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

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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

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[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 *6d*.

[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.

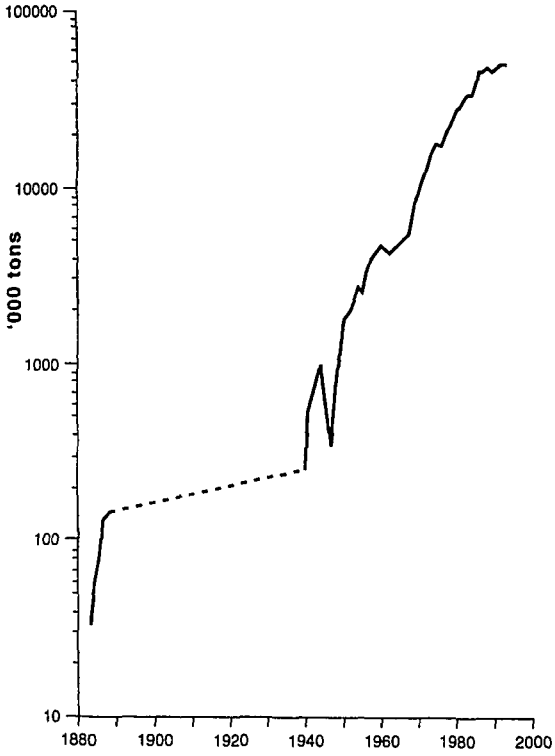

FIGURE 1
Silage production in Great Britain, 1884–1993.

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 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

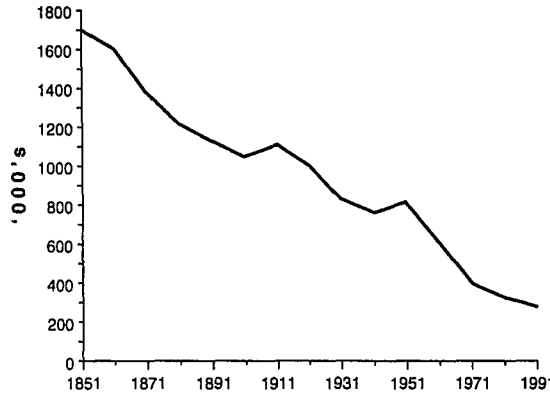

FIGURE 2
Number of farmworkers in Great Britain, 1851–1991.

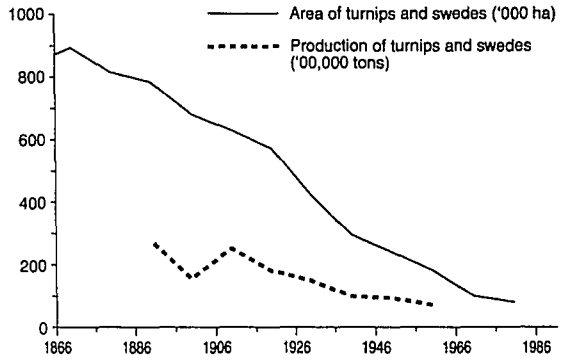

FIGURE 3
Area and production of turnips and swedes in Great Britain, 1866–1986.

[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.

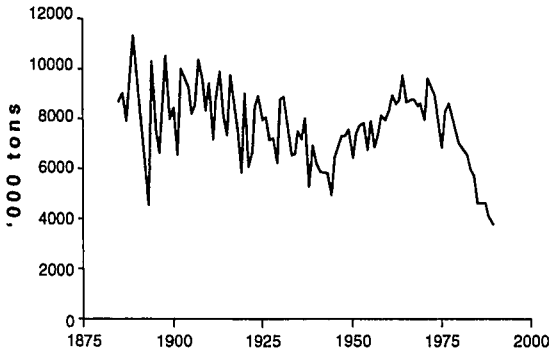

FIGURE 4
Hay production in Great Britain, 1885–1989.

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.

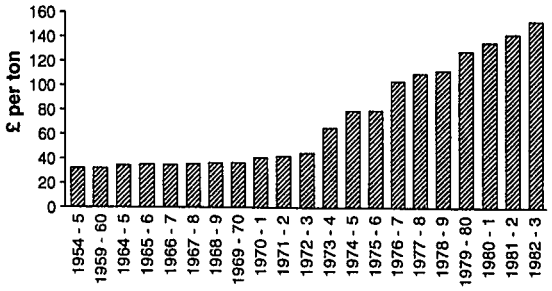

FIGURE 5
Prices of dairy compound feeds, 1954–83.

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.