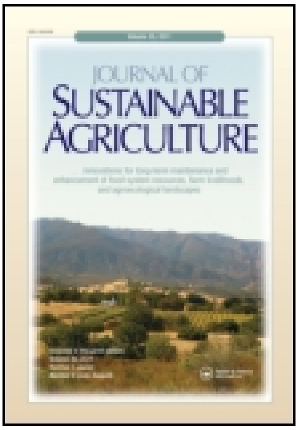

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Complex Traditions: Intersecting Theoretical Frameworks in Agroecological Research

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Complex Traditions: Intersecting Theoretical Frameworks in Agroecological Research

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The knowledge of traditional farmers is encyclopedic and ever changing as they continue learning from experiments and mutual interchange in the actualization of agroecology. The modern science of ecology is (or should be) the scientific basis of agroecology and should synergistically inform the ongoing accumulation of knowledge inherent in the practice of small-scale farmers. Traditional agricultural knowledge is deep but narrow, while modern ecological knowledge is broad but shallow. The intersection of traditional knowledge with modern ecology could result in the generation of knowledge that is simultaneously deep and broad.

KEYWORDS *TEK, traditional knowledge, ecological complexity, indigenous knowledge, scientific knowledge*

INTRODUCTION

Our proposition is dual: 1) Traditional small-scale farmers have a knowledge base that is fundamentally sound, and 2) that knowledge base is structurally similar to the growing scientific understanding of ecological complexity. It is a proposition that we expect will stir a dichotomous response, at least initially. On the one hand we suspect that there will be those who say, that is obvious, and it is simply not news for anyone vaguely familiar with anthropological or rural sociological work. On the other hand, there will be strong

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objections from other quarters, noting that excessive reliance on traditional knowledge is frequently nothing more than romantic drivel and that the modern science of ecology relates to traditional knowledge about as much as modern chemistry might relate to alchemy. We hope to engage both sides of this dichotomy.

If our proposition seems too obvious to bother with, we argue that it has been only recently that advances in the field of ecology have changed the way we look at ecosystems (Green et al. 2005; Vandermeer et al. 2010). Rather than the ordered equilibrium-like processes formerly thought to underlay assemblages of species, new analytical techniques have been brought to bear on ecosystem dynamics. We now understand that issues such as complex network structures, spatial dynamics, nonlinearities, stochasticity, and time lags all create unexpected outcomes and challenge older notions of stability and sustainability. Furthermore, new molecular tools have provided a new lens on processes as they happen in nature, complimenting the experimental approach that ecology had adopted in the decades of the 1970s and 1980s (Burton 1999). Putting these two approaches together, complex theoretical methods and new examination tools, we have a new ecology, one based as much on the insights of complex systems as on natural history.

If our proposition itself seems too romantic, we argue that the transformation of world agriculture at the end of World War II (Russell 2001) ignited a passion of irrational exuberance that has led to meltdown after meltdown, from massive pesticide resistance to hypoxic ocean zones, such that the wisdom of the traditionalists, even on the surface, is worth reconsidering. Furthermore, a discerning historical lens reveals a structure that has long been with us. None other than Robert Boyle noted that insights from the "trades," when coupled with systematic scientific structures provide a nutritious recipe for fundamental scientific discoveries (Conner 2005).[1] That is, the "wisdom of the ages" is wiser than we think. It just uses different words to describe phenomena. Richard Levins has noted what we refer to here as the Levins paradox—traditional agricultural knowledge is profound but local, while scientific knowledge is general but superficial (Lewontin and Levins 2007). The idea that advanced scientific knowledge can be seen as in accord with some of the principles long held by traditionalists should not really be a surprise to anyone not religiously committed to the modernist myth.

FOOD SOVEREIGNTY AS A UNIFYING CONCEPT

Both the idea of an ecological focus of research in agroecosystems and the generation of knowledge directly by farmer scientists and their interactions are given political life in the movement for food sovereignty. As stated in two of the six principles of food sovereignty from La Via Campesina and the Nyéléni 2007–Forum for Food Sovereignty (http://www.nyeleni.org/spip.php?article334):

> Food sovereignty builds on the skills and local knowledge of food providers and their local organizations that conserve, develop and manage localized food production and harvesting systems, developing appropriate research systems to support this and passing on this wisdom to future generations;
>
> Food sovereignty uses the contributions of nature in diverse, low external input agroecological production and harvesting methods that maximize the contribution of ecosystems and improve resilience and adaptation, especially in the face of climate change; it seeks to "*heal the planet so that the planet may heal us*"; and *rejects* methods that harm beneficial ecosystem functions, that depend on energy intensive monocultures and livestock factories, destructive fishing practices and other industrialized production methods, which damage the environment and contribute to global warming.

Food is produced by farming and the underlying purpose of food, ideology aside, is to provide nourishment for people. It is not, in any fundamental way, necessarily a commodity. Yet, prevalent ideology worldwide contends that which is not yet a commodity must be turned into one. Food sovereignty challenges this ideology at two different levels. First, as enshrined in much international work (e.g., De Schutter and Cordes 2011), human beings should have a right to food, not a right to choose to spend some of their money to buy food. This new model rejects the notion that food is nothing more than a tradable good, like any other. Second, human beings should have the right to collectively and democratically decide, at a local level, how food is to be produced. More complete summaries of the idea of food sovereignty are readily available (e.g., Rosset 2008; Altieri 2009).

HISTORICAL CONTINGENCY DROVE THE INDUSTRIAL AGRICULTURAL SYSTEM

It is not difficult to see the outlines of the problems we must address, even though they are enormous: one in three children is unhealthy because of food promoted by advertisers whose main concern is people's wallets, not their health (Nestle 2007); pesticide residues linger at levels that are deemed safe only through corporate lobbying, causing an unknown number of health problems (Pimentel et al. 1992); ocean dead zones result from massive artificial fertilizer applications (Nassauer et al. 2007; Diaz and Rosenberg 2008); global warming is exacerbated from many elements of the industrial agricultural model (Lin et al. 2011). In short, our problem is the production of food that is unhealthy for people with methods that are unhealthy for the environment. How did we get into this situation?

For at least 90% of our existence as a species we were hunters and gatherers (Lee and Daly 1999). The energy we required to do what needs to be done came from the substances acquired through hunting and gathering directly from nature—large vertebrate herbivores, fruits, tubers, grubs, and similar natural items. The adoption of agriculture enabled a far more efficient way of obtaining that energy and promoted a dramatic increase in our numbers and leisure (Cowan et al. 2006). We began a grand manipulation of nature, but were necessarily constrained by ecological laws and could only produce within the constraints of those laws. We engaged in what might be referred to as "natural systems agriculture," as it has been referred to more recently (Jackson 2002).

But then something rather dramatic happened. Beginning during the early decades of the last century, and culminating in earth-shattering changes in the post war years, our species forced into the agricultural enterprise the tools of the recent, spectacularly successful, Industrial Revolution (Hendrickson and James 2005). We automated, regularized, commoditized, monetarized, and chemicalized the process of generating food. What had been done in industry was now done in agriculture; human labor and ecological processes were replaced with fossil fuels. We applied, in myriad ways, industrial energy to the process of producing food. In the end, and largely as an unintended consequence of the giddiness of the Industrial Revolution's successes, we transformed the system that made our acquisition of energy more efficient, to a system that effectively used more energy than it produced—from an energy producing system to an energy consuming system (Pimentel et al. 1973; Pimentel and Pimentel 1979; Pimentel et al. 1992; Pimentel et al. 2005; Martinez-Alier 2011).

Furthermore, as a consequence of industrializing food production, it seemed quite natural to industrialize food consumption as well. A key problem was the ability to produce more food than people generally wanted to eat, or at least, more food than people needed to eat to stay healthy (i.e., when considering food as a commodity, it is inelastic). A tomato must be eaten within a few days after harvest, or at best a week or two under refrigeration, or it is basically lost to nature's recycling ways. But people would not cooperate with the new agricultural economics—they insisted on eating only the number of tomatoes that made them full. Two strategies evolved to deal with this problem. First, food preservation technology, long a traditional activity, especially in the North, became industrialized. The tomatoes were converted to tomato sauce that could be canned and stored virtually in perpetuity and, second, people were encouraged to eat more and more. Food scientists not only invented creative ways of extending shelf life, they also came to understand the basic human responses to taste and texture and, thus, how to manipulate those responses to encourage people to want more and more. Consequently, we had a revolution that resulted in food being processed into what Pollen (2007) calls "food-like substances" and people converted into consumption machines that ever increased the limits of their intake capacities. Indeed, in the modern food system people are referred to as simply consumers.

Today, the environmental crisis created by the industrial agricultural system is beginning to receive the same scholarly attention as climate change. Direct emissions of greenhouse gasses from industrial agriculture are now appreciated and juxtaposed with the troubling fact that there is little hard evidence that intensification has led to a global increase in food security, no matter how defined (Patel 2010). These observations, along with other environmental insults coming from the industrial system, have generated a number of critical reports. The most notable was the release of the U.N. and World Bank sponsored report, the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) in 2008 (IAASTD 2008). That report, similar to the early Intergovernmental Panel on Climate Change (IPCC) reports, noted a human and environmental health disaster on the horizon if the industrial agricultural system continued its trajectory. In a press release comment on that report, Robert Watson, one of the IAASTD co-chairs (and former chair of the IPCC) noted "business as usual is not an option" referring to the industrial agricultural system.

REFLECTIONS ON THE TRADITIONAL

In the 1990s, a Guatemalan entomologist, Helda Morales, began research for her doctoral dissertation among traditional Mayan maize producers in the Guatemalan mountains. In seeking to understand and study traditional methods of pest control, she began by asking the question, "What are your pest problems?" She was surprised to find almost unanimity in the responses of most of the farmers she interviewed: "We have no pest problems." Taken aback, she reformulated her questionnaire and asked, "What kind of insects do you have in your *milpa*," to which she received many answers, including all the main characteristic pests of maize and beans in the region. She then asked why these insects, known to be pests by professional entomologists, were not pests according to the Mayan farmers. Again, she received all sorts of answers, mostly in the form of how the agroecosystem was managed. The farmers were certainly aware that these insects could be problems, but they also had ways of managing the agroecosystem such that the insects remained below levels that would categorize them as pests. Morales' initial plan probably was influenced by her early training in agronomy and classical entomology, but her interactions with the Mayan farmers caused her to change her approach. Rather than study how Mayan farmers solve their problems, she focused on why the Mayan farmers do not have problems in the first place (Morales and Perfecto 2000).

The lessons from the Morales studies are many. And most point to the intellectual bankruptcy of standard agricultural research. The classical agronomist's approach is fixed by the idea that farmers always face "problems" that need solutions (or in the more decorative rhetoric of the post-World War II chemical companies, farmers have enemies that must be vanquished [Russell 2001]). Thus, pesticides became the armament, the magic bullet, that would be deployed to vanquish the pests.

This vanquish-the-enemy narrative became the focus of the classical agronomist—react to the problems, real or imagined, that emerge on the farm. In contrast, we argue that the agroecological research agenda should take a clue from the Morales' studies (Morales and Perfecto 2000). We need to understand why problems do *not* exist; that is, we need to understand the natural built-in regulators and the ecological complexity inherent in most traditional agricultural production systems (Lewis et al. 1997).

Along with the recognition that functioning farms indeed do function within ecological principles and part of the job of the researcher is to understand those principles, is the fact that farmers themselves have long been scientists and their knowledge is, although perhaps narrow in scope, quite deep in regards to their particular farm and farming system, frequently having benefitted from the accumulated knowledge of generation of their ancestors (Richards 1985; Wilken 1987; Grossman 2003; Toledo and Barrera-Bassols 2008). But, more important, farmers act as scientists in another way also. Much as science is accomplished through associations and scientific societies, which is to say science in the end is a social activity, farmer scientists have always engaged in interchanges (Leitgeb et al. 2011). The farmer in Valley X who tries a particular mode of planting cassava and finds that it works efficiently in resisting the onslaught of a particular pest, invariably shares that knowledge with a farmer in Valley Y when they meet in their common marketplace. Based on this obvious idea, some action-oriented researchers have promoted the idea of farmer-to-farmer interchange as a vehicle for development (Rölin and van de Fliert 1994; Bentley et al. 2003; Holt-Giménez 2006) and an important social tool for the generation of new scientific knowledge (Stuiver et al. 2004).

ECOLOGICAL COMPLEXITY

A rather surprising element of biological control was deduced in 1991 from elementary considerations of nonlinearities in the elementary equations of theoretical ecology (Arditi and Berryman 1991). The classical idea, presented initially in 1926, more or less simultaneously and independently by Lotka and Volterra, was that predators (the presumed biological control force) and their prey (the presumed pest) must oscillate with respect to one another. The oscillations may have complex dynamics associated with them, but underlying all of that complexity the fact of oscillations was both to be expected, and generally observed in nature (Vandermeer and Goldberg 2003).

Adding just a bit of realism to those equations resulted in the conclusion that the oscillations would sometimes damp down, but also could continue to oscillate forever. And, most importantly, these permanent oscillations generally occur when the expected equilibrium value of the prey is relatively low and, worse, the closer to zero the prey's equilibrium expectation is, the larger the oscillations, to the point that a very large number of predators will emerge and consume 100% of the available prey and then themselves all die, which is to say, the complete extinction of the predator.

The paradoxical situation as far as biological control is concerned is that a pest control technician may have the sincere goal of lowering the pest population. But to the extent that he or she is successful, the prey population tends to get pushed into the zone of the wild oscillations and eventual extinction of the control agent, clearly not what the practitioner intended. Unfortunately, for most biological control situations, not enough is known about the underlying ecological dynamics of the system to know when the system might be pushed over the instability threshold, leading to the inevitability of surprise in the system. With careful study such systems that today represent "unknowables" as far as a farmer is concerned, can become well enough understood to take prior action to prevent such a collapse. But it does require an understanding, indeed a relatively deep understanding, of the ecology of the system.

One of the key insights that modern ecology now brings to the table as a matter of course is the *chaos revolution* (Hastings et al. 1993). Its practical importance is frequently misunderstood, partly because of the emphasis on its inherently unpredictability. The misunderstanding arises partly from this emphasis. Chaotic fluctuations are, formally, completely unpredictable in the sense that beginning at two different, but almost identical situations, the future of the two trajectories cannot be predicted regardless of how much information one has about the system. So, for example, if you know that two apple orchards have almost, but not quite, the same number of apple maggots this year, and a third is almost, but not quite, free of apple maggots, that information is completely unrelated to how many pests will be in those three orchards a few years hence. On the one hand, this knowledge should invoke a bit of humility into any research program that seeks precise prediction of almost anything about an agroecosystem. On the other hand, the idea that our inability to predict precisely renders any attempt at understanding the system pointless reflects a misunderstanding of the insights of the chaos revolution.

To see the nature of this insight consider the following simple set up. Suppose we have some crop growing in two adjacent valleys. A population of some sort of pest caterpillar reproduces independently in each of the valleys, but may migrate (or be blown by the wind) between valleys at some small rate. If we plot the size of the populations in the two valleys over time, for a seven-year period, we might get something similar to that in Figure 1a, where the black symbols represent what happens over one particular seven-year cycle (each numeral stands for the year). Note that there is no obvious pattern discernible, which is a characteristic of a chaotic system. But there is something even worse! As represented in the open circles (and gray numerals), if we begin the system,with the same vital parameters, at a very slightly different point, the position of the points in subsequent years becomes totally unrelated in the two trajectories (the trajectory represented by the closed circles and the other trajectory represented by the open circles). Since in practice we can really never actually estimate the density of a real population in nature so closely that the two points at position 1 are distinguishable, our ability to predict what will happen is severely compromised. So, for example, if we know where the two populations are at point 1, does that tell us anything about where they will be after seven years (remember, we cannot really know whether we are following the closed circles or the open circles in Figure 1a)? The answer is, no, precise prediction is impossible.

However, if we run this model system for several thousand years (computer years, that is), the points plotted in Figure 1b emerge (each point is much smaller than in Figure 1a so as to fit them all in). While it is true that precise prediction is impossible, it is also true that the system is not at all

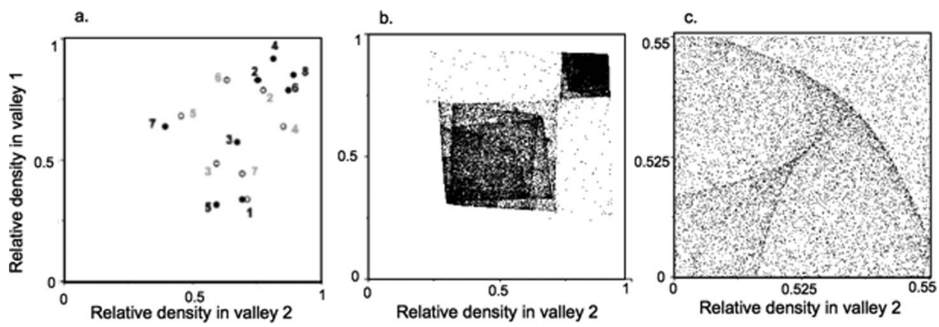

FIGURE 1 Relative densities of two populations in two adjacent valleys [equations are $N_i(t+1) = rN_i(t)(1-N_i(t)) - mN_i(t) + mN_j(t)$], where r is the rate of increase of the population and m is the migration rate between valleys, with parameter values $r = 6.637$; $m = 0.04$. a) Seven successive generations (years) for two different starting points (labeled 1), with one starting point leading to the points labeled with solid circles and the second labeled with open circles. Two arrows are indicated for clarity, solid arrows going from time 3 to 4 and from time 4 to 5 for one trajectory and dashed arrows going from time 3 to 4 and from time 4 to 5 for the other trajectory. Note the rapid deviation of the two trajectories from one another, a characteristic of chaotic systems. b) The picture after thousands of generations. Dashed lines indicate approximate position of a theoretical economic threshold for the two populations. c) Close up of part of the dense region (from 0.5 to 0.55) illustrating the pattern of various densities that are clearly nonrandom.

random. Indeed, we can say that most of the time both valleys will either be below the relative values of 0.75 or above those values, although occasionally one of the valleys will be above and the other below. Furthermore, there are some places within the two main concentrations of points that are more likely to occur than others. From a practical perspective if, for example, the economic threshold for this species is about 0.75, we see that this pest will normally be either a pest in both valleys, or not a pest in both valleys, but not always. Furthermore, if we focus in more closely (look at the region where both populations are between 0.5 and 0.55—Figure 1c) we see a fractal structure in which what is apparently random at one scale, has a significant structure at a smaller scale. Both fundamental unpredictability and rigid structure are contained within this chaotic system.

So, we see that a chaotic population is on the one hand completely unpredictable, at least with regard to precise prediction, but on the other hand has a very rigid structure. The task is to be able to recognize what is the proper scale at which the system should be examined, and to simultaneously arm ourselves with humility and heuristics—humility in our recognition that precision is an unattainable dream and heuristics in that a qualitative understanding of the system can emerge from the quantitative analysis. That is the message of the chaos revolution for serious ecological research in agroecology.

ECOLOGICAL COMPLEXITY INTERSECTING WITH TRADITIONAL KNOWLEDGE

At the Land Institute in Salinas Kansas, Wes Jackson (2002) has been promoting "natural systems agriculture." The idea is that the local natural ecosystem provides us with the vision of how an agroecosystem ought to be designed. Jackson's idea gains considerable force from tradition. More or less the same idea was elaborated in a more simplified form by Sir Albert Howard when he was dispatched to India by Queen Victoria to teach Indian farmers how to do agriculture. He discovered deep traditions, mainly based in a knowledge of local ecology that he judged did a better job than the modern agriculture the Victorian scientists were promoting. Other examples could also be cited (e.g., Gliessman et al. 1981; Ewel 1986; Wilken 1987; Toledo 1990; Altieri 1990, 2004; Sevilla Guzmán 1991; Denevan 1995; Berkes et al. 2000; Funes et al. 2002; Toledo and Barrera Bassols 2008). But Jackson (2002) brings to the table an explicit search for the dialectical relationship between the modern science of genetics and ecology and the structure of natural ecosystems. He notes that grain belt farming in North America seeks to impose an annual monoculture in an environment that has, at least since the Pleistocene, been characterized by a perennial polyculture. The problem, he notes, is that perennial grasses have not had the sort of genetic modifications that traditional farmers imposed on the annual grasses that make up the idea of annual monocultures, and set upon a program of genetic modification to create higher yielding perennial grasses (or, the perennialization of the classic grains).

In most tropical regions of the world one can see the influence of natural systems agriculture, practiced as a matter of course. For example, when coffee was brought to Latin America (at least in the northern part of the region), farmers began cultivating it beneath a canopy of shade trees (and frequently even under a natural forest canopy), knowing that its natural state is as a forest understory plant. Further development in the region lead to the development of what are now called coffee forests, well know to be a major refuge for biodiversity (Perfecto et al. 1996; Moguel & Toledo 1999). A similar evolution characterized cacao production in Brazil (Faria et al. 2006) and elsewhere and rubber in West Africa and Indonesia (Suyanto et al. 2001). We have been involved in the study of traditional forms of coffee production and have come to the conclusion that

> . . . producers have a universal and evident sense that the natural world offers ecosystem services that contribute to the stability, productivity, and sustainability of their farms. . . . [We find that] through the spatially explicit complexity of myriad interactions, many of which are multiply nonlinear, a higher notion of balance emerges—not the balance of Newton, but rather the balance of a shifting sand dune whose detailed structure changes minute to minute, but whose fundamental nature as a "sand dune" is never in doubt. Our understanding becomes not the crude, positivist logic that must identify a singular enemy to conquer, and a magic bullet with which to do so, but rather the holistic vision of a new kind of "balance" emerging from the very complexity that traditional farmers intuitively understood from the beginning. (Vandermeer et al. 2010)

DISCUSSION

The knowledge contained in the theory and practice of traditional farmers the world over is encyclopedic to be sure. As farmers continue learning from the experiments and understanding of each other and previous generations it is certain that more rational systems of agriculture will develop, even as the industrial system pushes its unrelenting advertising on them. It is likely that the industrial model will continue with that unrelenting advertising. The ecological alternative that we favor and that combines current ecological theory and traditional knowledge, to date has had limited, albeit growing influence. A problem that seems to be universally recognized is the dramatic level of uncertainty involved in our understanding of the ecological systems involved. The folly of following old research techniques is evident to all except those whose career depends on them (recalling Upton Sinclair's (1934) admonition "It is difficult to get someone to understand something when his or her salary depends on misunderstanding it" [109]). Yet, we must acknowledge that since World War II there have been hundreds, if not thousands, of researchers leveraging billions of dollars of research in support of the furtherance of the industrial system. They are exceedingly good at making that industrial system perform as best it can. In contrast, the ecological study of agroecosystems remains in its infancy. When that same billions of dollars are spent in trying to untangle the enormous complexity of ecosystems, when thousands of researchers have the same level of support, and when that cutting edge ecological research joins force with the traditional knowledge of farmers that have benefited from thousands of years of trial and error and experimentation, we can envision the day where we will be far better able to muster the ecological principles of agroecosystems in support of agroecological planning.

Thus, we envision a future where the science of ecology, especially as applied to agroecology, will become ever more enlightening. At the same time we envision a future in which small-scale farmers will have control of their own production systems, which is to say will have a full plate of food sovereignty, and will continue their own development of science. A major challenge, as we see it, is to creatively engage the Levins paradox. This will involve creative engagement on all sides of the issue.

We argue that the modern science of ecology has a great deal to offer the growing agroecosystem revolution. Indeed, we argue that, as the science of chemistry is the basis of chemical engineering, the science of ecology is (or should be) the basis of agroecology. Yet, it is also the case that the accumulated knowledge of the world's millions of small-scale farmers has a great deal to offer the modern science of agroecology. Indeed a common definition of agroecology incorporates traditional knowledge as one of the bases of agroecology. As Conner (2005) elaborated in his "A People's History of Science," the practical necessities of actually producing things (i.e., not ethereal trickery such as financial "instruments" but real goods and services that get used by people) has, through the ages, motivated people to understand how the world works. Science, at its core, is about that understanding. Indeed, we agree with Robert Boyle that, "as the naturalist may . . . derive much knowledge from an inspection into the trades, so by virtue of the knowledge thus acquired . . . he may be as able to contribute to the improvement of the trades" (Connor 2005, 22)—a principle that is probably more important than his famous law about gases. Indeed, it is perhaps the most important scientific principle of all—the Levins' paradox. Traditional knowledge is deep but local, while modern ecological knowledge is general but shallow. Is it too much to promote a research agenda that seeks to combine those two? To have at least as the ultimate goal (dream), the generation of knowledge that is simultaneously deep and general?

NOTE

1. "Trade" here refers to a skill or craft. Robert Boyle, seventeenth-century philosopher, chemist, and physicist, and namesake of Boyle's law of gases, was keen on understanding the way in which common tradesmen and women accumulated knowledge that was systematic, organized, and insightful, much as the modern scientific method. This point is discussed in detail by Conner (2005).

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