Bulletin of the GHI Washington

Supplement 3 (2006)

Did They Know What They Were Doing? An Argument for a Knowledge-Based Approach to the Environmental History of Twentieth-Century Agriculture

Frank Uekötter

"Did they know what they were doing?" The question provokes memories of the early days of environmental history research. As every scholar in the field knows, environmental history developed in close proximity to the environmental movement, and that has left a marked imprint on many a narrative. More than once, the full moral thrust of environmentally righteous anger came to bear on those who were deemed to be at fault for the state of the environment. However, environmental historians have grown more moderate as the field has evolved and "declensionist" is now a subject entry in Carolyn Merchant's *Columbia Guide to American Environmental History* rather than a predominant mood among researchers.[1] In his environmental history of the twentieth century, John McNeill urged researchers to be cautious in labeling changes in the environment as either good or bad, "because environmental changes usually are good for some people and bad for others," a standpoint that is currently evolving into a new scholarly consensus.[2]

And yet there are probably few fields where this line of reasoning is more difficult to adhere to than in the history of agriculture in the twentieth century. Ever since Rachel Carson pointed to the side effects of excessive use of pesticides, the public has taken notice of a long list of environmental problems: pollution of rivers, erosion and degradation of soils, loss of biodiversity, excessive consumption of energy, odorous discharges, eutrophication, methane emissions contributing to the greenhouse effect and increased vulnerability to epidemics due to the concentration of large numbers of animals.[3] One also needs to take into account the fact that the result of all these endeavors is overproduction with global consequences on an unprecedented scale. At the same time, it seems that there are few areas where the environmental movement has made less headway than in this field. In fact, even the recent boom of organic farming in Germany looks tiny if one is mindful of the organic farming lobby's original goals; while organic farming organizations were hoping in the early 1990s to cultivate 10 percent of Germany's farmland by the year 2000, the actual figure was 3.2 percent.[4] Clearly, every researcher working on the history of agriculture in the twentieth century will inevitably be tempted by cynicism.

The environmental critique of modern farming is well established, and repetition generally has not improved its sophistication. While Hermann Priebe offered a diligent and sober discussion of these problems in his still highly readable *Subsidized Nonsense* (*Die subventionierte Unvernunft*) of 1985, more recent publications, such as *Bananas for Brussels* (*Bananen für Brüssel*), take long excursions into the depths of populism.[5] Clearly, conventional farming has shown a remarkable resilience to its critics, raising doubts about the political wisdom of opening yet another round of criticism. These doubts are all the more important since the environmental negligence of farmers has its parallel in the neglect of environmental issues in the historiography of twentieth-century agriculture. The boom of agricultural history in recent years has produced a conventional narrative that centers on social and economic issues: the shrinking number of farmers and the increasing average size of their enterprises, the decline of the family farm and the support of farming by German and European taxpayers.[6] Countering this narrative with discussions of the environmental toll of modern farming would not only produce a history with few surprises, it would also merely replicate the highly dubious mode of discussion that current debates adhere to—one group talks about agricultural production and the other about environmental problems. Integrating both perspectives is the challenge that future debates, historiographic as well as political, will have to meet.

In order to achieve this goal, this essay proposes to focus on the knowledge base of agriculture as it changed over the course of the twentieth century. Many historians have commented on the rise of agricultural productivity in the last 100 years, but few have realized that it required not only new seeds, chemicals and machinery, but also a totally new kind of knowledge about the use of these tools. But who supplied the farmers with this new knowledge? Who defined "good practice" in farming—and who did not? Modern farming textbooks frequently boast about agriculture being an applied science, and the agricultural literature often celebrates scientific progress with unabashed naïveté.[7] But is the farmers' knowledge really based on the entire breadth of scientific knowledge, or is it instead heavily circumscribed? How does information flow from the researchers to the individual farmers—and what are the chances for feedback? One of the interesting features of a history of agricultural knowledge in the twentieth century is the fact that farmers never rebelled against the intrusion of scientific knowledge, even though this intrusion obviously threatened the farmers' ability to make independent decisions. How have farmers—a group with a legendary reputation for conservatism—come to accept advice on new farming methods so readily? How does a farmer sustain his traditional identity as "master in his house" if he cannot make major decisions without the advice of outside experts?

These are the questions that this project seeks to answer, and the title question is to be understood in the most literal sense: Do farmers still know what they are doing in their daily work? The results promise new perspectives on past and present problems of modern agriculture.

The Agrarian Knowledge Society: Theoretical Perspectives

Knowledge is omnipresent, and yet it is easy to overlook. This is probably the reason why so few historians outside the history of science have explicitly dealt with knowledge as a historical phenomenon.[8] Therefore, a history project of this kind is well advised to seek inspiration from other disciplines that have given more attention to this phenomenon. Specifically, this project may profit from the sociological discussion of the "knowledge society" as it has evolved since the mid 1960s.[9] The general idea of this theory, according to Helmut Willke, is that social processes in the most general sense "have come to be influenced to such an extent by operations depending on knowledge that processing information, interpretation of symbols and expert systems have become dominant compared to other factors of reproduction."[10] As the following discussion will show, this definition provides an adequate description of the current situation in the field of agriculture: the productivity of modern agriculture would be impossible without the systematic use of scientific knowledge. In fact, experts have come to dominate to such an extent in certain fields that agricultural production would be virtually impossible without input from these experts. Of course, one may quibble about the relative importance of knowledge as compared to other factors of production and whether one can in fact note a *dominance* of knowledge, but it seems of little merit to open such a discussion. Of course, one cannot operate a farm with knowledge alone since one needs capital, labor and land, to mention just some of the essentials. However, all these essentials are of no value without a body of knowledge that gives directions on their proper and effective use, which is what makes knowledge such a strategic asset. Focusing on knowledge is one-sided, but it is one-sided in a productive way.

In his seminal work on the knowledge society, Nico Stehr argued that scientific research has increasingly become the sole source of additional knowledge.[11] There is abundant evidence for this argument in the history of agriculture, and yet it is important not to overstate the point. The production of additional knowledge does not necessarily mean that this additional knowledge influences social production to any comparable extent. For example, it is fully possible that new agricultural knowledge does not find its way from the research center to the farmer. It is clear that scientific knowledge often finds its way into society in indirect ways; in the field of agriculture, it is up to a complex network of advisors to decide on the kind of information that farmers will get. Therefore, these advisors will need to occupy a prominent place in this story and they should not be seen as passive transmitters of new agricultural knowledge. With that in mind, Stehr's related argument that an increase in scientific knowledge will necessarily lead to an increase of options for action becomes somewhat doubtful.[12] If one network of experts achieves dominance in a certain field, they may block the transmission of certain kinds of information, resulting in a decrease and, ultimately, the general disappearance of options. If farmers can only turn to one group of experts for advice because other experts have been discredited, the farmers have no choice but to follow their suggestions, even if they sense that these advisors offer a biased selection of contemporary scientific knowledge. As this paper will show, this is more than a theoretical possibility.

On a more general level, it is important to realize that while the knowledge society may be a result of the rise of science in modern society, one should be wary of a simple conflation of the history of knowledge and the history of science. It is important to note that farming knowledge in particular has never simply been the result of scientific advice. Farming knowledge is to a considerable extent the result of experiences, traditions and everyday routines, and these non-scientific forms of knowledge deserve a prominent place in any history of agricultural knowledge. The focus on the increasing influence of scientific knowledge easily leads to a point of view that perceives every non-scientific type of knowledge as a mere leftover from previous times that is just waiting to be improved upon by scientific knowledge.[13] However, non-scientific forms of knowledge persist even in today's farming practice, and may in fact fulfill a number of important functions. The rise of the agrarian knowledge society, in short, is not merely part of a Weberian process of rationalization.[14]

However, stressing the non-scientific components within the system of agricultural knowledge represents a considerable historiographic challenge. While scientists usually produce an immense number of publications that document their ideas, approaches and theoretical underpinnings, no similar body of literature exists for non-scientific types of knowledge. Unlike scientists, farmers usually do not need to lay out their own knowledge in all its detail and with the implications fully and clearly delineated. Therefore, there is no body of records that provides a direct documentation of agricultural knowledge, and one should treat cautiously the hope that interviews may produce such a set of records. Interviews will most likely reveal more about how farmers *want* to see themselves than about how they actually are.[15]

Therefore, this paper proposes to investigate the history of agricultural knowledge by focusing on a group that agricultural history has for the most part ignored: the agricultural advisors. State agencies as well as private companies hired legions of experts to provide the farming community with information, making them an important part of the network of agricultural knowledge. In a nutshell, the advisors' job was to transform and condense information from the wide spectrum of agricultural sciences into handy little pieces of information that the farmers could use in their daily work. The criteria for the selection and condensation process deserve special attention. At the same time, these advisors gained an intimate knowledge of the farmers' reactions and their knowledge base, and, luckily, they have spoken about their experiences with striking openness on numerous occasions. In fact, there is a vast body of advisory literature and it is primarily this literature that the current project seeks to use, keeping in mind that it needs to be investigated from three different perspectives: first, as a condensation of results from the agricultural sciences that may include certain biases; second, as a source of knowledge for farmers; and third, as documentation of the farmers' feedback.

In this manner, this project takes what one might call a fruitful detour toward a history of agricultural knowledge. Acknowledging that farmers' knowledge is not accessible in a direct way because of a lack of sources—in fact, because of a frequent lack of verbalized knowledge—it focuses on the advisors as the key link between the farmers and the scientific experts. Admittedly, such a study cannot provide an exhaustive picture of an individual farmer's entire scope of knowledge, but it does provide what is arguably much more important on a general scale—a picture of the general conditions that regularly contributed to, as well as limited, farmers' knowledge. Such is the general approach to the history of knowledge that this paper seeks to advance: the history of agricultural knowledge should be written as the history of the structural conditions that left a marked imprint on both the form and the content of knowledge in the field of agriculture.

Open to Multiple Perspectives: The Soil as a Cultural Artifact

Cultivating the soil has always been an activity rife with cultural implications. Given the fundamental importance of the soil for agriculture, this is hardly surprising. In a way, Johannes Knecht was stating the obvious in his agricultural textbook of 1949, when he wrote that the soil was "the most important part of a farm" and that its proper cultivation was "the supreme skill of farming."[16] But there are as many types of soil as there are cultures and, as a result, the way farmers have treated soil has always been open to a wide range of perspectives. Human history provides a rich reservoir of ideas on how to cultivate the soil and how to maintain and foster its fertility.[17] Of course, the demise of religious interpretations in modern times has somewhat narrowed the range of approaches, and few would argue nowadays that one should identify fertile soils through their taste. Nevertheless, it is important to realize that ever since Justus von Liebig's critique of Albrecht Thaer's humus theory, there has been a plurality of scientific opinions.[18] Chemical, biological, bacteriological, geological and other approaches offer different perspectives on the soil, and maintaining and increasing soil fertility could mean very different things from these disciplinary points of view. Therefore, competition between these approaches offers a promising setting for a case study on the transformation of agricultural knowledge in the twentieth century.

In the previous section, I stressed the importance of incorporating non-scientific forms of knowledge into a history of agricultural knowledge, and the history of conceptions of the soil provides abundant evidence for the merits of such an approach. Farmers deal with the soil on a daily basis and this work produces a rich reservoir of experiences. Due to annual cycles of vegetation, much agricultural work is essentially routine work, and these routines and the tacit knowledge they include are an important part of the body of agricultural knowledge. This is all the more important as scientific experts have become increasingly influential in this field over the course of the twentieth century, putting traditional notions of the soil and farmers' tacit knowledge under growing pressure. To be sure, nostalgia is inappropriate in this context as "indigenous knowledge" was not necessarily better adapted to local environmental conditions. In fact, many reports show that farmers almost routinely mishandled the organic wastes they produced, resulting in a significant loss in nutritional value for organic waste as a fertilizer. For example, Hans Schlange-Schöningen, the author of a number of highly readable books on farming, noted that "many farmers do not have a grasp of the losses they incur" through inadequate handling of organic wastes.[19] However, while "indigenous knowledge" may often be a synonym for laziness or misinformation, it is important to analyze the causes and consequences of the gradual devaluation of farmers' own experiences.

Less than twenty years after the publication of Knecht's textbook, a booklet for distribution among farmers offered a much more constrained perspective on the soil: "The goal of agriculture," the booklet instructed, "is . . . the proper and purposeful transformation of nutrients into plant substance with the help of the soil as a mediator."[20] This extreme but by no means atypical quotation shows that the chemical approach emerged as the dominant one from the competition between the different sciences of the soil. Agricultural chemistry is now the dominant mode of perception among farmers, with other approaches playing an only marginal role at best. Therefore, maintaining soil fertility is now virtually synonymous with mineral replacement, a view that treats soil as a medium for storing minerals and organic matter. This conception is remarkably similar to that of Justus von Liebig in the mid nineteenth century and members of the scientific establishment frequently refer to Liebig to provide a historical justification for their views.[21] However, the simple line between Liebig and modern agricultural knowledge is little more than the construct of a scientific discipline undergoing a crisis of legitimacy. The chemical theory of plant nutrition had to establish its dominance over several other approaches, and these conflicts came to a head in the 1920s. The interwar years were a time of severe disagreement between different conceptions of fertilizer use and the result of the ensuing conflicts would determine the face of agriculture, as well as farmers' conceptions of the soil, to the present day.

The Interwar Years as a *Sattelzeit* in the Environmental History of Agriculture

The First World War marked a watershed in the history of agriculture in Germany. The lack of farm workers, and especially the almost complete confiscation of nitrate fertilizer for the production of explosives, disrupted a complex agricultural routine, and farming yields sharply declined as a result. Grain production fell from 27.1 million tons in 1914 to 17.3 million tons in 1918, while the potato harvest fell from 45.6 to 29.5 million tons.[22] Therefore, the postwar years saw feverish efforts to restore soil fertility and to remedy the effects of the wartime *Raubwirtschaft* (exploitative economy).[23] However, the supply of fertilizers had changed significantly since the 1910s. The invention of the Haber-Bosch process made atmospheric nitrogen available for fertilizer production, thus opening a practically limitless reservoir of the most critical plant nutrient.[24] At the same time, manure had become scarce as a result of wartime cutbacks on livestock and inadequate feed, which placed the traditional role of organic wastes in jeopardy.[25] As a result, increasing the use of mineral fertilizers became the rallying cry for the vast majority of agricultural experts, with the promise of the scientific establishment that with massive doses of mineral fertilizers, prewar yields would return almost immediately. In typical fashion, a brochure from 1921 declared, "The exhaustion of our soils can be remedied only through an intensive, rational use of mineral fertilizer."[26]

But the promise of a quick return to prewar conditions proved illusory. Per-acreage yields stayed below prewar figures for much longer than expected and the massive campaign for the use of mineral fertilizer came to appear dubious to many farmers. Mineral fertilizer was the most significant investment for many farmers and, with farmers struggling to keep out of debt during the 1920s, this issue was by no means unimportant.[27] In addition, the massive use of mineral fertilizer led to the acidification of many soils, inhibiting the growth of certain plants.[28] In 1923, Ernst Niggl warned that soil acidity constituted "a threat that has attracted too little attention so far."[29] Of course, farmers could use lime to restore a neutral condition, but this took two to three years to achieve results and involved significant costs. Also, one should not underestimate the impact of liming on the farmers' mindset: from the farmers' perspective, liming was irritating in that it took a chemical substance to remedy a problem caused by a chemical substance.[30] The prospect of ruining the most essential basis of agricultural production was disturbing, if not traumatic, for many farmers. One expert later noted that the most important consequence of this episode was the "psychological effect": "Agricultural chemistry lost credit in the eyes of many people."[31] In short, agricultural chemistry experienced a deep crisis of confidence, thereby providing an opening for other approaches to soil fertility.

One such competing approach grew out of the field of soil microbiology, which experienced a temporary boom in the 1920s. While bacteriology was instrumental in the rise of the medical sciences in the late nineteenth century, it had played a marginal role in the field of agriculture due to the dominance of agricultural chemistry.[32] As a result, scientific knowledge about bacteriological processes in the soil was generally scarce; Felix Löhnis, the most important agricultural bacteriologist of the 1920s, once spoke of a "still quite darkish field."[33] Löhnis had been a researcher at the University of Leipzig until 1914 when he joined the United States Department of Agriculture as an expert on soil bacteriology. In 1925, he returned to Leipzig to fill a newly created chair of agricultural bacteriology, a step which he hoped would encourage other universities to follow suit.[34] Löhnis was optimistic about the prospects of his field, not least because he saw the contemporary situation as generally conducive to agricultural bacteriology: "In the present time, with the urgent need to save labor and capital as much as possible, the rational use of soil bacteria working for free deserves all attention."[35]

However, agricultural bacteriology soon encountered a number of significant problems, the most important one being essentially homemade. Soil microbiology focused on the investigation of the basics of bacteriological processes in the soil and failed to provide farmers with answers to questions of practical relevance. Without a thorough understanding of the fundamentals of soil bacteriology, Löhnis argued, the business of giving advice to farmers would stand on very shaky ground.[36] To be sure, Löhnis would sometimes refer to practical farmers like Schultz-Lupitz and depict agricultural bacteriology as a response to the wishes of the farming community. However, there was never any systematic attempt to get back to these practitioners with specific rules of good practice.[37] In fact, even the question of whether there was a usable method of soil investigation based on bacteriology was absurd for him.[38] In a telling episode, he noted that more information on the effect of tillage on bacterial life would be desirable. However, lacking sufficient research on this issue, he urged farmers to find out the right approach for themselves "and then wait patiently until scientific research has found an explanation for their practical successes."[39] It seems the limitations of a discipline that only explained retrospectively what people were already doing were never apparent to Löhnis. Therefore, the field's prospects were already dim when Löhnis died unexpectedly in 1931, essentially ending all hopes of a soil microbiology boom in Germany. However, even these small beginnings were met with considerable hostility from the agricultural science establishment. The minutes of the committee on general fertilizer affairs of the Prussian Ministry of Agriculture provide a case in point. When a professor from the agricultural university of Berlin called for more attention to humus ("plants do not simply grow from mineral fertilizer") and expressed his regret about the recent death of Löhnis and the probable discontinuation of his chair, his statements met with strong opposition. At the following meeting, the professor spoke of the "polemic" he had encountered and stressed that he was using mineral fertilizer himself in order to forestall a new wave of attacks.[40] Clearly, the upswing of research in agricultural bacteriology was followed by a good degree of skepticism, if not hostility, within the agricultural chemistry establishment.

However, agricultural bacteriology was not the only competitor that the agricultural chemists faced in the 1920s. Since Rudolf Steiner's lectures on agriculture in 1924, a group of ardent anthroposophists had sought to develop a new kind of organic farming that refrained from the use of mineral fertilizer altogether. This "biodynamic agriculture" (*biologisch-dynamische Landwirtschaft*) quickly drew criticism from the agricultural science establishment to an extent that is difficult to understand at first glance. For example, in 1935 the director of the Federal Bureau of Biology (*Biologische Reichsanstalt für Land- und Forstwirtschaft*) wrote that, in his eyes, organic farming was "99 percent humbug."[41] When the German chemists' journal *Chemiker-Zeitung* published a scathing attack on organic farming in 1934, the article was supplemented by an editorial note complaining of the "heresies" in the field of soil fertility being proposed "with a fanaticism that is reminiscent of the dark ages of medieval ignorance."[42] After the Nazis' seizure of power in 1933, an article with the emblematic title "Hands off our reliable fertilizing methods!" even called upon the new regime to crack down on these "charlatans."[43]

In his book *Subsidized Nonsense*, Hermann Priebe wondered why a farming method that occupied less than one percent of Germany's arable land was creating such a stir, and it seems worthwhile to ask the same question for the interwar years.[44] "There is no doubt among the experts that only a small amount of ash will remain from this straw fire," one expert wrote.[45] But if the experts were certain about the prospects of organic farming with the Steiner method, it is difficult to understand the bitterness of their attacks. Why did the experts not simply lean back and wait until the anthroposophists had worked their way into bankruptcy? Why did the agricultural science establishment react with such vigor and even go to the extreme of trying to solve the dispute with the help of the Nazi regime? To be sure, the attacks were in part a response to the anthroposophists' marketing strategies. In their publicity efforts, organic farmers often focused on the public at large rather than merely on other farmers, suggesting a link between the use of mineral fertilizer and cancer.[46] The fear of cancer turned out to be a powerful marketing tool, and many consumers sought organic farming products as a result. Numerous farmers were selling their products as "grown without mineral fertilizer" in order to achieve better revenues, even though they had frequently followed the conventional methods of fertilizing. The certification of organic farming products and clear definitions of the "dos" and "don'ts" of organic farming were still several decades away, thus opening the door for fraud.[47] Of course, all this did not evoke any sympathy for organic farming in the agricultural science establishment, and yet it would be misleading to depict the massive attacks on organic farming as simply a response to a challenge from outside. In their critique of organic farming, the scientific establishment was also pursuing a number of strategic goals. In light of their interests and against the background of the crisis of confidence of the 1920s, one could even argue that the clash over organic farming was the perfect dispute at the perfect time.

On the most general level, the critics of organic farming sought to prevent the formation of a competing network of expertise. The campaign did not fully succeed in this regard—as the continued existence of organic farming up to the present demonstrates—but it did succeed in restricting organic farming methods to a small fringe. Even more importantly, the critics succeeded in preventing any meaningful exchange between conventional and organic farming; every practitioner knew that he could turn to either system of expertise, but not to both at the same time. Even on a scientific level, contacts were rare and were met with great skepticism; up to the 1980s, seeking a dialogue with organic farming experts put a scientist's professional reputation at risk.[48] In addition, the critique of organic farming helped to foster a general skepticism towards biological concepts of soil fertility and, ultimately, the controversy canonized a chemical understanding of soil fertility. The true importance of this impact becomes clear when one looks at the general character of the field. The agricultural chemistry establishment was a chaotic conglomeration of research institutions from completely different backgrounds: university departments and institutes sponsored by the farmers' corporate representations (*Landwirtschaftskammern*) mixed happily with institutes sponsored by the producers of mineral fertilizers. The importance of the latter becomes apparent when one considers the major producers of mineral fertilizer in Germany. Potash fertilizers came from state-owned mines, heavy industry sold phosphate from the production of steel in Thomas converters and IG Farben supplied nitrogen fertilizers. In other words, the three most powerful forces in the German economy were united by a common economic interest in chemical fertilizer. In light of this confluence of interests, the lack of a truly independent branch of agricultural chemistry is by no means surprising.

However, the complex mixture of industrial, agricultural and scientific concerns also suggests that rules of good scientific conduct were notoriously difficult to establish. There was neither a supreme authority that could define rules nor a forum where the profession could meet and develop rules of this kind (which Peter Galison refers to as a "trading zone"[49]). Therefore, the conflict with organic farming provided a perfect opportunity to hammer home a few important rules: do not get in touch with organic farming experts, do not seek an understanding of soil fertility that moves beyond chemistry and do not bother with organic fertilizers too much. Of course, every expert in the field was aware of the fact that the vast majority of farmers used manure on a regular basis—but at the same time, the general tendency in the field was to marginalize the study of manure as a fertilizer and to focus on mineral fertilizer instead. Over time, this turned into a highly influential bias; mineral fertilizer came to be regarded as the "true" fertilizer that commanded the lion's share of attention, while organic wastes were seen as marginal. As a result, manure did not attract major attention from the agricultural science establishment until long after the Second World War when it came to be viewed as an environmental problem rather than an agricultural asset.

The Mathematics of Biology: Quantifying Soil Fertility

While agricultural chemistry was competing with other schools of soil fertility, it was simultaneously struggling to resolve a second problem that was instrumental for its rise to predominance: the issue of dosage. The conventional literature provided ample information about the characteristics of individual nutrients, the types of fertilizer and their proper handling. However, as farmers relied on mineral fertilizer more and more heavily in the interwar years, they were no longer content with general information. Faced with a crisis of confidence and the significant economic risk of high fertilizer expenditures, they were asking for more precise directions: What amount of what type of fertilizer should they use for their crops? From the point of view of agricultural scientists, this posed a dilemma. They could not ignore this demand without risking their own jurisdiction over fertilizer use. But at the same time, there was no way to deny that they had no proper scientific method to meet this demand.

Many researchers conducted field experiments in a way defined by the head of the Darmstadt Agricultural Research Station, Paul Wagner. This method called for five plots of land with different inputs of nutrients: one plot received nitrogen, phosphate and potash fertilizer, three plots received two of these nutrients and one plot was left without fertilizer.[50] Therefore, these experiments could only produce qualitative results. They could indicate, for example, if the addition of a certain nutrient was necessary for plant growth, but provided little indication of exactly how much of it was required. On the issue of dosage, therefore, Wagner's method was irrelevant. Since they lacked an established method to produce reliable figures, many advisors tried to avoid the farmers' pointed questions for precise recommendations. Frequently, advisors encouraged farmers to use their intuition, citing "self-observation and self-examination" as the best sources of information.[51] "The general guideline for the choice and use of mineral fertilizers is the local and individual, as opposed to the schematic, approach," declared a 1930 handbook.[52] Even publications that offered precise figures by way of advice warned of a schematic approach to fertilizer use and called on farmers to take specific local conditions into account.[53]

It is interesting to note that the chemical method of soil analysis, which remains the standard method today, initially met with almost unanimous skepticism. For example, Gustav Höppner noted that a chemical analysis would only produce usable results in those rare cases where one nutrient was almost completely absent, thereby questioning whether the method was an improvement on Wagner's approach.[54] Another publication of the same year mentioned field experiments as the only reliable method, depicting chemical and other methods as potentially "misleading."[55] In 1924, an author explained that his own reservations were due to the fact that chemical investigations would only demonstrate the presence of certain minerals without revealing whether they were actually soluble and thus available to the plant.[56] In fact, even experts conducting these analyses were eager to tap other sources of information as well; one researcher supplemented his chemical analyses by handing a three-page questionnaire to farmers in order to consider a wide range of factors as fully as possible.[57] A 1926 handbook concluded that, "valuable as all these physical and chemical methods may be, personal observation, trained through constant practice, stands above them all."[58]

Despite the fact that such criticism of the chemical method was never fully addressed, the early skepticism gradually faded away over time. Nothing demonstrates this development more dramatically than today's system of soil analysis in which farmers are compelled to submit soil samples to a laboratory of the state-funded Agricultural Research Station (*Landwirtschaftliche Untersuchungs- und Forschungsanstalt*) at least once every six years. Farmers who submit an overview of their future crops to the institute will receive a printout, produced by a computer program euphonically named "DungPro," supplying them with detailed information on the nutrients their soil will require if it is to meet future projections.[59] This routine procedure is all the more remarkable since the uncertainties of the method have by no means disappeared. A recent handbook on plant nutrition and fertilizing, while praising soil sampling for its speed and low cost, also mentions that the method's lack of precision was a significant disadvantage.[60] The causes of error and imprecision are numerous: acres are usually not uniform in their mineral content, a problem that soil samples usually blank out in favor of an arithmetic average; the method does not account for concentrations at different depths; the solvent needs to extract within a matter of hours what plants would extract over several months; and the method inevitably needs to ignore the impact of future weather conditions.[61] All in all, the uncertainties are staggering.

However, scientific precision is not necessarily the most important issue in determining the selection of a certain method. In the consultation business, time constraints soon came to dominate the choice of methods. Eilhard Alfred Mitscherlich's soil investigation experience in Eastern Prussia provides a case in point. Faced with the task of writing some 2,000 reports within a brief span of time, Mitscherlich adopted a simple form that provided the farmers with basic quantitative information. More detailed, non-quantitative comments were postponed until the winter, when there was more time for personal meetings with the farmers. Time constraints, therefore, relegated such reports to the status of second-rate information.[62] The farmers' persistent demand for exact figures met with a growing readiness of scientists to supply this kind of information, and that created a crucial dynamic of its own that gradually pushed all scientific doubt to the margins. Interestingly, Mitscherlich took a much more skeptical view of his own method two decades later: "It is certain that one will never be able to tell the farmer how much of a certain fertilizer he should use on the basis of chemical soil analyses."[63] However, objections of this kind did little to curtail use of the method.

Today's advisory literature usually ignores the uncertainties of chemical soil analysis. As a recent article in a popular farming journal declared, "soil analyses are the indispensable tool for optimizing fertilizer use."[64] The environmental contingencies of this approach become apparent when one realizes that even if the figures are precise, the approach inevitably ignores a whole host of factors such as the condition and size of the humus layer, the amount of bacterial activity and the density of the soil. These and other parameters naturally have an influence on soil fertility, but they do not enter into the calculations of DungPro, which simply sees the soil as a temporary storage space for minerals. In fact, even a severe problem like erosion will remain undetected within this system of knowledge, a worrisome situation in a country where erosion is usually a long-term process, though without exigencies of the dust bowl variety. Clearly, there has been a good deal of erosion of both the German soil and of the body of agricultural knowledge that is meant to address such problems.

Coping with Expert Dependency

Agricultural chemistry emerged from the conflicts of the interwar years as the dominant discipline within agricultural science. However, by ignoring erosion and other environmental problems, it puts at risk the most essential elements of agricultural production. How did farmers react to all of this? Many essentially surrendered command over their fields to a software program, and it is difficult to imagine that such a deep shift of knowledge could occur without major repercussions. There is abundant evidence indicating that groups of any kind usually resist attempts to usurp their productive knowledge. Paradoxically, although farmers showed signs of resistance to scientific agriculture during the interwar years, their opposition dwindled at the same time the intrusion of scientific knowledge into agriculture was gaining full force. What factors account for this apparent surrender to scientific agriculture?

The most fundamental cause of this paradoxical situation is the immense degree of trust that farmers have developed towards farm advisors.[65] Without a strong sense of shared identity among farmers and the popular juxtaposition of "we the farmers" against "the rest of society," the trusting relationship between farmers and scientific advisors would be unthinkable.[66] But trust and collective identities were closely dependent on the apparent merits of acquired knowledge. Success, at least from the perspective of short-term production, was the key reason for the farmers' trust in outside advisors. In short, it seemed to pay to listen to them. While mineral fertilizer did not increase per-acreage yields as quickly as promised in the early 1920s, it certainly became clear in the long run that mineral fertilizer did boost agricultural productivity. The massive rise of per-acreage yields after the Second World War underscored the legitimacy of the agricultural advisors, lending them an aura of indispensability. This great sense of trust was apparent in farmers' attitudes toward a new software program that allows them to customize their fertilizer usage plans. The program was commissioned by Hydro Agri, a major producer of mineral fertilizer. Thus the program entails entrusting the calculation of fertilizer needs to a producer of fertilizer. Common sense would suggest that this is a risky undertaking, but farmers obviously think otherwise.[67]

But trust and productivity are only one part of the explanation. The other part is distraction: the preoccupation of today's farmers with other issues. It is by no means coincidental that the increasing dominance of scientific advisors developed at the same time as the mechanization of agricultural production: the former was possible only because it was embedded in the latter. Like the history of fertilizer use, the early relationship between the farmers and their machines went through a period of estrangement. In the 1920s, one author reported that many farmers still saw technology as "a necessary evil."[68] Similarly, Hans Schlange-Schoenichen mocked "tractor-fancy" in 1927 as an example of the excesses of modern farming.[69] But soon machines became a routine part of agricultural work and ultimately a source of pride. A new type of farmer emerged, the technologist with a penchant for up-to-date machinery and do-it-yourself repairs. In the 1990s, agricultural machinery dealers were selling (as opposed to installing) about 50 percent of the total number of spare parts because many farmers wanted to install these parts themselves.[70] Of course, saving money was part of the motivation, but so was a fancy for technology. Interestingly, the advisory literature was often hesitant about pushing the use of the latest machinery and instead called for caution and cool heads in this respect. However, this advice mostly fell on deaf ears. "Those who are buying the latest technology for reasons of prestige and progressiveness are usually producing with excessive costs," a recent handbook on farm economy noted; and it was by no means the first admonishment of this kind.[71] But the persistent increase in tractor horsepower since the Second World War provides a telling indication of farmers' priorities.

The links between the growing prominence of scientific experts and the mechanization of farm production were functional as well as ideological. On a functional level, machines required a great deal of attention and time for maintenance, thus diminishing the farmers' chance to monitor other parts of their enterprises as diligently as before. For example, while farmers traditionally learned much about their soils by walking behind the plough, farmers using tractors for tillage devoted much of their attention to the proper operation of the engine. Thus an expert who offered detailed information on proper fertilizer use could appear not as an intruder into a core area of farming knowledge, but as a welcome aide who brought clarity into an area that a farmer could not thoroughly deal with for lack of time. The impact of mechanization on farmers' identities was no less important. If a powerful tractor and up-to-date equipment are the farmers' new fetish, then a loss of interest in fertilizer seems only natural; after all, chemicals and odorous wastes are about the least prestigious farming tools one can imagine. As a result, farmers readily ceded authority on this dull subject to a trustworthy expert. For them, the key issue was not autonomy, but prestige. Naturally, it would take a major incentive, or incident, for these farmers to redirect their attention to the soil.

Conclusions

Do farmers still know what they are doing? Based on the previous discussion, the answer seems clear: no, they do not—and that is part of the problem. Under an advisory regime that ignores any non-numerical input, the farmer has basically no choice but to accept the DungPro printout and to follow its instructions. Furthermore, preoccupation with the latest machinery keeps most farmers from thinking about their fateful situation. Of course, a farmer may choose to distrust the experts' recommendations, but that leaves him with the dreary task of figuring it out for himself. In their book on the history and future of the soil, John Seymour and Herbert Girardet repeatedly note that farmers are heeding scientific advice while at the same time feeling uneasy about it.[72] At first glance this may look like irrational behavior—until one considers the available alternatives. If farmers are heeding advisors' recommendations, this is not due to the aura of scientific expertise or ignorance about the narrow approach the experts are taking. In many cases, farmers simply trust experts because they have little choice.

Of course, the experts themselves favor a completely different narrative. Members of the scientific establishment routinely point out that the systematic use of scientific knowledge brought productivity to unprecedented levels, making the fear of starvation generally unknown in Western society. Responding to environmental critics, a publication of the federal department of agriculture in 1980 defended the use of mineral fertilizers as follows: "Modern industrial society, blessed with a surplus of food, oftentimes forgets that without mineral fertilizer we would still be dependent on the vagaries of weather in our food supply, making frequent starvation crises inevitable."[73] It would be tempting to counter this argument by pointing to its ideological function—but such a response would adhere to a discursive pattern that environmental historians should question rather than underscore. Recent debates about agriculture frequently follow a strictly dichotomous pattern: one group talks about production, another group talks about the environmental toll, and both groups depict each other's line of reasoning as mere ideology. Breaking this stalemate requires a third perspective and it is the contention of this essay that a history of agricultural knowledge may provide such a perspective. It shows that the dichotomy between the two narratives is deceptive; the real issue should be the discursive pattern that *created* these distinct narratives. The question is not whether to side with the experts or their counterparts. Instead, we should be asking: Who is the expert, since when, and for what reason? When agricultural scientists pit their own expertise against the concerns of environmentalists, as the department of agriculture did in its apology for mineral fertilizers in 1980, it is only through a closer investigation of their claim to expertise that one can reveal the pitfalls of their argument. Productive agriculture does need scientific knowledge, but it does not need a constrained conception of soil fertility. In fact, a more comprehensive approach to soil fertility may be the truly productive path in the long run.

Therefore, a history of agricultural knowledge in the twentieth century should avoid both celebration of scientific progress and nostalgia for besieged indigenous knowledge. Both narratives have a point—and both narratives fail to grasp the story in its full complexity. Of course the agricultural sciences allow us to describe and predict processes in the soil more precisely than ever before. However, that raises the question of why so much of this scientific skill is lost in the daily routine of fertilizer use. Furthermore, while it is critical to note that the dominant system of knowledge increasingly pushed the farmers' experiences to the margins, that does not mean that a system of agricultural knowledge based primarily on the farmers' experience and intuition would produce higher yields. In fact, it is interesting that these conflicting narratives agree on one highly dubious point; they depict the rise of "scientific agriculture" in the twentieth century as a strangely monolithic process without actors, key decisions or alternatives. Exposing this notion as an ideological construct must be a key goal of a history of agricultural knowledge in the twentieth century.

In his monograph on the knowledge society, Nico Stehr notes that such a society differs from previous ones because its structure is to a greater extent the result of social action. "It is a society," Stehr explains, "where 'secondary' nature is vastly more important that 'primary' nature."[74] An environmental historian will read such a statement with a sense of alarm: What happens if the rules of the knowledge society are at odds with the dynamics of nature? From such a point of view, the agrarian knowledge society looks like a runaway steam train—a system of knowledge with a vast impact on nature and little room for feedback. The prospect of this situation is all the more reason to put the current system of agricultural knowledge under close scrutiny, something that people such as Renate Künast, who became Minister of Agriculture in the wake of the mad cow disease crisis in early 2001, have conspicuously failed to do. So far, reforms have concentrated for the most part on financial incentives and legal prohibitions, an approach that seeks to modify our current system of agricultural production without asking the most basic question: How do we make sure that the key pillars of the agrarian knowledge society remain in sync with the laws of nature? At present, it seems likely that the new system of agricultural knowledge will marginalize the experiences of farmers in the same way the old one did.

A recent publication on the future of sustainable agriculture urged the state to abandon its penchant for detailed rules and regulations. "The state should not command modes of production in a direct way," the authors wrote; instead, the state should concentrate on formulating some general guidelines and leave it to society to come up with concrete proposals.[75] In short, their call was for experimentation and an open exchange of ideas—and, most importantly, for a public discussion that reaches beyond established circles of experts. Perhaps a history of agricultural knowledge can make a significant contribution to such a discussion; after all, such a history can reveal the traditions, practices and lines of reasoning that so far have constrained our chances for an open discussion of the present and future of agriculture. Not least, such a history can reveal the path that led to the current silence on the issue: one group talks about production and another one about environmental problems, and both groups cherish their stereotypes of each other more than an open dialogue. One thing is clear: if we are to move towards an agriculture that is both productive and sustainable, we will require ideas and insights from both groups. No doubt this vision demands a great deal from all parties involved. But it also provides all parties with the kind of broad-based vision that is painfully missing in current clashes over agricultural "rights" and "wrongs." And perhaps this vision will even free researchers in the field from their constant flirtation with cynicism.

Notes

1 Carolyn Merchant, *The Columbia Guide to American Environmental History* (New York, 2002), 206.

2 John R. McNeill, *Something New Under the Sun: An Environmental History of the Twentieth-Century World* (London, 2000), xxiii.

[3] For an overview, see Frieder Thomas and Rudolf Vögel, *Gute Argumente: Ökologische Landwirtschaft*, 2nd ed. (Munich, 1993). On an international scale, see Jason Clay, *World Agriculture and the Environment: A Commodity-by-Commodity Guide to Impacts and Practices* (Washington, 2003).

[4] Alexander Gerber, Volker Hoffmann and Michael Kügler, "Das Wissenssystem im ökologischen Landbau in Deutschland. Zur Entstehung und Weitergabe von Wissen im Diffusionsprozeß," *Berichte über Landwirtschaft* 74 (1996): 591–627, here 608; Götz Schmidt and Ulrich Jasper, *Agrarwende oder die Zukunft unserer Ernährung* (Munich, 2001), 111.

[5] Hermann Priebe, *Die subventionierte Unvernunft. Landwirtschaft und Naturhaushalt* (Berlin, 1985); Volker Angres, Claus-Peter Hutter and Lutz Ribbe, *Bananen für Brüssel. Europa – wie unsere Steuern vergeudet werden* (Munich, 2000).

[6] For an overview of current approaches, see Daniela Münkel, ed., *Der lange Abschied vom Agrarland. Agrarpolitik, Landwirtschaft und ländliche Gesellschaft zwischen Weimar und Bonn* (Göttingen, 2000).

[7] E.g. Günther Thiede, *Die grüne Chance. Landwirte zwischen Tradition und Fortschritt* (Frankfurt/Main, 1992), 10.

[8] Achim Landwehr, "Einleitung: Geschichte(n) der Wirklichkeit," in *Geschichte(n) der Wirklichkeit. Beiträge zur Sozial- und Kulturgeschichte des Wissens*, ed. Achim Landwehr (Augsburg, 2002), 9–27, here 15.

[9] For an overview, see Nico Stehr, *Arbeit, Eigentum und Wissen. Zur Theorie von Wissensgesellschaften* (Frankfurt, 1994), 26ff.

[10] Helmut Willke, "Organisierte Wissensarbeit," *Zeitschrift für Soziologie* 27 (1998): 161–177, here 162.

[11] Stehr, *Arbeit*, 201.

[12] Ibid.

[13] See Landwehr, "Einleitung," 17.

[14] See Stehr, *Arbeit*, 16.

[15] Joachim Ziche, *Das gesellschaftliche Selbstbild der landwirtschaftlichen Bevölkerung in Bayern. Eine empirische Untersuchung*, Bayerisches Landwirtschaftliches Jahrbuch, vol. 47, special edition 2 (Munich, 1970) 112.

[16] Johannes Knecht, *Das Jahr des jungen Landwirts. Ein Lehr- und Handbuch für den landwirtschaftlichen Berufsschüler und Landwirtschaftslehrling*, 2nd ed. (Stuttgart; Ludwigsburg, 1949), 26.

[17] See Verena Winiwarter, "Landwirtschaftliches Wissen vom Boden. Zur Geschichte der Konzepte eines praktischen Umgangs mit der Erde," in *Erde*, ed. Bernd Busch (Cologne, 2002), 221–232; Ernst Ehwald, "Entwicklungslinien in der Geschichte der Bodenkunde vom klassischen Altertum bis zum 18. Jahrhundert," *Albrecht-Thaer-Archiv* 6 (1962): 95–110.

[18] See Ursula Schling-Brodersen, *Entwicklung und Institutionalisierung der Agrikulturchemie im 19. Jahrhundert. Liebig und die landwirtschaftlichen Versuchsstationen*, Braunschweiger Veröffentlichungen zur Geschichte der Pharmazie und der Naturwissenschaften 31 (Stuttgart, 1989); George E. Fussell, *Crop Nutrition. Science and Practice before Liebig* (Lawrence, 1971).

[19] Hans Schlange-Schöningen, *Das Wirtschaftsjahr des praktischen Landwirts* (Berlin, 1931), 83.

[20] W. Jahn-Deesbach, "Aufgaben und Probleme der Gründüngung im modernen Ackerbau," in *Bodenfruchtbarkeit ohne Stallmist?* ed. Ruhr-Stickstoff AG, Landwirtschaftliche Schriftenreihe Boden und Pflanze 12 (Bochum, 1965), 27–59, here 35.

[21] Herbert Kuntze and Wolfgang Voss, *Statusbericht Düngung*, Schriftenreihe des Bundesministers für Ernährung, Landwirtschaft und Forsten, Reihe A: Landwirtschaft—Angewandte Wissenschaft 245 (Münster-Hiltrup, 1980), 6.

[22] Wolfgang J. Mommsen, *Die Urkatastrophe Deutschlands. Der Erste Weltkrieg* (Stuttgart, 2002), 93.

[23] E. Langenbeck, *Zur Berufswahl des Landwirts*, Flugschriften der Deutschen Landwirtschafts-Gesellschaft 17 (Berlin, 1921), 8.

[24] See Margit Szöllösi-Janze, *Fritz Haber 1868–1934. Eine Biographie* (Munich, 1998).

[25] See Kuhn, "Landwirtschaftliche Produktion im Zeichen der Düngernot," *Mitteilungen der Deutschen Landwirtschafts-Gesellschaft* 35 (1920): 346–352, here 347.

[26] Dr. Smalakies, *Die Bedeutung der Kunstdünger für den Wiederaufbau der deutschen Landwirtschaft* (Berlin, 1921), 7.

[27] Schlange-Schöningen, *Wirtschaftsjahr*, 23.

[28] Schellenberger, *Zeitgemäße Vorschläge für die Düngung der landwirtschaftlichen Kulturpflanzen*, Arbeiten aus dem Gebiete der sächsischen Landwirtschaft 7 (Dresden, 1924), 17.

[29] Ernst Niggl, *Bedeutung und Anwendung der Kalkdüngung* (Berlin, 1923), 5.

[30] Paul Wagner, "Das Thomasmehl als Frühjahrsdünger," in *Unseren Freunden vom Thomasmehl*, ed. Verein der Thomasmehlerzeuger (Berlin, 1929), 3–6, here 4.

[31] F. Merkenschlager, "Zeitkrise und die sogenannte 'Biologisch-dynamische Düngung,'" *Natur und Kultur. Monatsschrift für Naturwissenschaft und ihre Grenzgebiete* 30 (1933): 121–125, here 123.

[32] H. Glathe, "Vorkommen und Tätigkeit von Mikroorganismen im Boden," in *Handbuch der landwirtschaftlichen Bakteriologie. Band II: Dünger- und Bodenbakteriologie*, 2nd rev. ed., eds. F. Löhnis et al. (Berlin, 1935), 159–629, here 182.

[33] Felix Löhnis, "Bodenbakterien und Bodenfruchtbarkeit," *Die Technik in der Landwirtschaft* 7 (1926): 247–251, here 247.

[34] Felix Löhnis, "Bodenbakterien und Bodenfruchtbarkeit," in *Vorträge gehalten anläßlich der sechsten sächsischen Landwirtschaftlichen Woche in Dresden vom 25.-29. Januar 1926 und des Vortragskursus für praktische Landwirte in Leipzig vom 5.-7. Januar 1926*, Arbeiten aus dem Gebiete der sächsischen Landwirtschaft 14 (Dresden, 1926), 173–183, here 174.

[35] Löhnis, "Bodenbakterien," 251.

[36] Felix Löhnis, "Die Aufgaben der Biologie des Bodens," *Fortschritte der Landwirtschaft* 2 (1927): 241–242, here 242.

[37] Löhnis, "Bodenbakterien," 247; Felix Löhnis, "Untersuchungen über Wirkung und Wert des Wirtschaftsdüngers," *Fortschritte der Landwirtschaft* 3 (1928): 817–821, here 818.

[38] Löhnis, "Aufgaben," 242.

[39] Löhnis, "Bodenbakterien," 251.

[40] Bundesarchiv R 3602 no. 67, Niederschrift der 80. Sitzung über allgemeine Düngerangelegenheiten im Preußischen Landwirtschaftsministerium am 13. Mai 1931, 14; Niederschrift der 81. Sitzung über allgemeine Düngerangelegenheiten im Preußischen Landwirtschaftsministerium vom 13. Mai 1932, 23.

[41] Bundesarchiv R 3602 no. 608, Director of the Biologische Reichsanstalt to the Reichsgesundheitsamt, January 10, 1935.

[42] *Chemiker-Zeitung* 58 (1934): 245.

[43] O. Flieg, "Hände weg von unseren bewährten Düngemethoden!" *Die Umschau. Illustrierte Wochenschrift über die Fortschritte in Wissenschaft und Technik* 37 (1933): 713–715. Similar G. Schnelle, O. Nolte, "Über die sogenannte Reformbewegung für Umstellung der Volkskost," *Fortschritte der Landwirtschaft* 8 (1933): 220–223.

[44] Priebe, *Unvernunft*, 27.

[45] Flieg, "Hände weg," 715.

[46] K. Scharrer, "Die 'biologisch-dynamische' Düngung im Lichte der Agrikulturchemie," *Chemiker-Zeitung* 58 (1934): 245–247, 267–270, here 245.

[47] Flieg, "Hände weg," 715.

[48] Gerber et al., "Wissenssystem," 596.

[49] See Peter L. Galison, "Context and Constraints," in *Scientific Practice: Theories and Stories of Doing Physics*, ed. Jed Z. Buchwald (Chicago; London, 1995), 13–41.

[50] Paul Wagner, *Anwendung künstlicher Düngemittel*, Thaer-Bibliothek 100, 7th ed. (Berlin, 1920), 32.

[51] Gustav Höppner, *Die Kunstdüngemittel und ihre Anwendung in der modernen Landwirtschaft*, Löbes Landwirtschaftliche Bibliothek, vol. 28/29 (Leipzig, 1911), 114.

[52] Friedrich Hartmann, *Kalkfibel in Frage und Antwortstil* (Coburg, n.d. [1930]), 27.

[53] E.g. Arbeitsgemeinschaft der deutschen Stickstoff-Industrie für das landwirtschaftliche Beratungswesen, *Düngungsratschläge für den Bauernhof*, 2nd ed. (Berlin, 1937), 57.

[54] Höppner, *Kunstdüngemittel*, 107.

[55] Max Gerlach, *Langjährige Feldversuche über die Wirkung der Kalisalze auf Sandböden*, Landwirtschaftliche Lehrhefte 5 (Berlin, n.d. [1911]), 3.

[56] Johannes Schneider, "Düngung," in *Praktisches Handbuch der Landwirtschaft*, ed. Johannes Schneider (Reutlingen, 1924), 53–94, here 56.

[57] J. König, *Die Ermittlung des Düngerbedarfs des Bodens* (Berlin, 1929), 11–13.

[58] Hermann Stremme, *Grundzüge der praktischen Bodenkunde* (Berlin, 1926), 40.

[59] See Günter Jacobs and Theo Remmersmann, "Erst untersuchen, dann düngen," *Landwirtschaftliches Wochenblatt Westfalen-Lippe* 31 (July 31, 2003): 32–34.

[60] Günther Schilling, *Pflanzenernährung und Düngung* (Stuttgart, 2000), 294.

[61] Ibid., 294, 299.

[62] Eilhard Alfred Mitscherlich, *Ein Leitfaden zur Anwendung der künstlichen Düngemittel*, 2nd rev. ed. (Berlin, 1931), 11–14.

[63] Eilhard Alfred Mitscherlich, *Erkenntnisse bei der Pflanzendüngung. Ein Festvortrag zur Feier des 250jährigen Bestehens der Deutschen Akademie der Wissenschaften zu Berlin*, Deutsche Akademie der Wissenschaften zu Berlin, Vorträge und Schriften, issue 44 (Berlin, 1952), 7.

[64] Jacobs and Remmersmann, "Erst untersuchen," 32.

[65] For the recent interest in trust as a historical phenomenon, see Ute Frevert, ed., *Vertrauen. Historische Annäherungen* (Göttingen, 2003).

[66] For a telling illustration of this line of reasoning, see Ulrich Planck, "Die Landwirtschaft in der Industriegesellschaft und die Industrialisierung der Landwirtschaft," *Zeitschrift für Agrargeschichte und Agrarsoziologie* 33 (1985): 56–77.

[67] See Theo Remmersmann, "Der Computer hilft bei der Düngeplanung," *Landwirtschaftliches Wochenblatt Westfalen-Lippe* 4 (January 22, 2004): 28–30.

[68] W. Endres, "Maschinentechnische Hilfsmittel des Landwirts," in *Die Technik in der Landwirtschaft*, ed. F. Christoph (Berlin-Schmargendorf; Leipzig, 1926), 256–288, here 256.

[69] Hans Schlange-Schöningen, *Rationalwirtschaft und Nationalwirtschaft. Betrachtungen eines praktischen Landwirtes* (Berlin, 1927), 42.

[70] Thiede, *Chance*, 65.

[71] Reiner Mohn, "Gesetzmäßigkeiten wirtschaftlichen Entscheidens und Handelns," in *Betriebslehre*, 7th ed., eds. Erwin Reisch, Gerhard Knecht and Julius Konrad (Stuttgart, 1995), 103–142.

[72] John Seymour and Herbert Girardet, *Fern vom Garten Eden. Die Geschichte des Bodens. Kultivierung—Zerstörung—Rettung* (Frankfurt, 1985).

[73] Kuntze and Voss, *Statusbericht Düngung*, 1.

[74] Stehr, *Arbeit*, 218.

[75] Schmidt and Jasper, *Agrarwende*, 166.