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Then and Now: Re-positioning the History of Agriculture within the History of Science and Technology

Giuditta Parolini*

Abstract

Twenty years ago, the history of agriculture was the Cinderella of the history of science and technology. Historians interested in scientific and technological developments were reluctant to engage with agriculture, a field whose scientific boundaries are ambiguous and where research does not take place only in a controlled laboratory environment, but also in open fields. Today the situation has greatly changed and a rich scholarship on the history of agriculture is emerging within the history of science and technology. This scholarship has repositioned the history of agriculture at the intersection of debates on science and technology, food and the environment, politics and society. The paper will highlight what has been achieved so far and sketch possible developments.

Keywords: agriculture, experiment, environment, food, politics, economics.

Résumé

Il y a vingt ans, l'histoire de l'agriculture était la Cendrillon de l'histoire des sciences et des technologies. Les historiens intéressés par les développements scientifiques et technologiques étaient réticents à s'engager dans l'agriculture, un domaine dont les frontières scientifiques sont ambiguës et où la recherche ne se fait pas seulement dans un environnement contrôlé en laboratoire. Aujourd'hui, la situation a beaucoup changé et une riche recherche sur l'histoire de l'agriculture émerge dans l'histoire des sciences et des technologies. Cette recherche a repositionné l'histoire de l'agriculture entre les débats sur la science et la technologie, l'alimentation et l'environnement, la politique et la société. L'article soulignera ce qui a été réalisé et esquissera les développements possibles.

Mots-clés : agriculture, expérimentation, environnement, alimentation, politique, économie.

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FOR more than three centuries, and with a distinct acceleration during the last one hundred years, science and technology have gained an increasingly relevant role in agriculture. Yet, the history of agriculture has not been a popular subject among historians of science and technology in the past. Only in the last few years this field has grown considerably, and now it stands out as one of the most dynamic areas in the history of science and technology, due to its multiplicity of approaches to the study of scientific practices and technological innovation, and its relevance in understanding key social and political questions, such as food availability and environmental problems. Agriculture, therefore, provides a very interesting case study for this thematic issue that explores how the history of science and technology has changed during the past two decades.

Twenty years ago, the history of agriculture was indeed the Cinderella of the history of science and technology. Agriculture does not even appear in the subject index of the *Companion to the History of Modern Science*, co-edited in the 1990s by Robert Olby, a well-known historian of biology (Cantor & al., 1996). Aside from a few exceptions (e.g. Finlay, 1992; Gayon & Zallen, 1998; Harwood, 2005), scholars interested in scientific and technological developments were reluctant to engage with agriculture, a field whose scientific boundaries are ambiguous and where research does not take place only in a controlled laboratory environment, but also in open fields.

An historical investigation of agricultural science, or better of the agricultural sciences, as the field encompasses a variety of disciplines ranging from soil science to agricultural engineering, would have required dealing with multiple issues, such as the field/laboratory divide and its impact on experimental methodologies, the eminently practical dimension of scientific investigations in agriculture and their political and economic drivers, and the coexistence of local and global perspectives, such as the role of national and international rural organisations, and the colonial and non-Western histories of agriculture. These issues did not fit the agenda of many historians of science and technology at a time when the attention was still focused on academic disciplines and their national developments.

Twenty years later, the situation has greatly changed and a rich scholarship on these topics is now emerging (e.g. Phillips & Kingsland, 2015). Contributions ranging from the history of experiments in agriculture to the examination of ecological and sustainability issues have been appearing in recent years. This scholarship is repositioning the history of agriculture within crucial debates in the history of science and technology, such as discussions on interdisciplinary methodologies and on the value of global approaches that explore non-Western case studies. At the same time,

this scholarship is aware of the necessity to maintain a constructive dialogue with political and economic histories of agriculture, and to establish strong links with research fields that have also expanded during the past twenty years, such as food history and environmental history.

This paper is a review piece that traces the transformations in the recent historiography of agricultural sciences and technologies by focusing on four main aspects: 1) agricultural experimentation; 2) the global and local dimensions of agriculture; 3) the integration with environmental and food history; 4) the connections to political and economic histories. Every review piece that addresses such a wide and varied field as agricultural sciences and technologies must, by necessity, concentrate on a few aspects. The four above have been selected keeping into account the themes that have received greater scholarly interest in recent years (see, for instance Fitzgerald & al., 2018) and therefore generated a larger number of publications. But they are also instrumental in proving that the growth of the history of agriculture within the history of science and technology is not only quantitative, but also qualitative, because these recent scholarly works are bringing the history of agriculture at the intersection of debates on science and technology, food and the environment, politics and society. The review will highlight what has been achieved so far and sketch possible developments.

Agricultural Experimentation in Field and Laboratories

In the 19th century the city of Berlin erected a monument to the agronomist Albrecht Daniel Thaer (1752-1828), whose teachings and experiments significantly contributed to reform Prussian agriculture. One and a half century later, Thaer's monument still survives in Berlin and the reliefs on the pedestal continue to pay homage to Thaer's practical teachings on sheep breeding and harvesting.

Thaer is one of the agricultural experimenters that historians of science are now re-discovering as part of their investigations on knowledge practices and epistemologies (Lehmbrock, 2014). Agricultural experiments, in fact, provide ample opportunities for addressing how scientific knowledge is produced and validated, and how it can be used to solve practical problems.

In Thaer's age and throughout the 19th century agricultural experiments used only chemical knowledge (Jones, 2016), but starting from the beginning of the 20th century the field of agricultural experimentation has considerably expanded. Nowadays it relies on tools and practices coming from genetics and genomics, entomology and phytochemistry, statistics

and soil science, just to mention a few of the disciplines that are contributing to agricultural research (Parolini, 2015b). Historians of science and technology are now interested in understanding how these experimental activities are done not only in traditional laboratory settings, but also in farms and fields, and what methodologies make them possible. In addition, the historiography of 20th century agricultural experimentation is increasingly concerned with the role of neglected social groups in agricultural experimentation, such as women scientists and amateurs. I will review the literature so far available on these topics pointing out its connections to the larger historiography of science and technology.

- *The Places of Agricultural Research*

The geographer David Livingstone has convincingly argued that place matters in science (Livingstone, 2003) and, following his example, many historians of science and technology have paid attention to the geographies of science in recent years. Agriculture has offered inspiration for quite a few of these studies, because agricultural knowledge is produced in a variety of sites, ranging from experimental fields to laboratories.

In the first half of the twentieth century the standard agricultural laboratory was usually equipped only with tools for the chemical analysis of plant and soil samples, and with optical microscopes, but during the past sixty years molecular biology, genomics, and synthetic biology have transformed scientific practices and technologies in agriculture. Scholarly interest has been especially focused on the role of model organisms used in laboratory research, such as *Arabidopsis thaliana* and *Brachypodium distachyon* (Leonelli, 2007; Lyons & Scholthof, 2015). These historical studies have uncovered how the selection of model organisms in plant science took into consideration not only the success of these organisms at the lab bench and the ease to sequence and map their genomes, but also the prospective applicability of the laboratory results to the actual production of crops and biofuels. Even *Arabidopsis*, which raised to the rank of model organism in plant science more for its simple genome than for its agricultural applications, has eventually become relevant for better understanding the behaviour of commercial crops (Buell & Last, 2010).

Similarly, the transformation of animal breeding practices in agriculture has benefitted from laboratory research that relied on medical technologies such as in vitro fertilization and from the tools of biotechnology (Wilmot, 2007; Franklin, 2007). In more recent times, cellular agriculture benefits from advances in synthetic biology to produce meat and milk at the lab bench rather than in a farmyard with the aim to lower the environmental impact of agriculture (Jönsson & al., 2019).

These studies of laboratory research in agriculture have been a precious addition to the historiography of the life sciences not just because they have contributed to increase knowledge of laboratory practices, but also because they have opened up and addressed key questions about science, technology, and society. For instance, the cloning of Dolly the sheep raised a huge debate on human cloning and not just on animal biotechnology; current research on substitutes of animal products is entangled in controversies among political and regulatory authorities, consumers, and the traditional farming community; alternative energy resources as biofuels are political as much as scientific objects. Therefore, these studies are not just part of the history of science and technology, but they also provide inspiration for sociological studies, and political and economic histories.

But let us return to the places of agricultural research. While laboratories have certainly played a key role in plant and animal research in agriculture, it is also true that many agricultural experiments can neither be conceived nor implemented in a laboratory setting. The reductionist approach of molecular and genomic methods is not always compatible with the multiplicity of environmental factors involved in agricultural problems nor artificial laboratory conditions can offer suitable results for field-based farming activities. Variety and fertiliser trials, breeding experiments, tests with frost protection equipment, etc. are heavily affected by weather, climate, soil, pests, and these environmental conditions cannot be reproduced in a laboratory. Even genetically modified crops, whose development is certainly a product of laboratory science, eventually need to be tested in the field, and it is at this stage that their nature of experimental objects can be perceived as a menace for society (Bonneuil & al., 2008; Bonneuil & Thomas, 2009).

In the past few years, historians of science have started to examine more systematically the history of field experimentation in agriculture, its institutional settings, stakeholders, and the controversies it generated (Maat, 2011; Berry, 2015; Parolini, 2015c). This exploration of the places where agricultural knowledge is produced and of the stakeholders involved in the process has not been limited to agricultural crops. Experimental activities involving livestock are increasingly examined, as farming work includes rearing animals as well as crop cultivation. Livestock research, which is mainly oriented to avoid losses and maximise production, requires the collaboration of farmers, vets, and scientific experts, it starts in the farm but often includes also laboratory research, and ultimately even concerns human health, as meat, milk, and eggs are integral part of the human diet and their quality and safety directly affect humans (Woods, 2017, 2019).

Unlike laboratories, whose standardised methods and procedures make the geographic location almost irrelevant, the study of experiments in field and farms requires also to address how agricultural knowledge produced according to local practices and in specific environmental conditions can be generalised to a greater area, the region, and how this ‘scaling up’ has been negotiated historically (Vetter, 2015).

This literature on field experimentation in agriculture has not been just a contribution to the history of agricultural experiments. It has also enriched our knowledge of experimental practices in the field sciences, a research area which began to interest historians about twenty years ago (Kucklick & Kohler, 1996; Kohler, 2002), and it has also acted as a bridge towards environmental topics (Vetter, 2011). An environmental trend can also be detected in the recent historiography of laboratory science connected to agriculture and plant research. Phytotrons, that is climate-controlled laboratories built to investigate how environmental factors affect growth and development of living organisms, became relevant sites of experimentation on commercial crops, their response to extreme conditions, and their ecological features in the Cold War era. These computer-controlled laboratories were a product of engineering applied to the life sciences, and their creation was fuelled by the human ambition to control the environment with technologies (Munns, 2017). Today, phytotron-like machines are used to study climate change and biodiversity, which are key scientific problems in the Anthropocene. Again, agriculture, science, technology, and their histories get all entangled while discussing these problems (Mahrane & Bonneuil, 2014; Hamilton & al., 2015), bringing once more agriculture at the centre of crucial debates in the history of science and technology.

- *Tools and Methods of Agricultural Experiments*

At the turn of the twentieth century the rediscovery of Mendel’s hybridisation experiments based on artificial crossings and the statistical analysis of the results offered new opportunities to understand and investigate heredity broadly conceived, including heredity in agro-industrial contexts (Bonneuil, 2015; Müller-Wille & Brandt, 2016). While the real impact of Mendelian genetics on farming practices remains a debated topic (Harwood, 2015; Derry, 2015), an interest in Mendelism has drawn many historians of science to the study of plant and animal breeders engaged in selecting crop varieties and livestock. These investigations have enriched the narratives of twentieth-century agricultural history and contributed at the same time to the history of genetics. They have pointed out the connections that exist between practical breeders and geneticists and they

have invited historians of science to take into account the influence of non-academic contexts on the work done by early geneticists. An example is offered by the Danish Wilhelm Johannsen, whose research on pure lines began while he was employed by the Carlsberg Brewery in Copenhagen (Bonneuil, 2016). Histories of plant and animal breeding have also contributed to disentangle the socio-economic factors at work in agriculture during the twentieth century and have offered improved explanatory tools to understand why and when plant varieties and animal breeds were introduced (e.g. Theunissen, 2012; Charnley, 2013; Holmes, 2018).

Histories of plant breeding have also contributed to bring the history of agriculture closer to the history of technology, because chemical and nuclear technologies have been mobilised in plant breeding programs to increase mutation rates and facilitate breeders' work. In these histories agricultural development and technological innovation go hand in hand and human and non-human actors are all part of the same narrative (Curry, 2016; Breitweiser & Zachmann, 2017).

As mentioned above, Mendelism relied not only on artificial crossings, but also on statistical analysis. Mathematical statistics became a cornerstone of genetics since its early years (Müller-Wille & Parolini, in print) and continues to be a crucial tool of genomics today (Stevens, 2013). Statistical methods for the design and analysis of experiments were decisive in implementing new strategies of field and laboratory experimentation in agriculture. These strategies were based on replication, randomisation, and the calculation of experimental errors and they successfully migrated from agriculture to many other scientific domains, whose histories can benefit from a better knowledge of these methods' development (Parolini, 2015a). Not only did statistical tools reshape experimental procedures in agriculture, they also contributed to establish objective criteria of assessment for farming products, like wine (e.g. Phillips, 2016). In these cases, the historiography of agriculture contributes also to our understanding of histories of consumers' experience and sheds light on the role that science and technology have in them.

- *Gender and Expertise*

During the second half of the 19th century, women gained access to higher education in Europe and the United States. Biology, botany, and the newly established discipline of genetics offered opportunities of employment to the female graduates that had qualifications equal to their male colleagues, but could be hired for much lower salaries (Richmond 2007). Several of these women found employment in institutions connected to agriculture, because biology, botany, and genetics were disciplines of

immediate relevance to agricultural research and cheaper female employment suited the scarce funding of many agricultural institutions. Yet, these women have been hardly mentioned in the history of agriculture for long time. The increased interest for gender within the history of science is changing the situation and there is an emerging literature on women's role in agricultural research, their training and achievements, and the discriminations they faced working in a male-dominated environment (Opitz, 2013, 2014).

Last but not least, histories of agricultural experimentation cannot be considered complete when they take into account only scientific experts and their institutions. Farmers and amateurs deserve a role in these histories, as they also did experiments and contributed to transform farming practices (Maat & Glover, 2012; Berlage, 2016).

The Global and Local Dimensions of Agriculture

During the 1920s the Italian agronomist Girolamo Azzi compiled his *magnus opus* on worldwide wheat cultivation entitled *Le climat du blé dans le monde* [Wheat Climates of the Earth] (Azzi, 1930). While he strived to make the entire Earth the object of his agro-ecological investigations, in practice Azzi composed the volume by accumulating national monographs on wheat cultivation and restricted the global analysis to the book conclusion. Azzi's project is representative of a tension common in agriculture. On the one hand, there is the aspiration to promote universal regulations and build global markets for agricultural commodities, but on the other hand there is the necessity to take into account local environmental conditions and farming practices. For this reason, global and transnational aspirations are complementary to local case studies in the history of agriculture. On the one hand, historians must take into account international organisations and institutions that contributed to shape rural practices worldwide and consider the circulation of agricultural knowledge and technologies in colonial empires and in the postcolonial age. On the other hand, historians must investigate the techno-scientific, social, and economic factors that are intrinsically connected to the development of rural communities.

Due to this complementarity of perspectives, the history of agriculture has contributed to promote global and transnational histories of science and technology, while continuing to produce also local studies focused on specific communities. I will argue below that both trends are enriching the historiography of science and technology.

- *Transnational and Global Histories of Agriculture*

As argued by John Krige, science and technology “transcend the boundaries of nations and nation states” (Krige, 2019) and in principle their histories should be transnational. In practice, however, historical investigations have often been restricted to the geographic boundaries of the nation without paying attention to the interconnections that exist between these national histories. Yet, agriculture offers many case studies for which transnational and global approaches are a necessity rather than a choice, as is the case with the worldwide circulation of plants, animals, and agricultural commodities in colonial and postcolonial settings. Krige’s edited collection on transnational histories includes, for instance, contributions on the migration of citrus cloning techniques from California to French-ruled Algeria (Saraiva, 2019) and on the role that U.S. experts and machinery played in the transformation of Indian agriculture during the colonial and post-colonial era (Kumar, 2019).

Transnational and global approaches can also be traced in recent investigations on cocoa (Macedo, 2016), seed circulation (Fullilove, 2017), wheat cultivation (Baranski, 2015), organic farming (Barton, 2018), and sugar technologies (Singerman, 2018). Aside from historians of science and technology, also historians of global history are actively using agricultural case studies to make their point on the complex networks that emerged since the nineteenth century to transfer goods, machines, and expertise across the world (Ortega, 2014). These transnational and global histories bring forward the entanglement existing in agriculture between plants and animals, people and places, artifacts and practices, and offer food for thought in current debates on agricultural sustainability, biodiversity, and environmental conservation.

As part of this trend towards writing global and transnational accounts, historians have also started to probe deeper into the foundation and work of international agricultural organisations, such as the International Institute of Agriculture (IIA), founded in 1905, and into the establishment of transnational networks in agriculture. An edited collection of essays on these topics recently appeared in *The Agricultural History Review* (Mignemi & Pan-Montojo, 2017). The collection offers new contributions on the role that international organisations had in agriculture during the first half of the twentieth century and their legacy in today’s agricultural systems. The essays deal with key institutions connected to the worldwide promotion of agriculture — besides the IIA, also the League of Nations and the International Labour Organisation — and highlight how these international organisations contributed to shape rural development. Paradoxical as it may seem, transnational bodies interested in agriculture

emerged also within organisations whose primary mission was not agriculture. This is the case for instance of the Commission for Agricultural Meteorology set up by the International Meteorological Organisation during the first half of the twentieth century. The work of this commission contributed to rebuild international cooperation in agriculture, especially among European nations, after the devastation produced by World War I (Parolini, in print).

- *Local Histories of Agriculture*

Alongside transnational and global histories of agriculture, historians of science and technology are still producing studies that focus on specific communities and geographic areas. These case studies remain crucial in agricultural history as local conditions affects farmers' needs and expectations. Local transformations of the environment, for instance due to improved irrigation, always have an impact on farming practices and multiple stakeholders — farmers, rural communities, investors, and local authorities — are involved and affected by these changes (e.g. Andres, 2015). Only studies that focus on a specific area and examine it in detail can make sense of these complex transformations and of their economic, social, and political impact.

These local studies are also important to provide information on specific geographic areas for which our knowledge is still scarce. This is the case of large parts of Africa and Asia, although in recent years historians have started to investigate them more systematically (e.g. McKittrick, 2015; Arch, 2015).

Local studies are also a starting point for writing comparative histories. A very interesting example of this approach is offered by Jonathan Harwood's *Europe's Green Revolution and Others Since* (Harwood, 2012). The author uses his research on plant breeding targeted at smallholder farmers in 19th- and early 20th-century Germany — Europe's Green Revolution — to trace a longer path for the post-1945 Green Revolution, its contested outcomes, and what this suggests for development studies.

The post-1945 Green Revolution was characterised by the use of agricultural technologies, which included high-yielding varieties of key cereals for the human diet (e.g. wheat and rice), massive use of chemical fertilisers and mechanisation of farming work. This approach to agricultural development certainly contributed to increased food production, especially in developing countries, but it also had a strong impact on the environment and a disruptive effect on local agricultural practices and rural economies. As the case of the Green revolution suggests, there are strong

interconnections between agriculture, food production and the environment, and historians cannot neglect them in their analyses. In the following section I will discuss how these interconnections are blurring the divide between agricultural, food, and environmental histories and are inviting historians working in these fields to formulate a common agenda.

The Integration with Environmental and Food History

Let us return for a moment to Girolamo Azzi and his investigations on wheat. Azzi was among the first to realise that crop yields — and consequently food availability — do not just depend on the plant variety chosen, but also on the environment in which the plant grows. Azzi, for instance, advised against the use of high-yielding wheat varieties that matured late and required a humid environment in the South of Italy, where temperatures were high and precipitations scarce during the summer. Their performance would have been worse than the performance of local varieties adapted to the dry season (Azzi, 1930). Today, Azzi is acknowledged as a founding father of agricultural ecology (Ross, 2017), but his work was rarely applied during the first half of the twentieth century. Indeed, during the Italian wheat campaign promoted by the fascist government in the 1920s, the value of Azzi's work was formally acknowledged, but plant breeders, farmers, and political authorities preferred to invest in agricultural technologies, rather than try to better understand the impact of environmental factors on wheat yields.¹

Azzi was an agronomist and always worked for agricultural institutions — at first the IIA and later an agronomy institute in Perugia —, but his story is not just part of agricultural history. Themes relevant to environmental and food history are also interlaced in Azzi's agricultural investigations on wheat and other crops, and only by taking all these aspects into account it is possible to write a comprehensive historical narrative. Azzi's case is certainly not unique in the panorama of agricultural history. Concerns for climate change and its consequences on the availability of agricultural commodities have brought the themes of farming, food, and the environment closer together. Historians interested in agriculture have been receptive to these concerns and their historical narratives have grown to include environmental and food themes, as I will explain below.

¹ Azzi's *Wheat Climates of the Earth* was presented during the First International Wheat Conference, which was held in Rome in 1927 and opened by the Italian fascist Prime Minister.

- *Agriculture and the Environment*

Agriculture is one of the human activities that transform the natural landscape. By replacing local vegetation with crops that can be sold on the market and by allowing livestock to graze in open air, farming alters previously established environmental equilibria. The use of chemical fertilisers and pesticides, and the construction of irrigation infrastructures also have a significant impact on nature and environmental historians have recognised the relevance of agricultural themes in their investigations since the 1980s (Worster, 1993; Crosby, 1995; Stewart, 2005).

In turn, environmental factors affect agriculture, too. Weather and climate remain key elements in the success and failure of farming activities, and soils and pests cannot be disregarded either. For the past ten years historians interested in the scientific, technological, social, and economic issues of agriculture have demonstrated an increasing attention for environmental themes (e.g. Brakensiek & Rösener, 2010). Plantations have been especially successful in opening up agricultural histories to environmental themes (Uekötter, 2014). Since the colonial age, they have been systems of intensive land and labour exploitation. They have grown around the world for producing a wide set of food and non-food commodities ranging from bananas and coffee to cotton and tobacco. They have shaped countries' environmental and economic histories, as argued by Michitake Aso for the rubber plantations in Vietnam (Aso, 2018), and they have replaced traditional farming methods even when their effectiveness and economic advantages for specific cultures, like cocoa, were called into question (Ross, 2014).

The plantation directly connects to ecology, a topic that is becoming increasingly relevant to bring together agricultural and environmental narratives. The twentieth century marked the beginning of a long-term alliance between ecology and agriculture, and historians are now starting to address more systematically the involvement of ecologists in crop cultivation and in the management of natural resources, and the role that ecological thinking had in the work of agricultural institutions. We still do not have a systematic picture of how the relationship between agriculture and ecology evolved, but a few contributions, ranging from national case studies to overviews of colonial practices, are already available (Hersey, 2011; Ross, 2017). It is especially important to write these histories, as present-day ecology does not overlap with the ideas that agricultural ecologists had of their work a century ago. Girolamo Azzi, for instance, was not concerned with themes such as sustainability and conservation, but he considered his agricultural ecology akin to rural economy (Azzi, 1928). In

addition, while environmental pollution caused by fertilisers and pesticides was not a main concern in the first half of the twentieth century, it has certainly become a main issue in the past sixty years and several contributions on the history of environmental pollution figure now in the recent historiography of agriculture (e.g. Jas, 2007; Sheail, 2013; Vail, 2018; Bertomeu-Sánchez, 2019). These contributions do not just address the environmental damage caused by pesticide use, but also deal with the consequences that these chemical substances have on food safety, as agricultural and environmental narratives often lead to food histories (Guillem-Llobat, 2019).

- *Feeding the World*

After World War II, the IIA was dissolved, and its functions and assets passed on to the newly founded Food and Agricultural Organization of the United Nations (FAO), whose headquarters soon moved from Washington to Rome, the city which had also hosted the IIA. For its logo FAO chose the motto *Fiat panis* and the stylised image of the head of wheat. Wheat was and is a crucial staple crop and, unsurprisingly, it is a main protagonist of agricultural histories regardless of whether they have been written to understand the impact of agricultural policies and weather factors on crop cultivation (Dronin & Kirilenko, 2013) or to address Green Revolution techniques and food supply (Baranski, 2015). In recent years, historians of science have started to consider also rice, the other main staple crop for the human population. Asian society and economy were deeply shaped by rice cultivation, but the history of rice as a food goes well beyond Asia and offer interesting case studies in Africa and in Western world, where rice, in its many varieties, is also part of the human diet (Bray & al., 2015).

Tea and coffee may not have the same place of wheat and rice in the human diet, but they have gained an equally important role in recent agricultural histories, because they offer an insight into the knowledge networks that made possible the acclimatisation and mass cultivation of these crops, and into the commercial routes that transformed tea and coffee in global commodities of colonial empires (Rappaport, 2017; Silva, 2018).

Food history and agricultural history do not converge only in relation to plant cultivation. Eggs, meat, milk, and dairy products, which are immediately relevant to human nutrition, are also the output of farming work. Their histories offer the opportunity to discuss the human and technological interventions required for producing and marketing these commodities alongside the close-to-nature rhetoric used in consumers'

advertising. As argued by Kendra Smith-Howard, the boundaries between the artificial and the natural and what consumers should worry about shifted over time. In the case of milk and dairy products, for instance, the fear of microbial contamination was replaced in the second half of the twentieth century by concerns over radioactive and antibiotics contamination (Smith-Howard, 2014). Antibiotics were (and remain) a main issue also in meat and egg production, due to their adverse effect on human health, and historians are increasingly interested not only in the role that scientific expertise and farming practices had in livestock management, but also in the actions taken by political authorities to safeguard consumers' health without hindering the development of agro-businesses. The final part of this review, therefore, will be devoted to the social value of farming and to the political and economic issues which are interwoven in agricultural narratives.

The Connections to Political and Economic Histories

During the 19th century, political authorities and economists began to use numbers and statistics systematically to evaluate agricultural performance (Bud-Frierman, 1996). National and international authorities, such as agricultural ministries, rural organisations, and the IIA, began to collect statistics on crop yields and cultivated land, on livestock, and on farming revenues and losses. In the first half of the twentieth century, this data collection effort was complemented by the institution of farm surveys (Short & al., 1999) and by the World Agricultural Censuses that started in the 1930s (Ribi Forclaz, 2016).

Agricultural statistics became instruments used to make — or to justify — policy and economic decisions and their collection was based as much on the effort of economists as on the work of other scientific experts interested in sampling methods (e.g. Yates, 1949). Historians are becoming increasingly interested in the role that these agricultural statistics had in the understanding of farming issues and in the agricultural economists involved in the field work required to produce these statistics (D'Onofrio, 2016). This is certainly a very welcome contribution to the historiography of science and technology as these case studies increase our understanding of how scientific expertise is negotiated and established among several stakeholders.

A better understanding of the value that numbers and statistics acquired in agriculture is also important to frame the narratives of agricultural development in twentieth-century totalitarian regimes. The achievement of specific productivity requirements oriented to food autarky

— for instance the target of 15 quintals per hectare set by the Italian fascist government for its wheat campaign (Saraiva, 2010, p. 461) — became part and parcel of the rhetoric that accompanied these agricultural projects. Breeders involved in creating hybrid wheat, potatoes, and pigs that could help achieve those targets were key actors in these political campaigns and their work became a propaganda tool for the fascist regimes (Saraiva, 2016).

The deep political, social, and economic impact of farming emerges also in the most recent historiography on the two world wars. As argued by Brassley & al. (2012), “[t]here is a long-established relationship between war, scarce and expensive food, and increasing farming profits. For all their modernity, the two world wars of the twentieth century demonstrated this as much as the conflicts of any pre-industrial period”. Disruption of trade networks for agricultural commodities, significant reduction of cultivated land and agricultural labour due to the war effort, and unavailability of fertilisers forced political authorities to policy interventions for farming and food management, generated increasing social tensions among the rural and the urban population due to food scarcity, and opened up debates on how to reform agricultural systems in the aftermath of the conflicts (Hamilton, 2014).

If the historiography so far mentioned deals only with Western and colonial contexts, this is just the outcome of the privileged attention that these geographic areas have received so far. Non-Western case studies can be similarly instructive. A recent example is offered by Sigrid Schmalzer’s analysis of the Green Revolution in socialist China (Schmalzer, 2016). In her account scientific farming, collectivist ideals, and people’s diets and expectations all come together in an in-depth exploration of how the ‘Western’ Green Revolution was adapted to Red Revolution China.

The Next Twenty Years

The majority of the books, journal articles, and theses mentioned in this review appeared in the past ten years and their very existence confirms that agriculture has definitely overcome its minority status within the historiography of science and technology. An increasing number of scholars are finding a stimulating source of case studies in agriculture, because agricultural narratives give the opportunity to investigate both laboratory research and field practices, and to delve into neighbouring fields, such as environmental history and food history. They allow also transnational and global approaches as well as detailed investigations of local case studies.

The achievements of the past decade and the remarkable growth that is evident comparing today's historiography of agriculture to the situation twenty years ago, certainly are a success story, but this does not mean that more ambitious goals cannot be set for the future. In agricultural history there are still many unexplored themes that deserve to find a place in the agenda of historians of science and technology for the next twenty years.

The first one is certainly the increase in the amount of non-Western case studies available. We know more on China and Japan, and on the European colonies, but we need a further effort, if we really want to have a truly global understanding of agricultural development. Large parts of Africa, and many areas in Central and South America have not been explored at all yet. Even within Europe, historical accounts are often abundant for the Western side of the continent, but they become scarce for the Eastern side. The historiography on Russian agriculture is certainly growing, but it seems still not enough to do justice to such a wide and diverse country, and to its long farming tradition shaped by dramatic political events. Asia too still requires to be investigated in greater detail. And what about the Australian continent?

Aside from increased geographic coverage, more research is needed to investigate how farming communities accepted or rejected science-based agriculture. This is certainly a key point when we try to understand why scientific and technological research born with the goal to improve farming work did not have any real impact on farmers or, in some cases, even caused the opposition of the farming community. This topic has been addressed mostly with reference to the failure of the Green Revolution in developing countries, but also agricultural modernization in Western nations offer interesting examples (Bivar, 2018). A better understanding of farming communities and their response to technoscientific novelties would also help to untangle paradoxes in modern agriculture, such as the one of 'conservation agriculture' (Hobbs & al., 2007). This is a set of management practices employed to minimise soil disruption and it has become increasingly important in twenty-first century sustainable farming. The paradox is that conservation agriculture is advocated both by agribusiness like Monsanto, whose agricultural practices are based on the use of pesticides like glyphosate, and by organic farmers, who evidently have a very different agenda. How can this be possible?

Granted, writing about farmers is much more difficult than writing about scientific experts or extension officers. Scientists' work was recorded in scientific journals and in patent applications, experts' theories and discoveries were featured in institutional accounts and, sometimes, someone felt that personal and professional papers of scientists were worth

conserving in an archive. Farmers, instead, remain largely anonymous. We know something about their associations and the journals they printed, but thoughts and attitudes of the individual farmer towards science-based agriculture cannot be investigated in the large majority of cases. Perhaps, we need to expand the array of sources we use to write our accounts of agriculture. Well into the first half of the twentieth century, peasants and farmers have been illiterate. We cannot hope to read their stories in journals and books, but this does not mean that they did not have a role in the history of scientific agriculture. We probably just need to look further and, as a few historians have already suggested (e.g. McMurry, 2014; Chacko, 2018), remember that plants, photographs, barns and landscapes can also be suitable sources for writing histories of science and technology in agriculture. For more recent times, oral histories can be a precious tool and institutions like the British Library are organising a systematic collection of interviews on farming, land management, and conservation.

Conservation is a key word to introduce the last area in which, I believe, the history of agriculture will become more and more entangled into accounts of science and technology in the near future. Agriculture is one of the human activities that more has impacted on the environment and any historical investigation of the environmental challenges faced by mankind cannot exclude farming, its sustainability in terms of soil conservation and carbon dioxide emissions, and at the same time its necessity to provide food for the growing human population. What is the role of agricultural science and technology in the Anthropocene? What is the respective influence of farming communities, citizens, and agribusinesses in shaping the response to climate challenges? What is the attitude of farmers towards conservation issues and science-based solutions for producing food, such as cellular agriculture or cloud-based farming platforms? These are just a few of the questions that will need to be addressed in twenty-first histories of science and technology concerned with environmental challenges, and again the history of agriculture will find itself at the intersection of debates on science and technology, food and the environment, politics and society.

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