university departments which would exist through the rest of the century had been established, but still not many students attended degree and diploma courses in relation to the number of farmers in the country; and that would continue to be the case throughout the twentieth century. Few farm workers had much formal training. Many more people had been exposed to extension lectures, however, and the extension system was firmly in being; that was perhaps the biggest change. And it had all happened since about 1890.

One of the first criticisms of the Royal Agricultural College was that it set out to train farmers but only succeeded in attracting those from a middle-class background. To some extent, the same criticism might be made of the universities and colleges which came later. Out of a sample of 234 students on courses of two years or more in 1911–12, only 52 were the sons of farmers, while 82 had some other connection with agriculture (and since 40 of those were at the Royal Agricultural College, that probably meant that they were the sons of landowners or land agents). On the other hand, 175 intended to go into farming, and another 46 into teaching. In short, it appears that one of the major functions of these institutions was to provide an agricultural training for those who could not get one at home.[90] But not all colleges were alike. Of forty-one students at Holmes Chapel in 1907, about three-quarters were the sons of farmers, retired farmers, landowners or land agents. The others were the children of merchants, engineers, accountants, secretaries, schoolmasters and stockbrokers. Some unusually precise information was collected in

88 Board of Agriculture and Fisheries, *Annual Report of the Education Branch*, Cd.7450 pp. 128–38, BPP, 1914, XI, p. 717; A. W. Ashby and I. L. Evans, *The Agriculture of Wales and Monmouthshire* (Cardiff, 1944), p. 142; Board of Agriculture, *Annual Report on the Distribution of Grants for Agricultural Education and Research, 1899–1900*, Cd.310, pp. 4–10, BPP, 1900, LXVIII, p. 9.

89 A. Bell, *Corduroy* (Harmondsworth, 1930), p. 5.

90 Richards, 'Agricultural science', p. 159. The students were at Aberdeen, Bangor, Newcastle, Leeds, Wye, the Royal Agricultural College and Holmes Chapel.

1912 about the subsequent occupations of the 141 students who passed the NDA examination between 1907 and 1911.[91]

Farming at home	27
Farm managers	3
Farming in colonies and foreign countries	15
Colonial and foreign agricultural posts	19
Engaged in estate office work	7
Dairy factory manager	1
Cheese-maker in dairy factory	1
Land valuers under Finance Act	4
Dairy chemist	1
Engaged in special research work	4
Milk testers in Scotland	4
Lecturers, etc., at British agricultural colleges or under county council	26
Assistant to Secretary, Scottish Agricultural Organization Society	1
Contractor for delivery of milk by motor from Ayrshire Creameries to Glasgow	1
Weslyan Minister	1
Continuing their studies, in several cases for university degrees	12
Deceased	2
No information available concerning	12
Total	141

From this list it appears that, although a minority went directly into farming in Britain, most entered occupations in which the education they had acquired was relevant to the job, and many had jobs in teaching or administration in which they might influence the way in which other people farmed. From this evidence it would appear that the diploma students were doing what they were supposed to do. But there were not many of them.

Quite what impact these students had on the agricultural industry is difficult to determine. In theory, there are several parameters which could be measured: rate of adoption of innovations, yield, total output, land, labour, capital or total productivity, or profitability. These would be measured for two representative groups of farmers, one of uneducated farmers and the other of educated farmers, and the results compared. But of course the results would be nonsense unless the farmers in the two samples had at least roughly similar farm sizes, soil types, capital equipment and, within each sample, levels of education. It is hardly necessary to say that such samples are not available. Moreover, this approach assumes that agricultural education is simply a matter of training, and has nothing to do with the personal development and satisfaction of the students involved.

91 The figures were reported in the *JRASE*, 73, 1912, p. 263.

An alternative approach to the question is to examine the reasons why those in power decided to expand education and then to ask whether the expansion had the desired result. Thus it appears that industrialists wanted more technical education in the late nineteenth century because they thought they were falling behind the Germans. If this were the case, they could then measure the impact of that education by assessing the extent to which they had caught up with the Germans.[92] But again, this line of argument produces difficulties when applied to agriculture. Both J. B. Lawes and J. A. Voelcker, two of the leading agricultural scientists of the time, told the Richmond Commission that they did not think that a greater knowledge of science would help farmers much, and Caird told the Royal Commission on the Depression of Trade and Industry that '... as a rule ... the farmers of this country understand their business', so that little advantage would arise from technical education. Many farmers agreed. They had not been impressed by what the *Farmer and Stockbreeder* called the 'trumpery certificates' issued by South Kensington. The problems of the Royal Agricultural College in the late 1870s had done its reputation no good. Mr Priday of Gloucestershire told the Central Chamber of Agriculture in 1890 that the farmers in his area who had been to the Royal or Downton had not done much on their return, while the Gloucestershire Dairy School was a failure because the surrounding community was indifferent to it. Consequently, he was against using the rates to pay for agricultural education. Others argued that colleges should survive only if they could be run at a profit. Many county councils were dominated by farmers who held the same views, and so the development of county services was restricted. Lord Cowper offered the Hertfordshire County Council a 240-acre farm rent-free, together with any necessary buildings, for educational purposes. His offer was turned down. As late as 1890 the *Journal of the Royal Agricultural Society* contained an article arguing that any demand for agricultural education should be met by private enterprise and not the state. One exception to this was education in dairying, which many farmers welcomed. Ironically, the travelling dairy schools placed much emphasis on the production of improved qualities of butter and cheese, whereas the expanding part of the dairy trade was the liquid milk market.[93]

Why, then, was government money invested? The story of the whisky money suggests that pure chance had something to do with it, but that was not the only factor. Another reason is perhaps connected with the Victorian respect for science, and it may be no accident that the first agricultural courses put such a heavy emphasis upon it. Thirdly, it was

[92] Heyck, *Transformation of Intellectual Life*, p. 82.

[93] Fisher, 'Public opinion and agriculture', pp. 74–93.

believed that education was one way of helping agriculture to help itself in times of depression, a view put forward in a series of private and official reports. Not all members of the farming lobby were anti-education; H. M. Jenkins, secretary and editor of the Royal Agricultural Society, and J. C. Morton, editor of the *Agricultural Gazette*, conducted campaigns for the better education of farmers in the 1860s and 1870s.[94] Part of this argument stemmed from the feeling that it was wrong or dangerous for labour to be leaving the land, as Rider Haggard reported after his tour of the country in 1901 and 1902. Perhaps farmers were also worried that wages might have to be increased. Certainly some of them seem to have taken the view that the education provided as a result of the 1870 Education Act enabled labourers' children to look for jobs outside farming. Whatever the reason, several of Rider Haggard's informants bemoaned the lack of agricultural education in schools, and Mr Vosper of Merrifield near Plymouth tried to do something about it by encouraging classes for technical education and giving prizes for good work. Some farmers in Cornwall thought that technical education would keep workers in agriculture because it would make the work more interesting; others thought that cricket clubs might have the same effect.[95]

Therefore the question appears to return to whether education produced what the Reay Committee called 'any marked general advance in the practice of farming'. In 1908, they argued, it was too soon to expect this, but there were signs that changes were taking place, and they mentioned avoidance of waste in the purchase of unsuitable artificial manures and feedingstuffs, local improvements in dairying and the management of grassland, and improvements in the selection of the best crop varieties. The attitude of farmers on the subject of science and book learning, they believed, was undergoing a change. Farmers were not against technical education through any fear of innovation, or distrust of theory, or dislike of change. The problem was that they did not always trust the information given to them, because they had tested it and found it wanting, or found it to be in conflict with their own experience, or had simply seen the experts disagree with each other. But attitudes were now changing, they felt, because better advice, of 'greater practical utility', was now being given to farmers. Clearly, the Reay Committee felt that agricultural education was not a waste of time or money. On the other hand, it felt bound to report the view of the Secretary of the Farmers' Club, who said that the colleges 'do not directly affect more than 5 per cent of the farmers of England', and of

94 Richards, 'Agricultural science', pp. 117–24; Fisher, 'Public opinion and agriculture', p. 75.

95 H. Rider Haggard, *Rural England*, vol. 1 (London, 1906), pp. 141, 189, 208, 222, 203; Fisher, 'Public opinion and agriculture', p. 88.

others who felt that 'the rank and file of farmers are not reached as they should be'.[96]

This could explain why Reay placed so much emphasis on the need to develop the farm institutes, to reach the 'rank and file'. After the universities and colleges they were the third and last, and possibly most important, level of the system of agricultural education. The universities would train the teachers, the researchers, and some of the farmers and landowners. The colleges would train more of the farmers and landowners, and also many of those in the ancillary industries. The farm institutes would train the working farmers and, eventually, some of the farm workers. This, basically, is the system which would last through the twentieth century. Of course, not all the problems had been solved, for the impact of education remained small and much expansion had still to come; but by 1914 a durable framework had been established.

[96] Reay Committee (note 78 above), pp. 11–12, 26–7. A later committee took the view that 'The Schemes recently brought into operation by the Board of Agriculture for providing education and technical advice for farmers were, before the war, promising good results, at any rate as far as the younger farmers were concerned.' See E. G. Strutt, L. Scott and G. H. Roberts, *British Agriculture, the Nation's Opportunity: being the minority report of the Departmental Committee on the Employment of Sailors and Soldiers on the Land* (London, 1917), p. 115.