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The impact of agricultural science 1850-2016: from a gentleman's amusement to the saviour or the world?

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Cet article est le texte d'une intervention effectuée lors du Colloque de l'Union européenne des académies d'agriculture UEAA (présidence française) « Science in agriculture : historical perspectives and prospective insights - Science en agriculture, perspectives historiques et prospective », Académie d'agriculture de France, Paris, 12 octobre 2016.

Résumé

Vers 1850, les sciences agronomiques se sont transformées : d'un passe-temps d'amateur, elles sont devenues un travail de professionnels. Et cela a soulevé de nouvelles questions : la science agronomique était-elle simplement l'application des sciences pures aux questions agricoles, ou bien était-elle plus, et, en ce cas, de quels problèmes les agronomes devaient-ils traiter ? Cet article soutient l'hypothèse d'un développement au 19 e siècle dû aux institutions agronomiques ; leurs modèles et leurs structures n'ont changé que récemment, en raison de la croissance des travaux de recherche et développement dans les pays à revenus intermédiaires. L'article traite ensuite brièvement des résultats et des lacunes de la discipline, et discute les facteurs qui peuvent expliquer la plus ou moins grande influence de ses découvertes. En conclusion, il plaide pour des recherches sur l'histoire internationale de l'agronomie.

Abstract

By 1850 agricultural science was already changing from an amateur pursuit to a professional occupation. As it did so, new questions arose: was agricultural science simply the application of the pure sciences to agricultural problems, or was it something more, and therefore with which problems should agricultural scientists concern themselves? This paper argues that the major nineteenth-century development was in the institutions of agricultural science, and that the patterns and structures developed then have only recently changed as a result of the increase in research and development in middle income countries. There follows a brief review of the achievements and shortcomings of the discipline, and a discussion of the factors that make its discoveries more or less influential. Finally the conclusion briefly argues for more work to synthesise a global history of agricultural science.

Keywords
agricultural science; R&D; science history; institutional change

Mots clés
science agricole, recherche et développement, histoire des sciences, changements institutionnels.

The title of this paper is designed to be debatable and disputable. Was agricultural science merely an amusement for gentlemen in the middle of the nineteenth century, with the implication that its results were unimportant and that it had little impact? Is the world currently facing problems that only agricultural science can solve, so that its impact is potentially enormous? And if the answer to either question is 'yes', or even 'yes, to some extent, up to a point', what happened to change agricultural science from one state to the other? The discussion in this paper is, as a result of the author's knowledge and experience, largely based on the British experience and the literature in English. Nevertheless, it is important to remember that comparable developments in agricultural science were happening in other countries, sometimes earlier, sometimes later (Fernández Prieto, 1992; Bieleman, 2010; Jones, 2016a).

Gentlemen with an interest in agriculture and some degree of scientific approach to its problems existed by 1850 (Vivier, 2016). This is not the place to attempt a complete listing of them, for to do so would be to survey the progress of agricultural science up to that date. Furthermore, to decide whether they were truly gentlemen is to stray into a minefield of social and historical semantics (Bédarida, 1991; Price, 1993). While de Saussure (1767-1845) was born into a family with money, Mathieu de Dombasle (1777-1843) was an estate manager, and Boussingault (1801-1887) received a professional training as an engineer, although by the end of their lives they would probably all have been accepted as gentlemen (Jones, 2016b; Jones, 2016c). Humphry Davy, born the son of a woodcarver in 1778, was employed by the Royal Institution when he published his *Elements of Agricultural Chemistry* in 1813, but he was a baronet by the time of his death in 1829 (Knight, 1992). Similarly, Justus von Liebig (1803-1873) was the son of a hardware merchant and employed as a professor at the University of Giessen when he published *Chemistry in its Applications to Agriculture* in 1840 (Brock, 1997). Albrecht Daniel Thaer (1752-1828), an adherent of the humus theory of plant nutrition and an agricultural writer and educator, might be described as a gentleman by virtue of his achievements and marriage. He trained in medicine, married the daughter of a nobleman, was given land by Frederick William III of Prussia, and made his Mögelin estate into an agricultural academy (Harwood, 2005). John Bennet Lawes (1814-1900) was born into a family of minor gentry in Hertfordshire in south-east England, inherited the family estate, and would have been wealthy enough to have lived off his private income, but the agricultural research for which his Rothamsted estate became famous was financed by the profits from the *Lawes Chemical Manure Company* (Russell, 1966; Dyke, 1993). By the middle of the nineteenth century, therefore, agricultural science was beginning to be more than simply a gentleman's amusement, although it would be difficult to argue that it had achieved the status of a profession in the same way that medicine or the law might be so called.

That the world faces problems of dealing with climate change and feeding a projected population of 9 billion by 2050 is indisputable; whether agricultural science can solve the problems is more debatable (Conway, 2012; Brassley and Soffre, 2016). The point is that agricultural science now has a claim to take part in the debate, and agricultural scientists are now among those who might have something useful to contribute to it. But this is not an undisputed claim, and agricultural scientists are unlikely to be alone in commenting on climate change and future food production. The problem they face, as Giuditta Parolini has argued, is that the definition of agricultural science is ambiguous (Parolini, 2015). To some it might seem to be simply the knowledge and techniques of the pure sciences (the alternative term is "natural sciences"), such as botany, zoology, genetics, chemistry, physics, etc, applied to agricultural problems. Others might argue that it is, or should be, husbandry, or farming operations, carried out under experimental conditions using scientific methods, with statistical analysis of the results. However, this second view of the subject risks confusion with agricultural technology and its history, which most observers would see as a wider or more comprehensive subject area. Deborah Fitzgerald, for example, defines agricultural technology as "the process of systematically cultivating plants and animals, including the economic, mechanical, human, scientific, and institutional forces that support such activity" (Fitzgerald, 1991). In her definition, therefore, the history of agricultural science would be no more than one component of the history of agricultural technology. There is also a problem of translation. "Agricultural science" translates into French as "les sciences agronomiques. Leaving aside the problem of its pluralisation, it is worth reminding non-English readers that an "agronomist" in Britain is a person concerned with the growth of crops, often by advising farmers on the selection of varieties and appropriate applications of fertilisers and pesticides. Clearly this implies a much narrower understanding of the term than "les sciences agronomiques" implies in French, and in other languages too.

There is also an argument about whether it is the role of the agricultural science simply to explain what is happening in agricultural processes, or to prescribe improvements or alternative methods for practising farmers to adopt. It is the contention of this article that this ambiguity is important because it creates uncertainty about who should do agricultural research and what they should do. It also implies that what constitutes agricultural science might change over time; that what would be recognized as agricultural science in one century might be different from how it was perceived earlier or later. Since sciences are human constructs, and consequently have a history, it is worthwhile to examine the emergence of agricultural science from something more than a gentleman's amusement to a possible solution of some of the world's major long-term problems. In that way it might perhaps be possible to see how this ambiguity has arisen.

Much of what was published as agricultural science in the 19 th century was more descriptive than analytical. In England the nearest thing to a journal of agricultural science in the 19 th century was the *Journal of the Royal Agricultural Society of England*. The Society was established in 1838, and one of its objectives, expressed in its motto "Practice with Science", was to encourage the application of science to agriculture. The first volume of the journal was published in 1840 (Goddard, 1988). By 1878 it was a mature publication, and that year's articles covered a variety of topics, from drainage, moorland reclamation, the early fattening of cattle, and the pathology of pleuro-pneumonia, to the chemical analysis of bat guano by the consulting chemist to the Society, Dr Voelcker. With the possible exception of this last article the remaining contents were almost entirely descriptive, and indeed Professor Yeo, writing on pleuro-pneumonia, stated that he had "tried to avoid any expressions which involve theories" (Yeo, 1878).

By the beginning of the 20th century in Britain the number of scientists working on agricultural problems had increased, and several of the more prominent ones decided that a new *Journal of Agricultural Science* was needed. Its first volume, in 1905, reflected the dominance of chemistry in the agricultural science of the time, but also contained one of the first articles applying Mendelian genetics to the breeding of wheat varieties (Biffen, 1905). It remained dominated by UK-based authors writing mostly on temperate agriculture until almost the end of the 20 th century, but in the last twenty years or so it has become an international journal, with a preponderance of authors based outside the UK and much greater coverage of tropical agriculture.

There seems to be little doubt that, despite the subsequent prominence of the *Journal of Agricultural Science*, the expansion of the subject in continental Europe and the USA was much more rapid in the later 19 th century than it was in Britain, at least of the number of research institutions is any measure of scientific activity. Even Japan and Brazil had as many research stations as Britain by the 1890s (Brassley, 2000; Harwood, 2009). This was reflected in the number of abstracts of agricultural science papers published in the *Monthly Bulletin of Agricultural Intelligence and Plant Diseases*, in which the impression is that only a small minority of the abstracted papers were in British publications. This *Monthly Bulletin* was published from 1909 by the International Institute of Agriculture, which had been established in Rome in 1905, and would go on to produce an increasing range of surveys of agricultural science and social science across the world until its work was subsumed into that of the United Nations Food and Agriculture Organisation after the Second World War (Pan-Montojo, 2016). It is clear that by the early 20 th century agricultural research was well-established across most European countries and the USA.

The effectiveness of agricultural research, then and later, is more difficult to judge. The ambiguity and uncertainty about what agricultural research is, or where its boundaries lie, make it difficult to assess its impact. Several different approaches may be found in the literature. Perhaps the most obvious is to analyze the impact of research on the output or productivity of agriculture. Silvey , for example, analyzed cereal yields in England and Wales and claimed that roughly half of the yield increase was the result of genetic change, and Harris conducted a similar exercise for potatoes (Silvey, 1978; Harris, 1980). The problem with this is that output can be affected by non-scientific factors such as agricultural policy and trade. In circumstances in which farmers are being encouraged by government policies, or high prices, to maximise output, they are likely to increase labour and capital inputs, and *vice versa* in different policy and trade environments. Another difficulty is that the effects of research can take a long time to reveal themselves. A study of productivity in agriculture in the USA argued that the effects of research and development might not become apparent for between 35 and 50 years (Alston *et al*, 2015).

An alternative approach is to examine the extent to which agricultural science produces discoveries or useful explanations of agricultural problems, on the assumption that farmers who understand why things happen will respond more quickly to environmental or policy changes. While this is probably true, it does not produce any easily-understood metrics for assessing impact. A third, and perhaps the most frequently-employed approach, is peer review, but Kuhn would probably argue that this is likely to be the least effective method because it is more likely to privilege the current paradigm and less likely to accept radical changes (Kuhn, 1962).

In the long run, it may be that one of the most useful ways of assessing science is to examine the development of its professional institutions. University departments, research stations, libraries, journals, and learned societies may not by themselves carry out research, but they increase the effectiveness of the individuals who do, and their influence may be greater than that of any single individual. Harwood, for example, has argued that the problems studied by biologists, and the methods and theories they produced, have all been affected by the institutions within which they worked (Harwood, 2009). Looking back from the twenty-first century, it might be argued that the greatest and longest-lasting contribution of the period between 1850 and 1914 was in the emergence of these institutions of agricultural research, and that those countries that were most successful in developing them, which would not include Britain, made the most progress. By 1850 gentlemen such as Thaer and de Saussure were dead, and their successors, such as Wilhelm Crusius (1790-1858) at *Mockern and Lawes at Rothamsted* were more employers of professional scientists than active scientists themselves, although Lawes was certainly a very active writer about agricultural science (Jones, 2016). The professionals, such as Justus von Liebig at Giessen and his student Joseph Henry Gilbert, who was employed by Lawes at Rothamsted, became the leaders of the discipline (Brock, 1997; Brassley, 2000). By 1900, according to one estimate (Grantham, 1984), there were 500 or so agricultural research stations in the world, employing 1500 professional scientists, but they were not evenly distributed. The bulk of them were in continental Europe and the USA, but very few were in Africa or Asia, and perhaps surprisingly few in Britain .

Grantham argued that the extent of agricultural research was likely to be greater if a country possessed a scientifically-literate bureaucracy, many scientists, farm organisations that favoured research, state funding, and succeeding generations of scientists trained by existing practitioners (Grantham, 1984). This neatly explains why there were so many researchers and research institutes in Germany and so few in Britain, at least until Sir Daniel Hall (1864-1942), who became the Director of Rothamsted after Lawes died in 1900, extracted funding for agricultural research from the Development Commission from 1910 onwards (Rogers, 1999). In 1892, for example, Britain, Spain and Portugal each had one agricultural experimental station, compared with 67 in Germany, 54 in the USA and 53 in France, according to one report (Cousins, 1895). Grantham's success conditions were met in the 20 th century in most developed countries, and, as the authorship of articles in the Journal of Agricultural Science mentioned above suggests, over the last twenty years the contribution of the middle-income countries, in particular China, India, Brazil and South Africa, has increased considerably. According to a report in the prestigious science journal Nature, by 2011 government-funded agricultural research spending in middle-income countries was higher than that in high-income countries, although the increasing proportion of private-sector research spending in the latter meant that the high-income countries still spent more in total. Since private-sector research may not be disinterested these trends have not always been welcomed. As the authors of the report concluded, "the retreat from public agricultural research and development by rich countries, and the continued comparatively low levels of investment in many poorer countries, are concerning" (Pardey *et al*, 2016).

The changes in agricultural technology that occurred in the 20 th century are well-known; the extent to which they were produced by agricultural science is perhaps more debatable. One area in which science clearly made a contribution was plant and animal breeding. From the use of Mendelian genetics to produce new wheat varieties early in the century, to the subsequent development of population genetics and the later development of genetic engineering, science obviously affected crop breeding (Brassley and Soffe, 2016). In animal breeding, the development of artificial insemination techniques, especially for cattle and pigs, was enormously influential. By 1960, 63 per cent of the dairy herds in Britain used only artificial insemination to impregnate their cows (MMB, 1960). Similarly, it is difficult to see how the range of herbicides, fungicides and insecticides currently available to arable farmers, or the vaccines, anti-parasitic treatments and antibiotics used by animal producers could have emerged without the efforts of scientists in general and agricultural scientists in particular (Blaxter and Robertson, 1995). On the other hand, the increased use of fertilisers and purchased livestock feeds appears to have more to do with the decisions of farmers than agricultural scientists, although the scientists have been involved in producing a greater range of products and finding ways in which they can be used with increased precision (Blaxter and Robertson, 1995). Likewise the mechanisation and motorisation of farming operations was perhaps more a product of the machinery industry than of agricultural science until recently, when there has been increased emphasis on automatic control of a variety of devices from tractors to milking machines (Dewey, 2008).

If it is clear that agricultural science has moved on from being a gentleman's amusement (if indeed it ever was so), is it also likely to be seen, in future, as the saviour of the world? The need to feed an increased world population is clearly a problem to which agricultural science might make a contribution. There is also the issue of agriculture's contribution to the greenhouse gases that promote global warming, and the concomitant question of how agriculture can react to climate change (Brassley and Soffe, 2016). Despite ideas about history repeating itself, historians also know that circumstances change so that the repetition is rarely exact; prediction is better left to economists, who can put error terms into their algorithms. To argue that agricultural science has assisted farmers in feeding a rapidly-increasing world population (from 1.2 billion in 1850 to 2.5 billions a century later, but then 7.3 billion at present) is one thing; to argue that they will continue to do so is a different matter (Cameron, 1993; Millstone and Lang, 2008).

Table 1: World and UK yield data

	World 1970	**World 2012**	**UK 1965-1969**	**UK 2014**
Wheat (tonnes per hectare)	1.5	3.1	3.9	8.6
Barley (tonnes per hectare)	1.7	2.7	3.6	6.4
Potatoes (tonnes per hectare)	13.3	18.9	24.9	47.0
Milk (litres per cow)			3686	7897

Source: World 1970 data from FAO, 1971; 2012 data calculated from http://faostat.fao.org/site/567 (accessed 26/7 April 2014). UK 1965-9 data from Marks and Britton, 1989:164, 175, 230; 2014 data from DEFRA, 2016: 42-57 .

As Table 1 demonstrates, world wheat yields have doubled since 1970, and perhaps more significantly yields of wheat, barley and potatoes in developed countries are at least twice the world average, so that there is much room for improvement with existing technology. On the other hand, there is some evidence that the rate of technical change in developed countries is slowing down (Alston *et al*, 2015). One estimate for the USA found that the annual rate of growth in multi-factor productivity was 2.07 per cent between 1949 and 1990, but only 1.18 per cent from 1990 to 2007 .

Many people would also argue that the undoubted achievements of agricultural science have also been accompanied by problems. Plant breeding has increased crop yields, but genetically modified organisms remain controversial, at least in Europe. Not all of the fertilisers applied to fields become incorporated into crops. Part of the nutrient content is washed into rivers, and thence to the sea, with effects that one observer termed "an unprecedented large-scale biogeochemical experiment whose eventual impacts we can predict only poorly" (Smil, 2001). Pesticides have enabled farmers to increase yields or reduce costs, but there are numerous examples of their deleterious effects on wildlife, from the impact of chlorinated hydrocarbons on the breeding success of raptors (*i.e.* hawks and falcons) to the effects of neo-nicotinoids on bees (Whitehorn *et al*, 2012; Henry *et al*, 2012; Goulson, 2013). Animal feeds by themselves are usually benign, but their increased use in intensive livestock operations has meant that the concentration of animals has increased in some regions to the point that it produces eutrophication problems. Many of the vaccines and anti-parasitic drugs used by farmers also appear to be without side-effects, but the use of antibiotics in agriculture, especially their incorporation in feeding stuffs for non-acute use, has led to antibiotic resistance problems (Bud, 2008). The contribution of science to farm mechanisation is, as argued above, debatable, but there is no doubt that the use of heavier machinery has produced soil structure problems, and the replacement of muscle power by fossil-fuel-derived power is obviously one of the sources of greenhouse gases.

At a more theoretical level, Scott has argued that agricultural science does not deal well with complexity, as a result of which it may ignore long-run effects such as the soil structure and water quality problems mentioned above, and that scientific approaches that have worked well in Europe and North America have been less successful in Africa (Scott, 1998). Similar methodological issues have been discussed by Harwood, who points out that experiment-based research does not always resolve conflict by producing evidence for one theory or against another (Harwood, 2015). He cites the example of high-yielding plant varieties that were tested under experimental conditions which proved to be more favourable than those found on the farms for which the new varieties were designed. Therefore, he argues, it is important to know why some theories and experiments have been more successful than others in persuading farmers to adopt new technologies. This question was discussed in relation to the development of artificial insemination in pigs by Brassley, who put forward the idea that different actors gain and lose authority over a scientific debate at various stages of the development of a technology, and that these authority changes are often accompanied by changes in the discourse employed, whether scientific or practical, and the media used, which can vary from scientific journals to word-of-mouth dialogue (Brassley, 2007).

In conclusion, to return to the questions posed at the beginning of this paper, it appears that by the middle of the 19^{th} century the time when gentlemen amateur scientists (or "natural philosophers", as they would probably have called themselves) might make a significant contribution to agricultural science was already passing. The subsequent history of the discipline is one in which, perhaps by the end of the nineteenth century, and certainly by the beginning of the First World War, it had developed the professional institutions that enabled it to be recognised as an independent branch of applied science. However, this is not to say that its role or purpose remained uncontroversial, or even that the boundaries of competence between agricultural science and other pure or applied sciences were firmly or clearly drawn. Nevertheless, researchers who would describe themselves as agricultural scientists can legitimately claim at least some of the credit for increased understanding of agricultural operations and for the technical changes that have enabled farmers to feed a dramatically-increasing world population. The other question posed at the outset, about whether this will continue to be the case, is, we have argued, not one for historians. They should be busy enough with further work on the history of agricultural science, which still lacks, at least in the English language, an approachable, comprehensive, international survey. Whether this survey should best be approached as a collection of studies of agricultural sciences in different countries, or of individual branches of the subject (e.g. fertilisers, plant physiology, genetics, animal growth studies, etc.) across the whole world, would depend upon the interests of the contributing historians. The ideal approach might be a study of the subject as a whole across the entire world from an individual scholar, but whether a historian exists with sufficient expertise and time to accomplish such a project is a different question.

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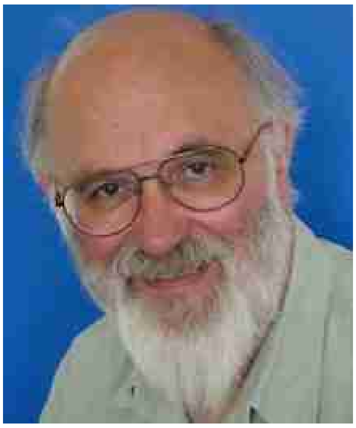

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