Towards a General Theory of Agricultural Knowledge Production: Environmental, Social, and Didactic Learning

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Abstract

Social scientists and input producers alike have seen farmer decision making as driven by environmental learning based on experimentation and empirical observation. A more robust body of theory influenced by behavioral ecology sees a major role for social learning based on emulation of models selected on social criteria, although the relationship between these learning modes is not well understood. But a larger problem is that these perspectives ignore what is here termed didactic learning, whereby various parties bring instruction to the farm. Although not previously theorized, didactic learning is often crucial in agricultural learning and also distinct because it is driven by off-farm interests. The outline of a general theory of farmer learning is presented, comprising an analysis of the salient characteristics of the three modalities and consideration of interaction among them. The successes of nonindustrial small farm management notwithstanding, there are serious limitations to the experimental basis of environmental learning. Agriculture is particularly suited to formal experimentation, but only because of simplifications that contradict the nature of actual decision making. Social learning is essential in agriculture but it may become maladaptive when environmental learning is particularly challenged. Among the entities involved in didactic learning are the state (with interests in monitoring and control), input developers and sellers (with interests in sales), and Non Governmental Organizations (with interests in media showing impacts of didactic learning). [agriculture, political ecology, farmer knowledge, technology adoption, agricultural extension, farmer learning]

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In the midst of a study of India's controversial first GM (genetically modified) crop—cotton containing Monsanto's "Bollgard" trait—a Monsanto executive emailed me concerning the surging number of farmers adopting the new seeds. "Like the adoption of any new technology," she wrote, "people planted [it] on smaller acres initially, but the ever-increasing Bollgard plantings demonstrate that the Indian farmer is willing to embrace a technology that delivers consistent benefits" (Stone 2007:67).

This model of the experiment-conducting environment-observing farmer is well entrenched, first enshrined in Ryan and Gross's classic study of hybrid corn in Iowa where farmers insisted on "experimentation before complete acceptance" (1943:18). Models of adaptiveness and experimentation in farmer learning have flourished in anthropology since the 1970s (Bentley et al. 2010:129–130). The landmark volume *Agricultural Decision Making* (Barlett 1980a) was based on the proposition that small farm patterns "are the consequence of long- and short-term adaptations based on observation and experimentation" (Barlett 1980b:3–4). Following key works by Bennett (1982), Brokensha et al. (1980), Ellen (1982), Richards (1985, 1986), and others, Richards wrote that the "experimenting, innovative, adaptive peasant farmer is now accepted as the norm" (1989:20). By 2000, Ellen and Harris (2000:4–5) would write that indigenous knowledge had been elevated "to a remarkable (some would say alarming) degree."

Unfortunately, this "alarming" enthusiasm left a blind spot for how learning could be non-experimental or even maladaptive. Indeed, the adaptive experiment-based model of farmer learning certainly clashed with what I was seeing in Warangal District, Andhra Pradesh.[1] If farmers were really basing adoption decisions on experimentation, why were they being blitzed at every turn by cotton seed ads on walls, in trees, and blaring from loudspeakers? Why were they asking input shop owners which cotton seeds to buy? Why were they showing herd behavior and planting whole

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fields to untried seeds that only recently appeared on the market? Clearly, *environmental learning*—observing and basing decisions on empirical payoff information from experiment—was not the only factor driving their behavior. In the key issue of seed choice, it was not even a major factor.

Some scholars have balanced environmental learning with the more purely social aspects of adaptation. Writers influenced by Boyd and Richerson's (1985) "dual inheritance" model of cultural evolution give a formal role to *social learning*, whereby individuals emulate models based on social criteria rather than payoff information. This perspective analyzes the processes by which social learning occurs, especially "transmission biases"[2] that shape how emulative models are chosen. Henrich (2001:992) argues that social rather than environmental learning is "the predominate force in behavioral change."

However, even this more synthetic perspective whisks from view a crucial third set of forces in farmer decision making. The Indian farmers were awash in influence from parties external to the farming community. These parties were driven by their own vested interests, and heeding their advice was quite different from empirical observation of cotton fields or emulating a local model.

External parties with vested interests were right there in Ryan and Gross's Iowa cornfields, acknowledged in publications but ignored in the theory building: seed salesmen were the leading source of early information on hybrid seed, and state extension agents promoted hybrid corn and disseminated favorable test plot results (Ryan and Gross 1943:16). These parties were just the tip of the iceberg: colonial officers, agricultural consultants, agricultural engineers, farmer field schools, environmental activists, measurement-minded bureaucrats, regulatory authorities, book authors, Non Governmental Organizations (NGOs), and organic schemes all tell farmers how to farm. These off-farm sources of advice, information, and exhortation are all agents of *didactic learning*, neglected in social/environmental learning models. Agricultural didacts' methods and agendas vary, but they comprise a conceptually coherent category in agricultural knowledge production, distinct from environmental and social learning because they introduce off-farm interests. Whether to sell products, make farming practices legible, achieve public recognition, or please funders, their interests are never fully aligned with the farmers'. Theorizing farmer decision making while neglecting external sources leaves an oddly apolitical perspective.

The following offers a framework for a general theory of agricultural knowledge production, with particular concern for small-scale farming, based on this tripartite model of learning modalities. It does not champion one process as predominant; even within one population of farmers in one place and at one time, the forces driving learning can vary by crop and situation. Rather it examines the salient characteristics of all three modalities—particularly the challenges to agricultural experimentation that impede environmental learning, the potential for social learning to lead to herding, and the divergences between didacts' and farmers' interests—and explores the relative importance of each and their interactions under various circumstances. In this analysis, I do not contrive to distinguish between "learning" and "decision making" which are often simultaneous: at any given moment, the farmer may opt to behave in accordance with past observations, pick a role model, or accept advice from outside the community. Indeed most major studies model decision making as inextricable from ways of learning (e.g., Barlett 1982; Nazarea-Sandoval 1995). I rely mainly on the "learning" terminology for consistency with the extant literature.

Environmental Learning

Central to environmental learning on the farm is the problem of experimentation. We will consider general challenges to experiment-based learning, then specific factors affecting situational variability in experiment-based learning. Lastly we will consider experimentation in formal research, which bears directly on social and didactic learning.

The Problem of On-Farm Experimentation

The reality of farmer experimentation is complex and poorly understood (Bentley 2006:451). Two key features of agriculture are that (1) farmers *do* experiment all the time, but that (2) most key aspects of farming are too complex, dynamic, and uncontrollable for *effective* experimentation.

Livestock and crop production involve hundreds of species interacting with changing environments. Managing these incompletely controlled factors is further complicated by the wide range of technologies that have direct and indirect, short- and long-term, predictable and unpredictable effects that vary in time and space. Even before considering complicating economic and social factors, the ecology of farming is a nightmare for controlled-variable experimentation.

But the farm also has economic variables that can trump agroecological conclusions, as solutions from one year are ineffective the next. Smallholder agriculture adds a vital social level, as labor is often mobilized through local social institutions rather than with cash. Indeed, Netting (1993) argues that sustainability in smallholder farming depends on social formations as much as on any land-use tactic.

With these layers of uncontrolled variables, all but the simplest farm experiments normally have serious confounds. Moreover, each "experiment" involves production on which the farmer's livelihood depends, which militates against setting it up simply to generate knowledge. Devoting land and labor to an experimental treatment that may fail is perilous, so most farm experiments are not proactive but reactive (Sumberg and Okali 1997). After reviewing experiments by African cultivators, Sumberg and Okali (1997) concluded that individual experiments are rarely novel or useful. Even when lauding farmer experimentation, Paul Richards' (1989) examples are mostly for simple variables such as germination rate (which farmers can gauge by mixing a sample of seeds with moist soil). Fertilizer tends to be more amenable to controlled experiment, and Bentley et al. (2010) describe a farmer's controlled fertilizer experiment. The experiment did not deserve the scorn it earned from the local extension agent, but it was limited to one crop on one soil type in one year.

Farmers experiment with the social components of production too, but these experiments are as hard to design as agroecological experiments. Johnson gives the example of the Yombe farmer who "argued that it might be more efficient to allot his wives responsibility for different rows in the same field than to allot them different fields in the traditional manner, and his experiment served to convince him he was right" (Johnson 1972:155). But this farmer's agro-social experiments were extremely limited because he could not, for the sake of a single datum on labor efficiency, interdict strict norms on gender, age, or status.

Environmental learning obstacles are somewhat mitigated by the visibility of farm operations, allowing collection of payoff information from neighboring farms. Yet these observations, even when augmented by information from other farmers, are usually hampered by incomplete knowledge of other farmers' inputs and practices (Conley and Udry 2001; Maertens and Barrett 2013:354).

Situational Variation in Environmental Learning

Beyond these general challenges, environmental learning varies with specific situations. On one hand is a record of experiment-based farmer ingenuity and success with integrated pest management (Bentley et al. 1994; Lansing 1991; Thurston 1992), disease control (Thurston and Parker 1995), indigenous breeding (Cleveland and Soleri 2002a; Nuijten et al. 2009), and intricate adjustments of labor mobilization to crop ecology (Stone et al. 1990). But there are myriad examples of non-learning: maize farmers baffled by crop diseases (Bentley 1989), rice farmers indiscriminately spraying pesticides (Vayda et al. 2004), millet farmers not knowing which hybrids they had in their fields (Tripp and Pal 2000:136), and even educated U.S. farmers duped by seed marketing (Smith 2010:21; Ziegenhorn 2000). The Warangal cotton farmers were a particularly striking case of impeded environmental learning. The farmer in Figure 1 is displaying two seed brands he purchased specifically to plant as a controlled comparison. Unbeknownst to him, they were exactly the same seed, marketed as different brands. The problem lies

Figure 1.
Warangal farmer showing what he thought were the two different seeds to be compared in the field. The small print in English, which he could not read, indicated both were the seed NCS-207-Bt. This seed was marketed under four brand names that year. Photo credit: G.D. Stone.

not with the farmer but with conditions of input supply; the man was not the village dunce, just a farmer confronting an opaque inputs market that obstructed environmental learning. The question for a general theory of agricultural learning is what conditions work for or against environmental learning.

The first part of the answer is *observability*—the extent to which payoff information is even visible to farmers. Thus, peasant farmers in Honduras "know more about plants, less about insects, and less still about plant pathology" largely due to differences in observability (Bentley 1989:25). (Observability may be shaped by local beliefs; Bentley points out that a belief in spontaneous generation leaves farmers less observant of insect reproduction.) Brush (1992) too found that even among long-time potato cultivators in the Andes, indigenous taxonomy of plant disease is poorly developed. Studies have found little or no indigenous knowledge of the causes of plant diseases, even among farmers with deep knowledge of other aspects of agronomy (Bentley and Melara 1991; Bentley and Thiele 1999).[3]

The Warangal cotton study theorized three impediments to environmental learning beyond simple observability (Stone 2007). First is *inconsistency* of a technology's effects, referring to qualities that become apparent only under special circumstances (Tripp 2001a) or that change through time as a result of factors that are hard for farmers to monitor (Sillitoe 1998:225). For example, the effects of insecticides on target and predator species vary from year to year, leading to insecticide resistance and fluctuations in insect populations. Second, *unrecognizability* refers to various types of "identity confusion" (Tripp 2001b) (Figure 1), a problem often exacerbated by marketing. Indian farmers had trouble distinguishing among different generations of Green Revolution wheats and more recently among GM cotton technologies. The problem is hardly unique to developing countries: American seed companies marketed hybrids under multiple "aliases" so that farmers did not know which seeds were identical or different (Kloppenburg 2004:107; Ziegenhorn 2000). Third is *overly rapid rate of change*: technology trialing takes time, so even when a technology is consistent and is recognizable, farmer assessments may not keep up with technological change. In Warangal, cotton brands poured into the market by the dozens and often lasted only a few years, contributing to a pattern of farmers careening from seed to seed (Stone et al. 2014). The cumulative result of these disruptions was *agricultural deskilling* specifically in cotton farming (the same farmers had better knowledge of the properties of rice seeds which offered greater consistency, recognizability, and moderate pace of change). Factors affecting the "learnability" of agricultural technologies and phenomena should be added in future research but this provides a set of foundational components specific to agriculture.

Formal Experimentation

Agriculture is as amenable to formal experimental research as it is resistant to actual farmer experimentation; in fact, standards of research design and basic statistics were developed in agricultural research. As early as the 1830s, a research program at Rothamsted, England, was running controlled trials in test plots, data from which later provided the basis for R.A. Fisher's (1935) seminal work on parametric statistics and the theory of experimental research design and randomized trials. Yet such experimental control contradicts the nature of farming as sketched above; the process of making something visible and studiable also renders it fundamentally different from agriculture in practice. Latour (1983:146) makes this point with Pasteur's research on livestock disease:

> [Pasteur] is the master of one technique of farming that no farmer knows, microbe farming. This is enough to do what no farmer could ever have done: grow the bacillus in isolation and in such a large quantity that, although invisible, it becomes visible. Here again we have, because of laboratory practice, a variation of scale: outside, in the "real" world, inside the bodies, anthrax bacilli are mixed with millions of other organisms with which they are in a constant state of competition. This makes them doubly invisible. However, in Pasteur's laboratory . . . it is freed from all competitors and so grows . . . visible to the watchful eye of the scientist. . .
>
> The translation that allows Pasteur to transfer the anthrax disease to his laboratory in Paris is not a literal, word-for-word translation. He takes only one element with him, the micro-organism, and not the whole farm, the smell, the cows, the willows along the pond or the farmer's pretty daughter.
>
> . . . But this version of the translation is still a weak one. In Pasteur's laboratory, there is a microbe, but

> anthrax infection is too disorderly a thing to be explained with a single cause only. So the outside interests could as well say that the laboratory has no real bearing on the spread of anthrax disease, and that it is just plain arrogance for a scientist to claim that he holds the key to a real disease "out there". . . .

The goal of agricultural experimentation is to isolate the subsystems of farming to develop products to sell to farmers, not to understand agriculture as a whole. Given the trouble with real-farm experimental learning, it should not surprise us that products bought by farmers may or may not benefit them in the long run (Stone and Flachs 2014). As argued below, adoption of the marketable products emanating from formal research is often aided by social and especially didactic learning.

Social Learning

Social learning is a hallmark of our species, even if it is apes that are eponymous for emulating behavior. Primate researchers studying social learning have assigned the term a thicket of changing and overlapping meanings (Whiten et al. 2004:38); likewise, psychologists use social learning models of cognitive processes while sociologists and economists cite various forms of social learning in innovation adoption (Rogers 2003). I use the term here as defined in Boyd and Richerson's (1985) work in behavioral ecology, where it is clearly and productively theorized, becoming a foundational concept in research on decision making (e.g., Henrich 2002; Henrich and Gil-White 2001; McElreath 2004; Stone 2007). Social learning refers to choosing behavioral models on social criteria—on who the models are, how many of them there are, or some other social standard rather than on payoff signals from their farming practices. Conceptually there is a key difference between copying Farmer X because his crops are productive and because he has high status. But while the distinction is valuable in building theory, in practice the two modalities may not cleave neatly (Stone 2007:71). Farmer X may be observing payoff information on a seed, but his decision to even try it may have been influenced by seeing a high status farmer grow it, and his interpretation of its performance may be influenced by what other farmers are saying about it. Thus environmental and social learning may penetrate each other.

The question of what criteria are used in selecting models for emulation is central to a theory of farmer behavior. Behavioral ecologists define two fundamental mechanisms of choosing social learning models: prestige bias and conformist (or frequency-dependent) bias (Boyd and Richerson 1985). Under prestige bias, "people copy ideas or practices from *individuals* [emphasis original] with specific qualities" (Henrich 2001:997). Henrich and Gil-White (2001) and Stone et al. (2014), among others, argue that people often copy behaviors and opinions from prestigious models that had nothing to do with generating the models' prestige. However, we must broaden this because social learners emulate not only *individual*s but social *groups*, as farming behaviors may move along gender lines (as with manioc farmers in the Peruvian Amazon; Boster 1986), or within ethnolinguistic groups (as with maize farmers in Chiapas; Perales et al. 2005), or between castes (as with cotton farmers in Warangal; Flachs 2016; Stone et al. 2014).

Under conformist bias, "humans preferentially imitate ideas and behaviors that are expressed by a majority of the group over traits expressed by the minority" (Henrich 2001:997). Many analyses assume that the "frequency of a trait among the individuals within the population provides information about the trait's adaptiveness" (Henrich and Boyd 1998:219). Boyd and Richerson argue that in spatially varying environments, emulating the most common behavior exhibited locally tended to lead to adaptive beliefs and values, and Henrich and Boyd (1998) used simulations to conclude conformist learning to be adaptive under a very broad range of conditions.

Yet conformist bias may be maladaptive, particularly when it leads to cascades. A farmer considering a technology or practice may be indifferent to a local plurality of 25 percent using it, but may readily adopt if the number is 75 percent. Each farmer who follows conformist bias to join the crowd enlarges the crowd and further promotes conformist bias. Economists model this self-amplifying process as an information cascade (Bikhchandani et al. 1998) or "recursive bandwaggoning" (Abrahamson 1991).

When a cascade is ephemeral, it is a fad. In Rogers' (2003:230) classic work on innovation adoption, fads are defined as "innovations that represent a relatively unimportant aspect of culture, which diffuse very rapidly, mainly for status reasons, and then are rapidly discontinued." With agriculture, this is wrong on two counts. Fads are always propelled in part by conformist bias, not simply the status or prestige Rogers cites. Moreover, fads may occur with behaviors of utmost importance in the running of a farm, especially when environmental learning fails. The Warangal cotton growers were an extreme case of impeded environmental learning producing fads, but agricultural history is littered with fads—even though they are downplayed because they challenge narratives of input producers and admirers of indigenous knowledge. The United States saw fads for Merino sheep in the 1800s; electroculture, charcoal fertilizing, and soil analysis in the early 1840s (Rossiter 1975:7; 114–133); hen fever in the 1850s (Burnham 1855); silkworms and hops in the 1860s; Belgian hares in the 1970s (Guinn 1904); and so on.[4] These were large-scale fads; unrecorded were thousands of local fads.

While we can identify social conditions that promote emulation, the reverse is not simply the lack of emulation. At the opposite end of the continuum is *aversion*, a social learning process by which farmers avoid objects or practices due to negative bias, potentially overriding environmental payoff signals. European farmers snubbed the productive and eminently edible potato in part because it was the staple of uncivilized American Indians and the backward Irish (Pollan 2001:199–200). In India, activists may adulate seed saving by farmers, but prosperous upper-caste Warangal farmers express pride at buying their seeds from the market, differentiating themselves from the seed-saving poor.

Social and Environmental Learning

Some role for both environmental and social learning is indispensable in agriculture. Given agriculture's complexity and the limitations to experimentation, no farmer could learn to operate a farm exclusively by observing payoff information. Emulating prestigious models and/or local trends provide a starting point, baseline, and safety net. This is not to say that the practices that become common are necessarily "optimal"; in fact, optimal practice is a problematic concept given that different groups of people often manage farms completely differently within the same environment.[5]

A key relationship between these two modalities is that as environmental learning becomes more costly and/or inaccurate, farmers rely increasingly on social learning (or didactic learning, below) (McElreath 2004; Richerson and Boyd 2005:13–14). In the Warangal case, where environmental learning was extraordinarily difficult, there was hyper-reliance on social learning and particularly conformist bias. Farmers routinely reported knowing little about the seeds they were buying except that they were popular that year, which led to remarkable seed fads (Stone 2007; Stone et al. 2014). Some farmers recognized the maladaptiveness of social learning running amok; one mordantly cited the Telugu expression that translates to "When one goat jumps down the well, all the goats jump down the well." Henrich and Boyd (1998:219) see conformist transmission as a force that "tends to establish and maintain cultural norms" but a lesson here is that unless informed by environmental learning, conformist transmission can generate fads rather than maintain norms. Indeed, subsequent studies of conformist transmission in India showed seed fads to cycle rapidly and regularly (Stone et al. 2014).

Didactic Learning

We have examined the inherent problems in environmental learning and the potentially maladaptive role of social learning in agriculture. But at least these problems are relatively free of external interests; the farmer's interest is in the farm prospering, the high-prestige models do not necessarily strive to be copied, and "the crowd" has no particular interest in expanding.

However, enter the panoply of external parties with potential interests in farmer decision making. Agriculture is big business, it is endlessly variable, it produces a copious flow of economically and culturally important products, and it has a seemingly unlimited capacity for absorbing inputs—all of which open niches for external interests in farmer behavior. Whether external parties pursue their interests through instruction, demonstration, exhortation, advertising, regulation, coercion, adulation, or shaming, farmers whose practices result from such interventions are engaged in didactic learning. Agricultural didacts are diverse but distinctive, acting primarily out of their own interests while claiming to act in the farmer's interests. We can recognize patterned interest bundles associated with commercial, governmental, and NGO interests, if we allow for some overlap in these categories.[6]

Commercial Didactics

We have noted that the main strength of formal experimentation in agriculture is the development of marketable products. Unsurprisingly, such research has always been complicated by, if not driven by, the profit motive. Formal agricultural science began to grow after 1840, with Justus von Liebig's influential laboratory research on agricultural chemistry (von Liebig 1840; Rossiter 1975) and John Lawes' field experiments at Rothamsted. Liebig himself promptly went into the fertilizer business once he identified potentially marketable fertilizers (Rossiter 1975:44). John Lawes did too; he was fixated enough on the commercial potential of his research to cancel his honeymoon to set up a factory to produce "Lawes Artificial Manure" (Dyke 1993). Agricultural histories cite academic chemist William Crookes' famous 1898 speech to a British scientific association as a clarion call to boost supplies of fixed nitrogen (Smil 2001:58–60); less well remembered is that Crookes too was in the fertilizer business (Leigh 2004:16). Those hybrid seeds that Ryan and Gross studied were the result of experimental breeding methods explicitly selected for their potential to establish property rights over seeds with commercial potential (Kloppenburg 2004:101–102).

In some cases, the process of conducting formal research on such products itself serves a didactic function. As Maat and Glover (2012:133) point out, field trials may be designed as much to market to farmers as to generate information for researchers.

Didacts in general claim to benefit the farmer, but commercial didacts characteristically make this case with reference to the free market and the presumption that farmers adopt only products that benefit them (as we saw in the Monsanto correspondence above). However, farmers often cannot foresee long-term or even medium-term impacts of technologies; adoption decisions are biased toward the short term (Stone and Flachs 2014), and agricultural faddism has a long history as noted. Commercial products also have a history of displacing environmental learning with didactic learning. This dynamic has played out with each phase of appropriationism in agriculture (Goodman et al. 1987), as with the 19th-century development of commercial fertilizers leading to a craze for professional soil analysis (Rossiter 1975) and the early 20th-century spread of tractors being linked to the rise of agricultural engineers (see below). It is illustrated in the case of hybrid corn seed in the United States:

> If a farmer was trying to build up a supply of good corn over the period of a few years, which is how selection worked, then there was little reason to buy fresh, unpredictable seed each year. For seed dealers, selection was decidedly a step in the wrong direction. Learning how to systematically select corn kept farmers in control of the crop in a way that buying seed did not... many farmers were quite proud of their ability to increase their own yields by selection. They knew exactly what their corn was and were not at the mercy of seed dealers, who made claims that might or might not be true. (Fitzgerald 1990:71)

Governmental Didactics

States have a long history of telling farmers how to farm, often driven by their interest in monitoring and control. Scott's (1998) *Seeing Like a State* concerns the extreme of didacticism, in which the state not only instructs but compels (with disastrous results). He too shows how state didactics are characteristically presented as being in the farmers' interests.[7]

"Agricultural extension"—normally a service run or encouraged by government for advising farmers—is the most established institution of didactic learning. Extension has traditionally constructed itself with the unproblematic aim of "improving agriculture" (e.g., True 1928). Individual extension agents are generally concerned with farmers' well-being, but they work for services with their own bureaucratic interests, and they trade in technical information generated by scientists with their own interests. Feder et al. (2001) trace public extension's poor performance directly to divergent interests. They note that researchers' performance is often assessed within the scientific community, which leaves them with little interest in opinions from the extension agents and makes for research priorities at odds with extension managers and farmers. There typically "are neither mechanisms nor incentives to make extension services accountable to farmers" (Anderson and Feder 2004:47).

Public extension services also have a history of sharing the interests of input sellers. As the American fertilizer industry grew in the 19th century, state chemists morphed from independent analysts to industry allies, and some land-grant schools were actually supported by fertilizer sales (Giesen and Hersey 2010:275; Marcus 1987). Tractor sales took off in the 1920s in part because of the advent of college agricultural instruction and agricultural engineers who urged tractor adoption to enhance the standing of their profession and to increase order and control on the farm (Fitzgerald 2003:77–82). Agricultural engineers did not always cloak how their interests diverged from farmers'.

Attacking an academic critic who pointed out that tractor adopters would pay more for gasoline than they had for feed, the American Society of Agricultural Engineers insisted that the “more workers any nation can have making labor-saving equipment and the fewer workers using such equipment, the better for the nation and the individual citizen” (Giesen and Hersey 2010:287–288).

Extension often follows its bureaucratic interests by prioritizing large-scale and wealthy farmers.[8] Even when tasked with involving farmer collaborators, participatory research projects chose wealthier men (Brush 2004) and pushed farmers to applaud increased yields —even where boosting yields was not a priority (Bentley et al. 2010:131). Still, extension projects in developing countries routinely claim to have “empowered” farmers (Mosse 2005; Rhoades 1998).

Figure 2.
Surrounded by photos of “success story” images, a staffer at an agricultural NGO shows off a pheromone trap being promoted in a current project. Photo credit: G.D. Stone.

NGO Didactics

Non Governmental Organizations would seem at least potentially better positioned to claim alignment with farmer interests. They generally are not intended to profit from or control farmers; indeed many NGOs as well as land grant colleges in the United States were founded explicitly to aid farmers. Yet NGOs often enjoy a lack of accountability that most states and corporations do not, and there are common contradictions between the interests of farmers and NGOs large and small.

One of history’s largest NGO interventions in agriculture was the Rockefeller Foundation-funded Green Revolution. Although popularly constructed as a change in seed technology, and recognized by scholars as a commercialization project (Ross 1998), the Green Revolution was also very much a didactic program. Asian farmers were exhorted to change management of fertilizer, irrigation, pesticides, and even planting schedules and social aspects of decision making (Lansing 1991). As Cullather (2010) shows vividly, the point was not just to induce farmers to farm differently, but to replace environmental and especially social learning with didactic learning. Beyond the commercial interests were clear geopolitical interests (Perkins 1997).

Divergences in interests may be followed down to small local farm-oriented NGOs. Figure 2 shows the image-filled “media room” in a Warangal rural development NGO that runs didactic farming projects (few of which have had sustained impacts). The images purport to depict farmers adopting and benefiting from the NGO’s interventions—each one a small version of the “success stories” that are “an increasingly important instrument in the competition for policy attention and financial resources” (Sumberg et al. 2012:187).

One of the most discussed didactic interventions in agricultural development circles is the farmer field school, usually run by NGOs. NGO-run field schools may have less investment in selling inputs than commercial didacts, but still are incentivized to generate short-term success stories; this is reflected in the rarity of long-term impact studies (Braun et al. 2006). Even the many short-term impact studies comprise a motley record, with some success mixed with lack of impact (e.g., Larsen and Lilleør 2014). In a rare study of impacts after eight years, Feder et al. (2004) found little change in practices or diffusion of knowledge.

However, when farmer interests are well aligned, results may be impressive. One example (although involving a university rather than an NGO) was from 1980 to 1993 when the convergence of Cold War funding and the arrival of agricultural scholars interested in indigenous practices allowed Honduras’s Zamorano University to work closely with farmers in research on experimentation and knowledge construction (Andrews 2011). This episode had beneficial impacts on pest management by farmers while generating considerable writing on farmer knowledge (e.g., Bentley and Thiele 1999; Bentley et al. 1994; Sherwood 1997).

But with the end of the Cold War, structural reforms of the 1990s, and the rethinking of development priorities, this work atrophied (Andrews 2011:63).

Didactic and Environmental Learning

Didactic learning is often assumed to fill in gaps in environmental learning, but it is often in didacts' interests to undermine environmental learning. With the spread of hybrid corn, farmers who had previously developed landraces and collaborated with public-sector breeders were told, "You may not know which strain to order. Just order FUNK'S HYBRID CORN. We will supply you with the hybrid best adapted to your locality" (quoted in Fitzgerald 1993:339). As environmental learning retreats, didactic learning itself is sold as a commodity, as seen in the booming trade in professional agricultural consulting in the United States (Wolf 1998). Didactic learning is mostly sold to large well-capitalized farms, but there are also examples of "emic didactics" in which environmental learning is propagated noncommercially among small farmers. It was a major conviction of the "farmer first" movement (Chambers et al. 1989; Scoones 1994) that the goal of agricultural programs should be to train and motivate farmers to improve on and spread information about innovations—essentially didactic learning in the service of environmental learning (Bunch 1989). Examples of such are the Honey-Bee Network (Gupta 2012), local-language magazines, and videos devoted to farmer-to-farmer communication (Padre et al. 2003; Van Mele et al. 2013).

Didactic and Social Learning

A salient feature of didactic interventions is entraining social learning to legitimate and popularize technologies and practices. This is done with conformist bias: asked which seed to plant, Warangal shopkeepers often recommend the seed "most farmers are buying." It is also done with prestige bias, as when input producers persuade high-prestige farmers to act as models. This occurred among the Iowa farmers studied by Ryan and Gross (1943); the Iowa Agricultural Experiment Station, after all, funded the study to promote their technologies through more effective didactic learning. The findings on how information spread among categories of farmers was promptly put to use by extension agents in farmer educational programs (Ruttan 1996:56).

The ideotype of the early adopter later elided with that of the "progressive farmer" (Roling 1988). Often provided free inputs, progressive farmer practices are termed "demonstrations," as if they facilitate environmental learning. But prospective customers passing the demonstration field or attending a sponsored on-farm event can only observe a small segment of the relevant payoff information. If the point of demonstration plots were truly to promote environmental learning, there would obviously be no need to recruit high-prestige farmers.

An alternative to influencing the behavior of high-prestige farmers is to manufacture prestige for farmers acting in the didact's interests. In the United States, contests beginning in earnest in the 1890s rewarded farmers for large and uniform corn cobs (Fitzgerald 1993:329) and continued with contests for egg-laying (New Jersey State Agricultural Experiment Station 1922), and on to sustainable farming in Africa (Lusembo et al. 2007).

Conclusions

The first aim here was a better understanding of farmer decision making, theories of which have struggled to move beyond environmental and social learning, thereby neglecting didactics and off-farm interests. The second aim was to consider each learning modality, including salient characteristics, intrinsic obstacles, and contradictions in farmer decision making. The final aim was to offer an introductory account of the interaction among the three learning modalities, providing the scaffolding of a general theory of farmer decision making.

The model of the rational peasant decision maker that crystallized in the 1980s was based on environmental learning and experiment (Barlett 1980b:3–4). This was an important corrective to dismissive misunderstandings of small farmer behavior, and it has continued to be a fruitful perspective; however, it overstates the heuristic value of experimentation and closes off key components in learning. All farmers experiment, but experiments tend to be most instructive on atomized components of the enterprise, with the more crucial aspects of farm management being too complex and uncontrolled for effective experiment. Formal research thrives on atomizing agricultural production by parsing the farm into commodity-friendly subsystems that are incommensurate with actual farm decision making.

Social learning is a core adaptive strategy, indispensable in so complex and variable an enterprise as agriculture. It is usefully theorized as a distinct form of learning although in practice it is entangled with environmental and didactic learning. But it is important that farmers often follow other farmers' signals on grounds other than actual observation of payoff information, especially on the basis of prestige and herd effects. A key interaction between environmental and social learning is that some payoff information normally comes to be reflected in local customary practices: local "received wisdom" almost always contains some payoff-based wisdom. But there is great variability in how payoff information actually affects social learning. Here, "deskilling" situations are instructive, as they help isolate factors impeding environmental learning and also show the results of such impediments.

Remarkably, the modality of didactic learning has been largely ignored among major theories of agricultural learning despite its obvious presence. It is a diverse modality, but in general agricultural didacts are distinct in being driven by off-farm interests while claiming to meet farmer interests. The principal subcategories of commercial, governmental, and NGO didactics each have distinctive features.

Didactic learning articulates with environmental learning in important ways. One of the most important interactions is that states and firms (and even some NGOs) engage in agricultural research, which isolates agricultural processes to generate technologies and protocols that can be offered to or imposed on farmers. Didactic learning also articulates with social learning; for instance, when technologies are being offered or imposed, a basic strategy is to recruit farmer demonstrators who possess traits making them likely models of emulation.

This framework for understanding agricultural decision making is new, generalized, and preliminary. An example of a promising future research direction would be analysis of changes in learning modalities across varying time scales. For example, Byerlee (1998) argues that extension usually has its greatest impact in the early stages of dissemination of a new technology, when the information disequilibrium (and the productivity differential) is greatest. As more farmers become aware of the new technology, the impact of extension diminishes until the need for more information-intensive technologies arises (Anderson and Feder 2004). But the shape of the drop-off in didactic learning and replacement by some mix of environmental and social learning will vary with the technology and the situation into which it is introduced, yielding distinctive learning functions, which would be invaluable in illuminating the dynamics of agriculture.

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Notes

1. Warangal District is now part of the new state of Telangana.
2. "Bias" here refers to patterns in who an individual copies. "Unbiased" transmission would be copying of parents or random individuals (Henrich and Boyd 1998:219).
3. Imputed causal agents of crop disease include phases of the moon, lightning, menstruating women, and drunks (Bentley and Thiele 1999). Bennett (1943) recorded similar thinking about crop welfare among 1940s U.S. farmers.
4. The 1860s saw the planting of tens of millions of mulberry trees in California alone, before the "trees died from neglect and the silk worms starved to death" (Guinn 1904). Agricultural fads sometimes reappear many years later; electroculture is an example (Electroculture and Magnetoculture 2014).
5. Examples include Stone (1997) on Tiv and Kofyar settlers in Nigeria, and Atran et al. (2002) on three ethnic groups in the Maya lowlands; see also Bennett (1982) on differing management styles.
6. I avoid the rubric of "science" as scientists have differing interests in different capacities. However, see Cleveland and Soleri (2002b) for a comparison of the interests of the farmer and the scientist/breeder.
7. Scott focuses on developing countries, but U.S. state interactions with indigenous Americans also provide rich illustrations. Jefferson's second inaugural address cited "humanity" in offering to "teach agriculture" to the American Indians, but the real state interest was in the Indians adjusting to life on reservations (Hurt 1987:96–107).
8. See Chambers (2008) for further discussion of biases in rural interventions.

References Cited

Abrahamson, Eric 1991 Managerial Fads and Fashions: The Diffusion and Rejection of Innovations. Academy of Management Review 16(3):586–612.

Anderson, Jock R., and Gershon Feder 2004 Agricultural Extension: Good Intentions and Hard Realities. The World Bank Research Observer 19(1):41–60.

Andrews, Keith L. 2011 Recollections and Reflections on the Integrated Pest Management Program in Zamorano from 1980 to 1993. Ceiba 52(1):55–64.

Atran, Scott, Douglas Medin, Norbert Ross, Elizabeth Lynch, Valentina Vapnarsky, Edilberto Ucan Ek', John Coley, Christopher Timura, and Michael Baran et al. 2002 Folkecology, Cultural Epidemiology, and the Spirit of the Commons: A Garden Experiment in the Maya Lowlands, 1991–2001. Current Anthropology 43(3):421–450.

Barlett, Peggy F., ed. 1980a Agricultural Decision Making: Anthropological Contributions to Rural Development. New York: Academic.

———, ed. 1980b Introduction: Development Issues and Economic Anthropology. *In* Agricultural Decision Making: Anthropological Contributions to Rural Development. Peggy Barlett, ed. Pp. 1–16. New York: Academic.

———, ed. 1982 Agricultural Choice and Change: Decision Making in a Costa Rican Community. New Brunswick, NJ: Rutgers University Press.

Bennett, John W. 1943 Changing Agricultural Magic in Southern Illinois: A Systematic Analysis of Folk-Urban Transition. Social Forces 22(1):98–106.

——— 1982 Of Time and the Enterprise: North American Family Farm Management in a Context of Resource Marginality. Minneapolis: University of Minnesota Press.

Bentley, Jeffery W. 1989 What Farmers Don't Know Can't Help Them: The Strengths and Weaknesses of Indigenous Technical Knowledge in Honduras. Agriculture and Human Values 6:25–31.

——— 2006 Folk Experiments. Agriculture and Human Values 23 (4):451–462.

Bentley, Jeffery W., and Werner Melara 1991 Experimenting With Honduran Farmer-Experimenters. ODI Agricultural Admin. Network Newsletter 24:31–48.

Bentley, Jeffery W., and Graham Thiele 1999 Bibliography: Farmer Knowledge and Management of Crop Disease. Agriculture and Human Values 16:75–81.

Bentley, Jeffery W., Gonzalo Rodríguez, and Ana González 1994 Science and People: Honduran Campesinos and Natural Pest Control Inventions. Agriculture and Human Values 11(2–3):178–182.

Bentley, Jeffery, Paul Van Mele, and George Acheampong 2010 Experimental by Nature: Rice Farmers in Ghana. Human Organization 69(2):129–137.

Bikhchandani, Sushil, David Hirshleifer, and Ivo Welch 1998 Learning from the Behavior of Others: Conformity. Fads, and Informational Cascades. Journal of Economic Perspectives 12:151–170.

Boster, James S. 1986 Exchange of Varieties and Information between Aguaruna Manioc Cultivators. American Anthropologist 88:428–436.

Boyd, Robert, and Peter J. Richerson 1985 Culture and the Evolutionary Process. Chicago: University of Chicago Press.

Braun, Arnoud R., et al. 2006 A Global Survey and Review of Farmer Field School Experiences. Wageningen, the Netherlands: International Livestock Research Institute.

Brokensha, David W., D. Michael Warren, and Oswald Werner 1980 Indigenous Knowledge Systems and Development. Lanham: University Press of America.

Brush, Stephen B. 1992 Ethnoecology, Biodiversity, and Modernization in Andean Potato Agriculture. Journal of Ethnobiology 12(2): 161–185.

Brush, Stephen B. 2004 Farmers' Bounty: Locating Crop Diversity in the Contemporary World. New Haven, CT: Yale University Press.

Bunch, Roland 1989 Encouraging Farmers' Experiments. *In* Farmer First: Farmer Innovation and Agricultural Research. Robert Chambers, Arnold Pacey, and Lori Ann Thrupp, eds. Pp. 55–61. London: Intermediate Technology Publications.

Burnham, George P. 1855 The History of the Hen Fever. Melrose: Russet House.

Byerlee, Derek 1998 Knowledge Intensive Crop Management Technologies: Concepts, Impacts, and Prospects in Asian Agriculture. *In* Impacts of Rice Research. Prabhu Pingali and Mahabub Hossain eds. Los Baños, Philippines: International Rice Research Institute.

Chambers, Robert 2008 Revolutions in Development Inquiry. London: Earthscan.

Chambers, Robert, Arnold Pacey, and Lori Ann Thrupp 1989 Farmer First: Farmer Innovation and Agricultural Research. London: Intermediate Technology.

Cleveland, David A., and Daniela Soleri, eds. 2002a Farmers, Scientists and Plant Breeding: Integrating Knowledge and Practice. Wallingford, UK: CAB International.

——— 2002b Introduction: Farmers, Scientists and Plant Breeding: Knowledge, Practice and the Possibilities for Collaboration. *In* Farmers, Scientists and Plant Breeding: Integrating Knowledge and Practice. David Cleveland and Daniela Soleri, eds. Pp. 1–18. Wallingford, UK: CAB International.

Conley, Timothy, and Christopher Udry 2001 Social Learning through Networks: The Adoption of New Agricultural Technologies in Ghana. American Journal of Agricultural Economics 83(3):668–673.

Cullather, Nick 2010 The Hungry World: America's Cold War Battle against Poverty in Asia. Cambridge: Harvard University Press.

Dyke, George V. 1993 John Lawes of Rothamsted: Pioneer of Science, Farming and Industry. Harpenden: Hoos Press.

Electroculture and Magnetoculture 2014 Electroculture: Free Cosmic Energies, Electricity & Magnetism for Fertilisation, Increased Yields and Healthy Plants. Electroculture, Good Vibes for Agriculture blog, http://www.electrocultureandmagnetoculture-.com/, accessed March 25, 2016.

Ellen, Roy 1982 Environment, Subsistence and System: The Ecology of Small-Scale Social Formations. Cambridge: Cambridge University Press.

Ellen, Roy, and Holly Harris 2000 Introduction. *In* Indigenous Environmental Knowledge and Its Transformations. R. Ellen, Peter Parkes, and A. Bicker, eds. Pp. 1–33. London: Routledge.

Feder, Gershon, Anthony Willett, and Willem Zijp 2001 Agricultural Extension: Generic Challenges and the Ingredients for Solutions. *In* Knowledge Generation and Technical Change: Institutional Innovation in Agriculture. Steven Wolf and David Zilberman, eds. Pp. 313–353. Norwell: Kluwer.

Feder, Gershon, Rinku Murgai, and Jaime B. Quizon 2004 The Acquisition and Diffusion of Knowledge: The Case of Pest Management Training in Farmer Field Schools, Indonesia. Journal of Agricultural Economics 55(2):217–239.

Fisher, Ronald Aylmer 1935 The Design of Experiments. Edinburgh: Oliver and Boyd.

Fitzgerald, Deborah 1990 The Business of Breeding: Hybrid Corn in Illinois 1890–1940. Ithaca: Cornell University Press.

——— 1993 Farmers Deskilled: Hybrid Corn and Farmers Work. Technology and Culture 34:324–343.

——— 2003 Every Farm a Factory: The Industrial Ideal in American Agriculture. New Haven & London: Yale University Press.

Flachs, Andrew 2016 Cultivating Knowledge: The Production and Adaptation of Knowledge on Organic and GM Cotton Farms in Telangana, India. PhD thesis, Washington University in St. Louis.

Giesen, James C., and Mark Hersey 2010 The New Environmental Politics and Its Antecedents: Lessons from the Early Twentieth Century South. The Historian Summer 72(2):271–298.

Goodman, David, Bernardo Sorj, and John Wilkinson 1987 From Farming to Biotechnology: A Theory of Agro-Industrial Development. Oxford: Basil Blackwell.

Guinn, J. M. 1904 Some Historic Fads and Fakes. Annual Publication of the Historical Society of Southern California 6(2):148–157.

Gupta, Anil K. 2012 Innovations for the Poor by the Poor. International Journal of Technological Learning, Innovation and Development 5(1):28–39.

Henrich, Joseph 2001 Cultural Transmission and the Diffusion of Innovations: Adoption Dynamics Indicate That Biased Cultural Transmission Is the Predominate Force in Behavioral Change. American Anthropologist 103(4):992–1013.

——— 2002 Decision-Making, Cultural Transmission and Adaptation in Economic Anthropology. *In* Theory in Economic Anthropology. Jean Ensminger, ed. Pp. 251–295. Walnut Creek, CA: AltaMira Press.

Henrich, Joe, and Robert Boyd 1998 The Evolution of Conformist Transmission and the Emergence of Between-Group Differences. Evolution and Human Behavior 19(4):215–241.

Henrich, Joseph, and Francisco J. Gil-White 2001 The Evolution of Prestige: Freely Conferred Deference as a Mechanism for Enhancing the Benefits of Cultural Transmission. Evolution and Human Behavior 22(3):165–196.

Hurt, R. Douglas 1987 Indian Agriculture in America: Prehistory to the Present. Lawrence: University of Kansas Press.

Johnson, Allen W. 1972 Individuality and Experimentation in Traditional Agriculture. Human Ecology 1(2):149–159.

Kloppenburg, Jack Ralph, Jr. 2004 First the Seed: The Political Economy of Plant Biotechnology, 1492–2000, 2nd edn. Madison: University of Wisconsin Press.

Lansing, J. Stephen 1991 Priests and Programmers: Technologies of Power in the Engineered Landscape of Bali. Princeton: Princeton University Press.

Larsen, Anna Folke, and Helene Bie Lilleør 2014 Beyond the Field: The Impact of Farmer Field Schools on Food Security and Poverty Alleviation. World Development 64:843–859.

Latour, Bruno 1983 Give Me a Laboratory and I Will Raise the World. *In* Science Observed: Perspectives on the Social Study of Science. Karin Knorr-Cetina and Michael Mulkay, eds. Pp. 141–170. London and Beverly Hills: Sage.

Leigh, G. J. 2004 The World's Greatest Fix: A History of Nitrogen and Agriculture. Oxford: Oxford University. Press.

Lusembo, Peter, Ahmed Kyambadde-Kyeyune, and Heinz Loos 2007 Contests as a Tool to Enhance Farmer Innovativeness and Sharing of Information for Sustainable Farming: A Case for Uganda. Paper presented at the Conference on Tropical and Subtropical Agricultural and Natural Resource Management. Witzenhausen, Germany.

Maat, Harro, and Dominic Glover 2012 Alternative Configurations of Agronomic Experimentation. *In* Contested Agronomy: Agricultural Research in a Changing World. James Sumberg and John Thompson, eds. Pp. 131–145. New York: Routledge.

Maertens, Annemie, and Christopher B. Barrett 2013 Measuring Social Networks' Effects on Agricultural Technology Adoption. American Journal of Agricultural Economics 95(2):353–359.

Marcus, Alan 1987 Setting the Standard: Fertilizers, State Chemists, and Early National Commercial Regulation, 1880–1887. Agricultural History 61:47–73.

McElreath, Richard 2004 Social Learning and the Maintenance of Cultural Variation: An Evolutionary Model and Data from East Africa. American Anthropologist 106:308–321.

Mosse, David 2005 Cultivating Development: An Ethnography of Aid Policy and Practice. London: Pluto Press.

Nazarea-Sandoval, Virginia D. 1995 Local Knowledge and Agricultural Decision Making in the Philippines: Class, Gender and Resistance. Ithaca: Cornell University Press.

Netting, Robert McC. 1993 Smallholders, Householders: Farm Families and the Ecology of Intensive, Sustainable Agriculture. Stanford: Stanford University Press.

New Jersey State Agricultural Experiment Station 1922 Annual Report of the New Jersey State Agricultural Experiment Station.

Nuijten, Edwin, Robbert van Treuren, Paul Struik, Alfred Mokuwa, Florent Okry, Béla Teeken, and Paul Richards. 2009 Evidence for the Emergence of New Rice Types of Interspecific Hybrid Origin in West African Farmers' Fields. PLoS One 4(10):e7335.

Padre, Shree, Sudarshana, and Robert Tripp 2003 Reforming Farm Journalism: The Experience of Adike Pathrike in India. AgRen Network Paper 128.

Perales, Hugo R., Bruce F. Benz, and Stephen B. Brush 2005 Maize Diversity and Ethnolinguistic Diversity in Chiapas, Mexico. Proceedings of the National Academy of Sciences of the United States of America 102(3):949–995.

Perkins, John H. 1997 Geopolitics and the Green Revolution : Wheat, Genes, and the Cold War. New York: Oxford University Press.

Pollan, Michael 2001 The Botany of Desire: A Plant's-eye View of the World. New York: Random House.

Rhoades, Robert E. 1998 Participatory Watershed Research and Management: Where the Shadow Falls. Gatekeeper Series 81. London: International Institute for Environment and Development.

Richards, Paul 1985 Indigenous Agricultural Revolution: Ecology and Food Production in West Africa. London: Hutchinson.

——— 1986 Coping With Hunger: Hazard and Experiment in an African Rice Farming System. London: Allen and Unwin.

——— 1989 Farmers Also Experiment: A Neglected Intellectual Reource in African Science. Discovery and Innovation 1(1):18–25.

Richerson, Peter J., and Robert Boyd 2005 Not by Genes Alone: How Culture Transformed Human Evolution. Chicago and London: University of Chicago Press.

Rogers, Everett M. 2003 Diffusion of Innovations, 5th edn. New York: Free Press.

Roling, Niels 1988 Extension Science, Information Systems in Agricultural Development. Cambridge: Cambridge University Press.

Ross, Eric B. 1998 The Malthus Factor: Population, Poverty, and Politics in Capitalist Development. London: Zed Books.

Rossiter, Margaret W. 1975 The Emergence of Agricultural Science: Justus Liebig and the Americans, 1840–1880. New Haven and London: Yale University Press.

Ruttan, Vernon W. 1996 What Happened to Technology Adoption-Diffusion Research? Sociologia Ruralis 36:51–73.

Ryan, Bryce, and Neal C. Gross 1943 The Diffusion of Hybrid Seed Corn in Two Iowa Communities. Rural Sociology 8:15–24.

Scoones, Ian, and John Thompson, eds. 1994 Beyond Farmer First: Rural People's Knowledge, Agricultural Research, and Extension Practice. London: Intermediate Technology.

Scott, James C. 1998 Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed. New Haven: Yale University Press.

Sherwood, Stephen G. 1997 Little Things Mean a Lot: Working with Central American Farmers to Address the Mystery of Plant Disease. Agriculture and Human Values 14(2):181–189.

Sillitoe, Paul 1998 The Development of Indigenous Knowledge: A New Applied Anthropology. Current Anthropology 39(2):223–252.

Smil, Vaclav 2001 Enriching the Earth: Fritz Haber, Carl Bosch, and the Transformation of World Food Production. Cambridge, MA: MIT Press.

Smith, Jane S. 2010 The Garden of Invention: Luther Burbank and the Business of Breeding Plants. New York: Penguin.

Stone, Glenn Davis 1997 Predatory Sedentism: Intimidation and Intensification in the Nigerian Savanna. Human Ecology 25:223–242.

——— 2007 Agricultural Deskilling and the Spread of Genetically Modified Cotton in Warangal. Current Anthropology 48:67–103.

Stone, Glenn Davis, and Andrew Flachs 2014 The Problem with the Farmer's Voice. Agriculture and Human Values 31(4):649–653.

Stone, Glenn Davis, Robert McC. Netting, and M. Priscilla Stone 1990 Seasonality, Labor Scheduling and Agricultural Intensification in the Nigerian Savanna. American Anthropologist 92:7–24.

Stone, Glenn Davis, Andrew Flachs, and Christine Diepenbrock 2014 Rhythms of the Herd: Long Term Dynamics in Seed Choice by Indian Farmers. Technology in Society 36:26–38.

Sumberg, James, and Christine Okali 1997 Farmers' Experiments: Creating Local Knowledge. Boulder: Lynne Rienner.

Sumberg, James, Robin Irving, Elisabeth Adams, and John Thompson 2012 Success Making and Success Stories: Agronomic Research in the Spotlight. *In* Contested Agronomy: Agricultural Research in a Changing World. James Sumberg, and John Thompson, eds. Pp. 186–203. New York: Routledge.

Thurston, H. David 1992 Sustainable Practices for Plant Disease Management in Traditional Farming Systems. Boulder: Westview Press.

Thurston, H. David, and Joanne Parker 1995 Raised Beds and Plant Disease Management. *In* The Cultural Dimension of Development: Indigenous Knowledge Systems. D. Michael Warren, L. Jan Slikkerveer, David Brokensha, and Wim Dechering, eds. Pp. 140–146. London: ITP.

Tripp, Robert, and Suresh Pal 2000 Information and Agricultural Input Markets: Pearl Millet Seed in Rajasthan. Journal of International Development 12:133–144.

Tripp, Robert 2001a Can Biotechnology Reach the Poor? The Adequacy of Information and Seed Delivery. Food Policy 26 (3):249–264.

——— 2001b 'Twixt Cup and Lip—Biotechnology and Resource-Poor Farmers. Nature Biotechnology 19(2):93.

True, Alfred Charles 1928 A History of Agricultural Extension Work in the United States, 1785–1923. Washington: US Dept of Agriculture.

Van Mele, Paul, Jonas Wanvoeke, Josephine Rodgers, and Blythe McKay. 2013 Innovative and Effective Ways to Enhance Rural Learning in Africa. *In* Realizing Africa's Rice Promise. Marco Wopereis, David Johnson, Nourollah Ahmadi, Eric Tollens, and Abdulai Jalloh, eds. Pp. 367–378. Wallingford, UK: CABI Publishing.

Vayda, Andrew P., Bradley B. Walters, and Indah Setyawati 2004 Doing and Knowing: Questions About Studies of Local Knowledge. *In* Investigating Local Knowledge: New Directions, New Approaches. Alan Bicker, Paul Sillitoe, and Johan Pottier, eds. Pp. 35–58. London: Ashgate.

von Liebig, Justus 1840 Orig, English Translation 1847 Organic Chemistry in Its Application to Agriculture and Physiology. Philadelphia: T.B. Peterson.

Whiten, Andrew, Victoria Horner, Carla Litchfield, and Sarah Marshall-Pescini 2004 How Do Apes Ape? Learning & Behavior 32 (1):36–52.

Wolf, Steven A., ed. 1998 Privatization of Information and Agricultural Industrialization. Boca Raton: CRC Press.

Ziegenhorn, Randy 2000 The Commodification of Hybrid Corn: What Farmers Know. *In* Commodities and Globalization: Anthropological Approaches. Angelique Haugerud, M. Priscilla Stone, and Peter D. Little, eds. Pp. 135–150. Lanham: Rowman & Littlefield.