8 Taming Nature: An Agriculture of Legibility and Simplicity

Yes, enumerate the carriage parts—
Still not a carriage.

When you begin making decisions and cutting it up
  rules and names appear
And once names appear, you should know when to stop.
—*Tao-te-ching*

The necessarily simple abstractions of large bureaucratic institutions, as we have seen, can never adequately represent the actual complexity of natural or social processes. The categories that they employ are too coarse, too static, and too stylized to do justice to the world that they purport to describe.

For reasons that will become apparent, state-sponsored high-modernist agriculture has recourse to abstractions of the same order. The simple "production and profit" model of agricultural extension and agricultural research has failed in important ways to represent the complex, supple, negotiated objectives of real farmers and their communities. That model has also failed to represent the space in which farmers plant crops—its microclimates, its moisture and water movement, its microrelief, and its local biotic history. Unable to effectively represent the profusion and complexity of real farms and real fields, high-modernist agriculture has often succeeded in radically simplifying those farms and fields so they can be more directly apprehended, controlled, and managed. I emphasize the *radical* simplification of agricultural high modernism because agriculture is, even in its most rudimentary, neolithic forms, inevitably a process of simplifying the floral profusion of nature.[1] How else are we to understand the process by which man has encouraged certain species of flora that he found useful and discouraged others that he found a nuisance?

The logic behind the radical simplification of the field is almost precisely identical to the logic behind the radical simplification of the forest. In fact, a simplified agriculture, which was developed earlier, served as the model for scientific forestry. The guiding idea was the maximization of the crop yield or profit.[2] The forests were reconceptualized as "timber farms" in which a single species of tree was planted in straight rows and harvested like a crop when it was "mature." The preconditions of such simplifications were the existence of a commodity market and competitive pressure, on states as well as on entrepreneurs, to maximize profits or revenue. In the monocropped field and single-species forest alike, the innumerable other members of the biotic community were ignored unless they had some direct bearing on the health and yield of the species to be harvested. Such narrowing of attention to a single outcome—invariably the one of most commercial or fiscal interest—confers an analytical power that allows foresters and agronomists to track carefully the influence of other factors on this single dependent variable. Within its ambit, there is no denying the extraordinary power of this approach to increase yields. As we shall see, however, this potent but narrow perspective is troubled both by certain inevitable blind spots and by phenomena that lie outside its restricted field of vision. To continue the metaphor, this narrowness in turn means that production agronomy is occasionally blindsided by factors outside its analytical focus and is forced, by the resulting crisis, to take a broader perspective.

The question we shall address in this chapter is why a model of modern, scientific agriculture that has apparently been successful in the temperate, industrializing West has so often foundered in the Third World. In spite of these indifferent results, the model has been pressed by colonial modernizers, independent states, and international agencies. In Africa, where the results have been particularly sobering, an agronomist with great experience has claimed that "one of the crucial lessons of the past fifty years or so of ecological research focused on African agriculture is that the 'dramatic modernization' option has a track record so poor that a return to slower and more incremental approaches must now be given serious and sustained attention."[3]

We will not be much concerned in this discussion with the particular reasons that made this scheme or that cropping plan fail. To be sure, the familiar bureaucratic pathologies as well as openly predatory practices have often greatly compounded these failures. My claim, however, is that the origin of these failures can be traced to a deeper level; these were, in other words, systemic failures and would have occurred under the best assumptions about administrative efficiency and probity.

At least four elements seem to be at work in these systemic failures. The first two are linked to the historical origin and institutional nexus of high-modernist agriculture. First, given their discipline's origin in the temperate, industrializing West, the bearers of modernism in agricultural planning inherited a series of unexamined assumptions about cropping and field preparation that turned out to work badly in other contexts. Second, given the presumptions about expertise embodied in modernist agricultural planning, the actual schemes were continually bent to serve the power and status of officials and of the state organs they controlled.[4]

The third element, however, operates at a deeper level: it is the systematic, cyclopean shortsightedness of high-modernist agriculture that courts certain forms of failure. Its rigorous attention to productionist goals casts into relative obscurity all the outcomes lying outside the immediate relationship between farm inputs and yields. This means that both long-term outcomes (soil structure, water quality, land-tenure relations) and third-party effects, or what welfare economists call "externalities," receive little attention until they begin to affect production.

Finally, the very strength of scientific agricultural experimentation—its simplifying assumptions and its ability to isolate the impact of a single variable on total production—is incapable of dealing adequately with certain forms of complexity. It tends to ignore, or discount, agricultural practices that are not assimilable to its techniques.

Lest there be any misunderstanding about my purpose here, I want to emphasize that this is not a general offensive against modern agronomic science, let alone an attack on the culture of scientific research. Modern agronomic science, with its sophisticated plant breeding, plant pathology, analysis of plant nutrition, soil analysis, and technical virtuosity, is responsible for creating a fund of technical knowledge that is by now being used in some form by even the most traditional cultivators. My purpose, rather, is to show how the *imperial pretensions* of agronomic science—its inability to recognize or incorporate knowledge created outside its paradigm—sharply limited its utility to many cultivators. Whereas farmers, as we shall see, seem pragmatically alert to knowledge coming from *any* quarter should it serve their purposes, modern agricultural planners are far less receptive to other ways of knowing.

Varieties of Agricultural Simplification

Early Agriculture

Cultivation is simplification. Even the most cursory forms of agriculture typically produce a floral landscape that is less diverse than an unmanaged landscape. The crops that mankind has cultivated have, when fully domesticated, become dependent for their survival upon the management of cultivators—such activities as making a clearing, burning brush, breaking the soil, weeding, pruning, manuring. Strictly speaking, a crop in the field is not an artificial landscape, inasmuch as all fauna, not excluding human beings, modify their environment in the course of food gathering. What is certain, however, is that most of *Homo sapiens*'s cultivars have been so adapted to their altered landscape that they have become "'biological monsters'" which could not survive in the wild.[5]

Millennia of variation and conscious human selection have favored cultivars that are systematically different from their wild and weedy cousins.[6] Our convenience has led us to prefer plants that have large seeds and are easy to germinate, have more blossoms and hence more fruit, and whose fruits are more easily threshed or shelled. Cultivated maize thus has a few large ears with large kernels whereas wild or semidomesticated maizes have very small cobs with small kernels. The difference is most starkly captured by the contrast between the huge, seed-laden commercial sunflower and its diminutive woodland relative.

Beyond the question of the harvest itself, of course, cultivators have also selected for scores of other properties: texture, flavor, color, storage quality, aesthetic value, grinding and cooking qualities, and so on. The breadth of human purposes has led not to a single, ideal cultivar of each species but rather to a great many varieties, each distinctive in some important way. Thus we have the varieties of barley grown for porridge, for bread, for beer, and for feeding livestock; and thus "sweet sorghum for chewing, white-seeded types for bread, small, dark, red-seeded types for beer, and strong-stemmed, fibrous types for house-construction and basketry."[7]

The greatest selection pressure, however, came from the dominant anxiety of cultivators: that they not starve. This most basic of existential concerns also led to a great variety of cultivars, termed the "landraces" of the various crops. Landraces are genetically variable populations that respond differently to different soil conditions, levels of moisture, temperature, sunlight, diseases and pests, microclimates, and so forth. Over time, traditional cultivators, operating as experienced applied botanists, have developed literally thousands of landraces of a single species. A working knowledge of many, if not all, of these landraces provided cultivators with enormous flexibility in the face of environmental factors that they could not control.[8]

For our purposes, the long development of so many landraces is significant in at least two respects. First, while early farmers were transforming and simplifying their natural environment, they also had a surpassing interest in fostering a certain kind of diversity. A combination of their wide interests and their concern about the food supply impelled them to select and protect many landraces. The genetic variability of the crops they grew provided some built-in insurance against drought, flooding, plant diseases, pests, and the seasonal vagaries of climate.[9] A pathogen might affect one landrace but not another; some landraces would do well in a drought, others in wet conditions; some would do well in clayey soil, others in sandy soil. Placing a large number of prudent bets, finely tuned to microlocal conditions, the cultivator maximized the dependability of a tolerable harvest.

The variety of landraces is significant in another sense. *All* modern crops of any economic significance are the product of landraces. Until about 1930 all scientific crop breeding was essentially a process of selection from among the existing landraces.[10] Landraces and their wild progenitors and "escapes" represent the "germ plasm" or seed-stock capital upon which modern agriculture is based. In other words, as James Boyce has put it, modern varieties and traditional agriculture are complements, not substitutes.[11]

Twentieth-Century Agriculture

Modern, industrial, scientific farming, which is characterized by monocropping, mechanization, hybrids, the use of fertilizers and pesticides, and capital intensiveness, has brought about a level of standardization into agriculture that is without historical precedent. Far beyond mere monocropping on the model of scientific forestry explored earlier, this simplification has entailed a genetic narrowing fraught with consequences that we are only beginning to comprehend.

One of the basic sources of increasing uniformity in crops arises from the intense commercial pressures to maximize profits in a competitive mass market. Thus the effort to increase planting densities in order to stretch the productivity of land encouraged the adoption of varieties that would tolerate crowding. Greater planting densities have, in turn, intensified the use of commercial fertilizers and therefore the selection of subspecies known for high fertilizer (especially nitrogen) uptake and response. At the same time, the growth of great supermarket chains, with their standardized routines of shipping, packaging, and display, has inexorably led to an emphasis on uniformity of size, shape, color, and "eye appeal."[12] The result of these pressures was to concentrate on the small number of cultivars that met these criteria while abandoning others.

The production of uniformity in the field is best grasped, however, through the logic of mechanization. As factor prices in the West have, since at least 1950, favored the substitution of farm machinery for hired labor, the farmer has sought cultivars that were compatible with mechanization. That is, he selected crops whose architecture did not interfere with tractors or sprayers, which ripened uniformly, and which could be picked in a "once-over" pass of the machine.

Given the techniques of hybridization being developed at roughly the same time, it was but a short step to creating new crop varieties bred explicitly for mechanization. "Genetic variability," as Jack Ralph Kloppenberg notes, "is the enemy of mechanization."[13] In the case of corn, hybridization—the progeny of two inbred lines—produces a field of the genetically identical individuals that are ideal for mechanization. Varieties developed with machinery in mind were available as early as 1920, when Henry Wallace joined forces with a manufacturer of harvesting equipment to cultivate his new, stiff-stalked variety with a strong shank connecting the ear to the stalk. An entire field of plant breeding, termed "phytoengineering," was thus born in order to adapt the natural world to machine processing. "Machines are not made to harvest crops," noted two proponents of phytoengineering. "In reality, crops must be designed to be harvested by machine."[14] Having been adapted to the cultivated field, the crop was now adapted to mechanization. The "machine-friendly" crop was bred to incorporate a series of characteristics that made it easier to harvest it mechanically. Among the most important of these characteristics were resilience, a concentrated fruit set, uniformity of plant size and architecture, uniformity of fruit shape and size, dwarfing (in the case of tree crops especially), and fruits that easily break away from the plant.[15]

The development of the "supermarket tomato" by G. C. (Jack) Hanna at the University of California at Davis in the late 1940s and 1950s is an early and diagnostic case.[16] Spurred by the wartime shortage of field labor, researchers set about inventing a mechanical harvester *and* breeding the tomato that would accommodate it. The tomato plants eventually bred for the job were hybrids of low stature and uniform maturity that produced similarly sized fruits with thick walls, firm flesh, and no cracks; the fruits were picked green in order to avoid being bruised by the grasp of the machinery and were artificially ripened by ethylene gas during transport. The results were the small, uniform winter tomatoes, sold four to a package, which dominated supermarket shelves for several decades. Taste and nutritional quality were secondary to machine compatibility. Or to put it more charitably, the breeders did what they could to develop the best tomato within the very sharp constraints of mechanization.

The imperatives of maximizing profits and hence, in this case, of mechanizing the harvest worked powerfully to transform and simplify both the field and the crop. Relatively inflexible, nonselective machines work best in flat fields with identical plants growing uniform fruits of perfectly even maturity. Agronomic science was deployed to approximate this ideal: large, finely graded fields; uniform irrigation and nutrients to regulate growth; liberal use of herbicides, fungicides, and insecticides to maintain uniform health; and, above all, plant breeding to create the ideal cultivar.

The Unintended Consequences of Simplification

Reviewing the history of major crop epidemics, beginning with the Irish potato famine in 1850, a committee of the United States National Research Council concluded: "These encounters show clearly that crop mono-culture and genetic uniformity invite epidemics. All that is needed is the arrival on the scene of a parasite that can take advantage of the vulnerability. If the crop is uniformly vulnerable, so much the better for the parasite. In this way virus diseases have devastated sugar beets with 'yellows,' peaches with yellows, potatoes with leaf roll and X and Y viruses, cocoa with swollen shoot, clover with sudden death, sugarcane with mosaic, and rice with hoja blanca."[17] After a corn leaf blight had devastated much of the 1970 corn crop, the committee had been convened in order to consider the genetic vulnerability of all major crops. One of the pioneer breeders of hybrid corn, Donald Jones, had foreseen the problems that the loss of genetic diversity might bring: "Genetically uniform pure line varieties are very productive and highly desirable when environmental conditions are favorable and the varieties are well-protected from pests of all kinds. When these external factors are not favorable, the result can be disastrous . . . due to some new virulent parasite."[18]

The logic of epidemiology in crops is relatively straightforward in principle. All plants have some resistance to pathogens; otherwise they and the pathogen (if it preyed upon only that plant) would disappear. At the same time, all plants are genetically vulnerable to certain pathogens. If a field is populated exclusively by genetically identical individuals, such as single-cross hybrids or clones, then each plant is vulnerable in exactly the same way to the same pathogen, be it a virus, fungus, bacterium, or nematode.[19] Such a field is an ideal genetic habitat for the proliferation of precisely those strains or mutants of pathogens that thrive and feed on this particular cultivar. The uniform habitat, especially one in which plants are crowded, exerts a natural-selection pressure, as it were, that favors such pathogens. Given the right seasonal conditions for the pathogen to multiply (temperature, humidity, wind, and so on), the classic conditions for the geometric progression of an epidemic are in place.[20]

In contrast, diversity is the enemy of epidemics. In a field with many species of plants, only a few individuals are likely to be susceptible to a given pathogen, and they are likely to be widely scattered. The mathematical logic of the epidemic is broken.[21] A monocropped field, as the National Research Council report noted, increases vulnerability appreciably inasmuch as all members of the same plant species share much of their genetic inheritance. But where a field is populated by many genetically diverse landraces of a given species, the risk is vastly reduced. Any agricultural practice that increases diversity over time and space, such as crop rotation or mixed cropping on a farm or in a region, acts as a barrier to the spread of epidemics.

The modern regime of pesticide use, which has arisen over the past fifty years, must be seen as an *integral* feature of this genetic vulnerability, not as an unrelated scientific breakthrough. It is precisely because hybrids are so uniform and hence disease prone that quasi-heroic measures have to be taken to control the environment in which they are grown. Such hybrids are analogous to a human patient with a compromised immune system who must be kept in a sterile field lest an opportunistic infection take hold. The sterile field, in this case, has been established by the blanket use of pesticides.[22]

Corn, as the most widely planted crop in the United States (85 million acres in 1986)[23] and the first one to be hybridized, has provided nearly ideal conditions for insect, disease, and weed buildup. Pesticide use is correspondingly high. Corn accounts for one-third of the total market for herbicides and one-quarter of the market for insecticides.[24] One of the long-term effects, which is readily predictable according to the theory of natural selection, has been the emergence of resistant strains among insects, fungi, and weeds, necessitating either larger doses or a new set of chemical agents. Some pathogens, again predictably, have developed what is termed "cross-resistance" to a whole class of pesticides.[25] As more generations of the pathogen are exposed to the pesticide, the likelihood that resistant strains will emerge is correspondingly greater. Above and beyond the troubling consequences of pesticide use for the organic matter in the soil, groundwater quality, human health, and the ecosystem, pesticides have exacerbated some existing crop diseases while creating new ones.[26]

Just prior to the corn leaf blight in the South in 1970, 71 percent of all acreage in corn was planted to only six hybrids. The specialists investigating the blight stressed the pressures of mechanization and product uniformity that led to a radically narrower genetic crop base. "*Uniformity*," the report asserted, "is the key word."[27] Most of the hybrids had been developed by the male-sterile method using "Texas cytoplasm." It was this uniformity that was attacked by the fungus *Helminthosporium maydis;* those hybrids created without Texas cytoplasm suffered only trivial damage. The pathogen was not new; in its report, the National Research Council committee imagined that it was probably in existence when Squanto showed the Pilgrims how to plant corn. While *H. maydis* may have from time to time produced more virulent strains, "American corn was *too variable* to give the new strain a very good foothold."[28] What was new was the vulnerability of the host.

The report went on to document the fact that "most major crops are impressively uniform genetically and impressively vulnerable [to epidemics]."[29] Exotic germ plasm from a rare Mexican landrace proved to be the solution to breeding new hybrids that were less susceptible to the blight. In this and many other cases, it was only the genetic diversity created by a long history of landrace development by nonspecialists that provided a way out.[30] Like the formal order of the planned section of Brasília or collectivized agriculture, modern, simplified, and standardized agriculture depends for its existence on a "dark twin" of informal practices and experience on which it is, ultimately, parasitic.

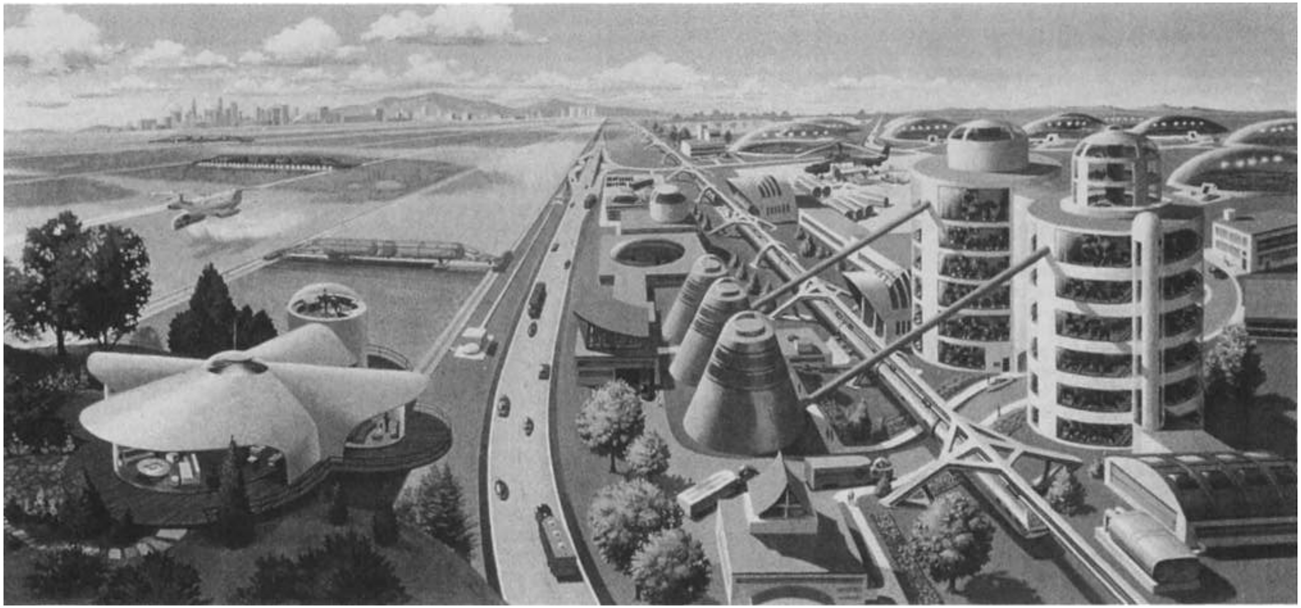
The Catechism of High-Modernist Agriculture

The model and promise of American agricultural modernism was absolutely hegemonic in the three decades from 1945 to 1975. It was the prevailing "export model." Hundreds of irrigation and dam projects modeled roughly on the Tennessee Valley Authority (TVA) were begun; many large and highly capitalized agricultural schemes were inaugurated with great fanfare; and thousands of advisers were dispatched. There was a continuity in personnel as well as in ideas. Economists, engineers, agronomists, and planners who had served in the TVA, the U.S. Department of Agriculture, or the Department of the Treasury moved to the United Nations, the Food and Agriculture Organization, or USAID, bringing their experience and ideas with them. A combination of American political, economic, and military hegemony, the promise of loans and assistance, concerns about world population and food supply, and the great productivity of American agriculture made for a degree of self-confidence in the American model that is hard to overestimate.

A few skeptics like Rachel Carson were beginning to question the model, but they were greatly outnumbered by a chorus of visionaries who saw an unlimited and brilliant future ahead. Typical of the optimism was an article by James B. Billard entitled "More Food for Our Multiplying Millions: The Revolution in American Agriculture," which appeared in a 1970 issue of *National Geographic*.[31] Its vision of the farm of the future, reproduced here in figure 34, was not an idle fantasy; it was, we are told, drawn "with the guidance of U.S. Department of Agriculture specialists." Billard's text is one long paean to mechanization, scientific marvels, and huge scale. For all the technical wizardry, he envisions a process of simplification of the landscape and centralization of command. Fields will be larger, with fewer trees, hedges, and roads; plots may be "several miles long and a hundred yards wide"; "weather control" will prevent hailstorms and tornadoes; atomic energy will "level hills" and make irrigation water from seawater; satellites, sensors, and airplanes will spot plant epidemics while the farmer sits in his control tower.

At the operational level, the credo of American agriculture for export incorporated the same fundamental convictions. Both the exporters and the vast majority of their eager clients were committed to the following truths: the superior technical efficiency of large-scale farms, the importance of mechanization to save labor and break technical bottlenecks, the superiority of monocropping and hybrids over polycropping and landraces, and the advantages of high-input agriculture, including commercial fertilizers and pesticides. Above all, they believed in large, integrated, planned projects rather than piecemeal improvements, partly because the large, capital-intensive schemes could be planned as nearly pure technical exercises, rather like the design of the Soviet collective farm that was invented in a Chicago hotel room. The greater the industrial content of a scheme and the more its environment could be made uniform (through controlled irrigation and nutrients, the use of tractors and combines, the development of flat fields), the less was left to chance.[32] Local soils, local landscape, local labor, local implements, and local weather appeared to be almost irrelevant to the prepackaged projects. At the same time, schemes conceived along these lines emphasized the technical expertise of the planners, the possibility of central control, and, not least, a "module" that could be redeployed to almost any locale. For local elites anxious to have a modern show project over which they could preside, the advantages were also obvious.

The lamentable fate of the vast majority of these projects, whether private or public, is by now a matter of record.[33] They failed in most



34. Illustration of the farm of the future, painted by Davis Meltzer "with the guidance of U.S. Department of Agriculture specialists," from a 1970 issue of *National Geographic*. The caption details the farm of the early twenty-first century: "Grainfields stretch like fairways and cattle pens resemble high-rise apartments. . . . Attached to a modernistic farmhouse, a bubble-topped control tower hums with a computer, weather reports, and a farm-price ticker tape. A remote-controlled tiller-combine glides across the 10-mile-long wheat field on tracks that keep the heavy machine from compacting the soil. Threshed grain, funneled into a pneumatic tube beside the field, flows into storage elevators rising close to a distant city. The same machine that cuts the grain prepares the land for another crop. A similar device waters neighboring strips of soybeans as a jet-powered helicopter sprays insecticides.

"Across a service road, conical mills blend feed for beef cattle, fattening in multilevel pens that conserve ground space. Tubes carry the feed to be mechanically distributed. A central elevator transports the cattle up and down, while a tubular side drain flushes wastes to be broken down for fertilizer. Beside the farther pen, a processing plant packs beef into cylinders for shipment to market by helicopter and monorail. Illuminated plastic domes provide controlled environments for growing high-value crops such as strawberries, tomatoes, and celery. Near a distant lake and recreation area, a pumping station supplies water for the vast operation."

cases despite lavish credit subsidies and strong administrative backing. While each failure had its own peculiarities, the level of abstraction at which most projects were conceived was fatal. Imported faith and abstraction prevailed, as we shall see, over close attention to the local context.

Modernist Faith Versus Local Practices

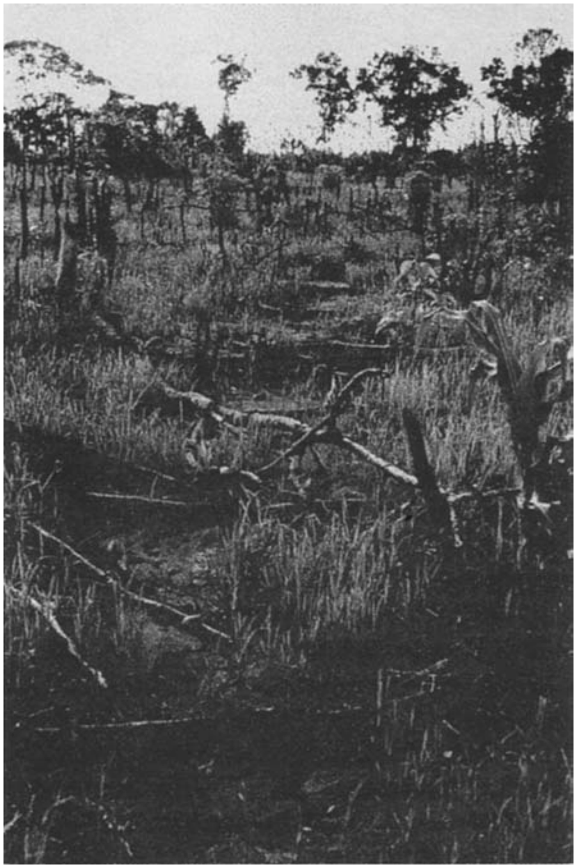
We can explore the contrast between imported faith and local context by juxtaposing several tenets of the catechism of high-modernist agriculture with the local practices that appeared to violate them. And as we shall see, contrary to contemporary expectations, these practices turned out to be scientifically sound and in some cases superior to the program of farming being urged or imposed by the agricultural reformers.

Monoculture and Polyculture

Nothing better illustrates the myopic credo of high-modernist agriculture, originating in temperate zones and brought to the tropics, than its nearly unshakable faith in the superiority of monoculture over the practice of polyculture found in much of the Third World.

To take West African indigenous farming systems as an example, colonial agricultural specialists encountered what seemed to them to be an astonishingly diverse regime of polycropping, with as many as four crops (not to mention subspecies) in the same field simultaneously.[34] A fairly representative instance of what met their eyes is depicted in figure 35. The visual effect, to Western eyes, was one of sloppiness and disorder. Given their visual codification of modern agricultural practice, most specialists knew, without further empirical investigation, that the apparent disorder of the crops was a symptom of backward techniques; it failed the visual test of scientific agriculture. Campaigns to replace polyculture with pure-stand planting were pushed with equal fervor by colonial officials and, after independence, by their local successors.

We have gradually come to understand a quite specific logic of *place*—in particular, tropical soils, climate, and ecology—that helps to explain the functions of polyculture. The diversity of species naturally occurring in a tropical setting is, other things being equal, consistently greater than the diversity of species in a temperate setting. An acre of tropical forest will have far more species of plants, although fewer individuals of each species, than will an acre of temperate woodland. Thus unmanaged nature in temperate climates *looks* more or-



35. Construction of stick bunds across incipient gullies in a Sierra Leone rice field

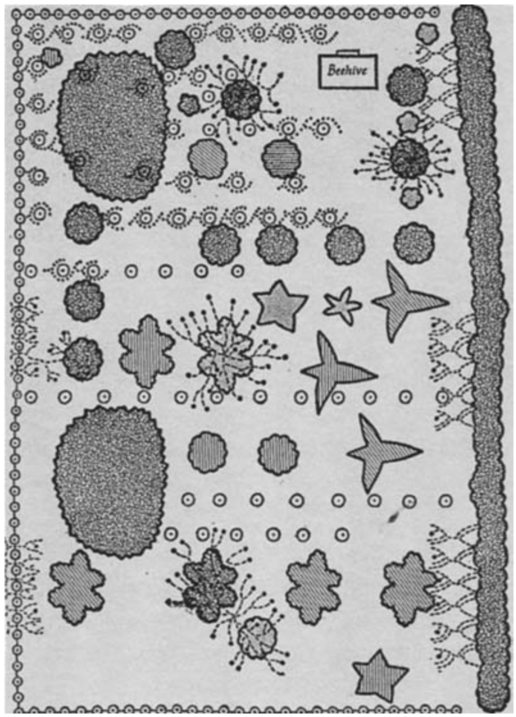
derly because it is less diverse, and this may play a role in the visual culture of Westerners.[35] In favoring polyculture, the tropical cultivator also imitates nature in his techniques of cultivation. Polyculture, like the tropical forest itself, plays an important role in protecting thin soils from the erosive effects of wind, rain, and sunlight. Furthermore, the seasonality of tropical agriculture is governed more by the timing of rains than by temperature. For this reason, a variety of polycropping strategies allows farmers to hedge their bets about the rains, holding the soil with drought-resistant crops and interspersing among them crops that can take best advantage of the rains. Finally, the creation of a uniform, controlled farming environment is intrinsically more difficult in a tropical setting than in a temperate one, and, where population densities are low, the labor requirements of extensive terracing or irrigation are uneconomic in the strict neoclassical sense of the word.

Here one may recall Jane Jacobs's important distinction between visual orderliness on one hand and functional working order on the other. The city desk of a newspaper, a rabbit's intestines, or the interior of an aircraft engine may certainly look messy, but each one reflects, sometimes brilliantly, an order related to the function it performs. In such instances the apparent surface disarray obscures a more profound logic. Polyculture was a floral variant of such order. Only a very few colonial specialists managed to peer behind the visual confusion to its logic. One of them was Howard Jones, a mycologist in Nigeria, who wrote in 1936:

> [To the European] the whole scheme seems . . . laughable and ridiculous, and in the end he would probably conclude that it is merely foolish to crowd different plants together in this childish way so that they may choke one another. Yet if one looks at it more closely there seems a reason for everything. The plants are not growing at random, but have been planted at proper distances on hillocks of soil arranged in such a way that when rain falls it does not waterlog the plants, nor does it pour off the surface and wash away the fine soil. . . . The soil is always occupied and is neither dried up by the sun nor leached out by the rain, as it would be if it were left bare. . . . This is but one of many examples that might be given that should warn us to be very cautious and thorough before we pass judgement upon native agriculture. The whole method of farming and outlook of the farmer are so entirely new to us that we are strongly tempted to call it foolish from an instinctive conservatism.[36]

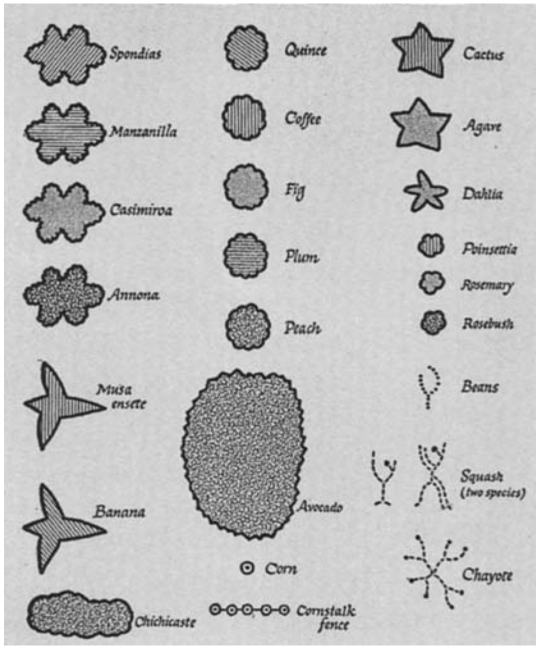
Elsewhere in the tropical world, a few astute observers were uncovering a different agricultural logic. A striking example of visual order versus working order was provided by Edgar Anderson, on the basis of his botanical work in rural Guatemala. He realized that what appeared to be overgrown, "riotous" dump heaps that no Westerner would have taken for gardens exhibited, on closer inspection, an exceptionally efficient and well-thought-out order. Anderson sketched one of these gardens (figures 36 and 37), and his description of the logic he discerned in it is worth quoting at length.

> Though at first sight there seems little order, as soon as we started mapping the garden, we realized that it was planted in fairly definite crosswise rows. There were fruit trees, native and European in great variety: annonas, cherimoyas, avocados, peaches, quinces, plums, a fig, and a few coffeebushes. There were giant cacti grown for their fruit. There was a large plant of rosemary, a plant of rue, some poinsettias, and a fine semiclimbing tea rose. There was a whole row of the native domesticated hawthorn, whose fruits like yellow, doll-size apples, make a de-



36. Edgar Anderson's drawing of an orchard garden in Santa Lucia, Guatemala

licious conserve. There were two varieties of corn, one well past bearing and now serving as a trellis for climbing string beans which were just coming into season, the other, a much taller sort, which was tasseling out. There were specimens of a little banana with smooth wide leaves which are the local substitute for wrapping paper, and are also used instead of cornhusks in cooking the native variant of hot tamales. Over it all clambered the luxuriant vines of the various cucurbits. Chayote, when finally mature, has a large nutritious root weighing several pounds. At one point there was a depression the size of a small bathtub where a chayote root had recently been excavated; this served as a dump heap and compost for the waste from the house. At one end of the garden was a small beehive made from boxes and tin cans. In terms of our American and European equivalents, the garden was a vegetable garden, an orchard, a medicinal garden, a dump heap, a compost heap, and a beeyard. There was no problem of erosion though it was at the top of a steep slope; the soil surface was practically all covered and apparently would be during most of the year. Humidity would be kept during the dry season and plants of the same sort were so isolated from one another by intervening vegetation that pests and diseases could not readily spread from plant to plant. The fertility was being conserved; in addi-



37. In his drawing of an orchard garden in Santa Lucia, Anderson used glyphs that identify not only the plants but also their general categories. Circular glyphs indicate fruit trees of European origin (plum, peach); rounded, irregular glyphs indicate fruit trees of American origin (manzanilla). Dotted lines stand for climbing vegetables, small circles for subshrubs, large stars for succulents, and wedge-shaped figures for plants in the banana family. The narrow mass seen at the right side of figure 36 represents a hedge of chichicaste, a shrub used by the Mayas.

tion to the waste from the house, mature plants were being buried in between the rows when their usefulness was over.

It is frequently said by Europeans and European Americans that time means nothing to an Indian. This garden seemed to me to be a good example of how the Indian, when we look more than superficially into his activities, is budgeting his time more efficiently than we do. The garden was in continuous production but was taking only a little effort at any one time: a few weeds pulled when one came down to pick the squashes, corn and bean plants dug in between the rows when the last of the climbing beans were picked, and a new crop of something else planted above them a few weeks later.[37]

Like the micrologic of the Guatemalan garden, the logic of West African polycropping systems, long dismissed as being primitive, has finally been recognized. In fact, they came under investigation partly as a reaction against the many monocropping schemes that miscarried. The advantages were often evident even at the level of narrow productivist outcomes; and once other goals such as sustainability, conservation, and food security were considered, their advantages seemed especially striking.

Various forms of polyculture are the norm in 80 percent of West Africa's farmland.[38] Given what we now know, this should occasion little surprise. Intercropping systems are best adapted to soils of low fertility, which characterize much of West Africa. Their use produces greater gains in yield on such soils than on soils of high fertility.[39] One reason seems to be that optimal planting densities are greater in intercropping than in monocropping, and the resulting crowding appears, for reasons that are poorly understood but may have to do with root fungi interactions, to improve the performance of each cultivar. Crowding at the later stage of cropping also helps to suppress weeds, which are otherwise a major constraint in tropical farming. Since the mixture of cultivars usually combines grains and legumes (maize and sorghum, for example, with cowpeas and groundnuts), each crop has complementary nutritional needs and rooting systems that extract nutrients from different levels in the soil.[40] In the case of relay cropping, it appears that the residues of the first crop gathered benefit the remaining crop. The diversity of cultivars on the same field also has a beneficial effect on the health of the crops and hence on yields. Mixed crops and the scattering of particular cultivars limit the habitat of various pests, diseases, and weeds that otherwise might build up to devastating proportions, as they do on monocropped plots.[41] In fact, two specialists who were very much out of step with the agronomic establishment of the 1930s and 1940s went so far as to suggest that "the systematic study of mixed cropping and other native practices might lead to comparatively minor modifications in Yoruba and other forms of agriculture, which might in the aggregate do more to increase crop production and soil fertility than revolutionary changes to green manuring or mixed farming."[42]

The multistoried effect of polyculture has some distinct advantages for yields and soil conservation. "Upper-story" crops shade "lower-story" crops, which are selected for their ability to thrive in the cooler soil temperature and increased humidity at ground level. Rainfall reaches the ground not directly but as a fine spray that is absorbed with less damage to soil structure and less erosion. The taller crops often serve as a useful windbreak for the lower crops. Finally, in mixed or relay cropping, a crop is in the field at all times, holding the soil together and reducing the leaching effects that sun, wind, and rain exert, particularly on fragile land. Even if polyculture is not to be preferred on the grounds of immediate yield, there is much to recommend it in terms of sustainability and thus long-term production.

Our discussion of mixed cropping has thus far dealt only with the narrow issues of yield and soil conservation. It has overlooked the cultivators themselves and the various other ends that they seek by using such techniques. The most significant advantage of intercropping, Paul Richards claims, is its great flexibility, "the scope [it] offers for a range of combinations to match individual needs and preferences, local conditions, and changing circumstances within each season and from season to season."[43] Farmers may polycrop in order to avoid labor bottlenecks at planting and at harvest.[44] Growing many different crops is also an obvious way to spread risks and improve food security. Cultivators can reduce the danger of going hungry if they sow, instead of only one or two cultivars, crops of long and short maturity, crops that are drought resistant and those that do well under wetter conditions, crops with different patterns of resistance to pests and diseases, crops that can be stored in the ground with little loss (such as cassava), and crops that mature in the "hungry time" before other crops are gathered.[45] Finally, and perhaps most important, each of these crops is embedded in a distinctive set of social relations. Different members of the household are likely to have different rights and responsibilities with respect to each crop. The planting regimen, in other words, is a reflection of social relations, ritual needs, and culinary tastes; it is not just a production strategy that a profit-maximizing entrepreneur took straight out of the pages of a text in neoclassical economics.

The high-modernist aesthetic and ideology of most colonial agronomists and their Western-trained successors foreclosed a dispassionate examination of local cultivation practices, which were regarded as deplorable customs for which modern, scientific farming was the corrective. A critique of such hegemonic ideas comes, if it comes at all, not from within, but typically from the margins, where the intellectual point of departure and operating assumptions, as was the case with Jacobs, are substantially different. Thus the case for the rationality of mixed cropping has largely come from rogue figures outside the establishment.

Perhaps the most striking of these figures was Albert Howard (later Sir Albert), an agricultural researcher who worked under local patronage for more than three decades in India. He was known chiefly for the Indore process, a scientific procedure of making humus from organic wastes, and unlike most Western agronomists, he was an avid observer of forest ecology and indigenous practices. Concerned above all with soil fertility and sustainable agriculture, Howard observed that the natural diversity of the forest and local polycropping practices were both successful means of maintaining or increasing soil health and fertility. Soil fertility was a matter of not simply chemical composition but also structural properties: the soil's tilth (or crumb structure), its degree of aeration, its moisture-holding power, and the "fungus bridge" (the mycorrhizal association) necessary to humus creation.[46] Some but not all elements in this complex soil interaction could be precisely measured, while others could be recognized by a practiced observer but not readily measured. Howard undertook elaborate experiments in humus production, soil structure, and plant response and was able to show field-trial yield results superior to those achieved by standard Western practices. His main concern, however, was not with how many bushels of wheat or maize could be gotten from an acre as with the health and quality of the crops and soil over the long haul.

The case for polyculture has worked its way back to the West, although it remains one voiced by only a tiny minority. Rachel Carson, in her revolutionary book *Silent Spring*, published in 1962, traced the destructive use of massive doses of pesticides and herbicides to monocropping itself. The problem with insects, she explained, resulted from the "devotion of immense acreage to a single crop. Such a system set the stage for explosive increases in specific insect populations. Single crop farming does not take advantage of the principles by which nature works, it is agriculture as an engineer might conceive it to be. Nature has introduced great variety into the landscape, but man has displayed passion for simplifying it. . . . One important check is a limit on the amount of suitable habitat for each species."[47] Just as Howard believed that monoculture had contributed to the loss of soil fertility and its corrective, the growing use of chemical fertilizers (260 pounds per acre in the United States in 1970), so Carson argued that monoculture spawned the exploding population of pests and its corrective, the massive application of insecticides—a cure that turned out to be worse than the disease.

For these and other reasons, there are at least faint indications that some forms of polycropping might be suitable for Western farmers as well as Africans.[48] This is not the place to attempt to demonstrate the superiority of polyculture over monoculture, nor am I qualified to do so. There is no single, context-free answer to this issue, for answers would depend on any number of variables, including the goals sought, the crops sown, and the microsettings in which they were planted.

What I have tried to demonstrate, however, is that polyculture, even on the narrow production-oriented grounds favored by Western agronomy, merited empirical examination as one among many agricultural strategies. That it was instead dismissed summarily by all but a handful of rogue agronomists is a tribute to the power both of imperialist ideology and of the visual aesthetic of agricultural high modernism.

The case of polyculture also raises an issue relevant to both agricultural practice and social structure, an issue that we will ponder at greater length in the remainder of this book: *the resilience and durability of diversity*. Whatever its other virtues or demerits, polyculture is a more stable, more easily sustainable form of agriculture than monocropping. It is more likely to produce what economists call Hicksian income: income that does not undermine factor endowments, which will permit that income flow to continue indefinitely into the future. Polyculture is, at the same time, more supple and adaptable. That is, it is more easily able to absorb stress and damage without being devastated. Elegant research has recently shown that, at least up to a point, the more cultivars that a given plot has, the more productive and resilient it is.[49] Polyculture, as we have seen, is more resistant to the insults of weather and pests, not to mention more generous in the improvements it effects in the soil. Even if monoculture could be shown to always give superior yields in the short run, polyculture might still be considered to have decisive long-term advantages.[50] The evidence from forestry has some application to agriculture as well: monocropped forests like those in Germany and Japan have led to ecological problems so severe that restoration ecology has been called to the rescue in order to reestablish something approaching the earlier diversity (in insects, flora, and fauna) necessary to the health of the forest.[51]

Here it is worth noting the strong parallel between the case for diversity in cultivation and forestry and the case that Jacobs made for diversity in urban neighborhoods. The more complex the neighborhood, she reasoned, the better it will resist short-term shocks in business conditions and market prices. Diversity, by the same token, provides many potential growth points which can benefit from new opportunities. A highly specialized neighborhood, by contrast, is like a gambler placing all his bets on one turn of the roulette wheel. If he wins, he wins big; if he loses, he may lose everything. For Jacobs, of course, a key point about the diversity of a neighborhood is the *human* ecology it fosters. The variety of locally available goods and services and the complex human networks that it makes possible, the foot traffic that promotes safety, the visual interest that an animated and convenient neighborhood provides—all interact to make such a location's advantages cumulative.[52] The diversity and complexity that cause systems of flora to become more durable and resilient work, at another level apparently, to cause human communities to become more nimble and satisfactory.

Permanent Fields Versus Shifting Cultivation

Most West African farmers practiced some form of shifting cultivation.[53] Variously called slash-and-burn cultivation, swiddening, and rotational bush fallow, shifting cultivation involves the temporary cultivation of a field cleared by cutting and burning most of the vegetation. After being worked for a few years, the field is abandoned for a new plot. Eventually, when new growth has restored the original field to something like its original fertility, it is cultivated again. Polycropping and minimum tillage were often combined with shifting cultivation.

Like polycropping, shifting cultivation, as we shall see, turns out to be a rational, efficient, and sustainable technique under the soil, climate, and social conditions where it is generally practiced. Polycropping and shifting cultivation are almost invariably associated. Harold Conklin's early, detailed, and still unsurpassed account of shifting cultivation in the Philippines noted that, for a newly cleared plot, the *average* number of cultivars in a single season was between forty and sixty.[54] At the same time, shifting cultivation is an exceptionally complex and hence quite illegible form of agriculture from the perspective of a sovereign state and its extension agents. The fields themselves are "fugitive," going in and out of cultivation at irregular intervals—hardly promising material for a cadastral map. The cultivators themselves, of course, are often fugitive as well, moving periodically to be near their new clearings. Registering or monitoring such populations, let alone turning them into easily assessable taxpayers, is a Sisyphean task.[55] The project of the state and the agricultural authorities, as we saw in the Tanzanian case, was to replace this illegible and potentially seditious space with permanent settlements and permanent (preferably monocropped) fields.

Shifting cultivation also gave offense to agricultural modernizers of whatever race, because it violated in almost every respect their understanding of what modern agriculture *had* to look like. "Early attitudes to shifting cultivation were almost entirely negative," Richards notes. "It was a bad system: exploitative, untidy, and misguided."[56] The finely adapted logic of shifting cultivation depended on disturbing the landscape and ecology as little as possible and mimicking, where it could, many of the symbiotic associations of local plants. This meant that such fields looked far more like unimproved nature than the neatly manicured, rectilinear fields that most agricultural officers were used to.

The ecological caution of shifting cultivation, in other words, was the reason behind the appearances that so offended development officials.

Rotational bush fallow had a good many other advantages that were rarely appreciated. It upheld the physical properties of upland and hill soils which, once destroyed, were difficult to restore. The rotation itself, where land was abundant, ensured the long-run stability of the practice. Shifting cultivators rarely removed large trees or stumps—a custom that limited erosion and helped the soil structure but that struck agricultural officials as sloppy and unsightly. With some exceptions, swidden plots were cultivated by hoe or dibble stick rather than plowed. To Westernized agronomists, it appeared that the farmers were merely "scratching the surface" of their soils out of a deplorable ignorance or sloth. Where they encountered farming systems involving deep plowing and monocropping, they believed they had encountered a more advanced and industrious population.[57] The burning of the brush accumulated in clearing a new swidden was also condemned as wasteful. After a time, however, both shallow cultivation and burning were found to be highly beneficial; the former preserved the soil, especially in areas of high rainfall, while the latter reduced pest populations and provided valuable nutrients to the crop. Experiments showed, in fact, that burning the brush *in* the field (rather than hauling it off) contributed to better yields, as did a carefully timed burn.[58]

To someone trained to a Western perspective, the total effect of such cultivation practices had "backwardness" written all over it—heaps of brush waiting to be burned on unplowed, half-cleared fields littered with stumps and planted with several interspersed crops, none of them sown in straight rows. And yet, as the hard evidence accumulated, it was clear that appearances were deceiving, even in productionist terms. As Richards concludes, "The proper test for any practice was whether it worked in the environment concerned, not whether it looked 'advanced' or 'backward.' Testing requires carefully controlled input-output trials. If 'shallow' cultivation on 'partially cleared' land gives better returns relative to the inputs expended than rival systems, and these results can be sustained over time, then the technique is a good one, irrespective of whether it was invented yesterday or a thousand years ago."[59] Lost in the early blanket condemnations of shifting cultivation was the realization that the practice was deployed in a highly discriminating way by African cultivators. Most farmers combined permanent bottomland cultivation of some kind with swidden cultivation of the more fragile hillsides, uplands, or forests. Rather than not knowing any better, as was often assumed, most shifting cultivators were familiar with a range of cropping techniques among which they selected with care.

Fertilizer Versus Fertility

The best fertilizer on any farm is the footsteps of the owner.
—Confucius

Commercial fertilizers have often been touted as magical inoculations for improving poor soils and raising yields; extension agents have routinely referred to fertilizers and pesticides as medicine for the soil. The actual results have often been disappointing. Two major reasons for the disappointment are directly relevant to our larger argument.

First, recommendations for fertilizer applications are inevitably gross simplifications. Their applicability to any *particular* field is questionable, since a map of soil classes is likely to overlook an enormous degree of microvariation between and within fields. The conditions under which fertilizers are applied, the "dosage," the soil structure, the crops for which they are intended, and the weather immediately prior and subsequent to their application can all greatly influence their uptake and effect. As Richards observes, the unavoidable variation by farm and field "requires a more open-ended approach, with, in all probability, farmers doing much of the necessary experimentation for themselves."[60]

Second, fertilizer formulas suffer from an analytical narrowness. The formulas themselves derive from the work of a remarkable German scientist, Justus Freiherr von Liebig, who, in a classic manuscript published in 1840, identified the main chemical nutrients present in the soil and to whom we still owe the current standard fertilizer recipe (N, P, K). It was a brilliant scientific advance, with far-reaching and usually beneficial results. Where it tended to get into trouble, however, was when it posed as "imperial" knowledge—when it was touted as the way in which all soil deficiencies could be remedied.[61] As Howard and others have painstakingly shown, there are a range of intervening variables—including the physical structure of the soil, aeration, tilth, humus, and the fungus bridge—that greatly influence plant nutrition and soil fertility.[62] Chemical fertilizers can in fact so thoroughly oxidize beneficial organic matter as to destroy its crumb structure and contribute to a progressive alkalization and a loss of fertility.[63]

The details are less important than the larger point: an effective soil science must not stop at chemical nutrients; it must encompass elements of physics, bacteriology, entomology, and geology, and that is at a minimum. Ideally, then, a practical approach to fertilizers requires, simultaneously, a general, interdisciplinary knowledge, which a single specialist is unlikely to have, *and* attention to the particularity of a given field, which only the farmer is likely to have. A procedure that blends a purely chemical nutrient perspective with soil classification grids and that leaves the particular field far behind is a recipe for ineffectiveness or even disaster.

A History of "Unauthorized" Innovation

For most colonial officials and their successors, high-modernist commitments led them to form inaccurate assumptions about indigenous agriculture and blinded them to its dynamism. Far from being timeless, static, and rigid, indigenous agricultural practices were constantly being revised and adapted. Some of this plasticity was part of a broad repertoire of techniques that could be adjusted, for example, to different patterns of rainfall, soils, pitches of land, market opportunities, and labor supplies. Most African cultivators were typically utilizing more than one cultivation technique during a season and knew many more that might come in handy. When entirely novel cultivars from the New World became available, they were adopted with alacrity where appropriate. Thus maize, cassava, potatoes, chiles, and a variety of New World pulses and gourds were incorporated into many African planting regimens.[64]

The history of "on-farm" experimentation, selection, and adaptation was, of course, a very old story indeed, both in Africa and elsewhere. Ethnobotany and paleobotany have been able to trace in some historical detail how hybrids and variants of, for example, the main Old World grains or New World maize were selected and propagated for a host of different uses and growing conditions. The same observation holds true for those plants that are vegetatively propagated—that is, propagated by cuttings rather than by seeds.[65]

On a strictly dispassionate view, more specialists would have concluded that there were many grounds for considering every African farm as something of a small-scale experimental station. It stands to reason that any community of cultivators who must wrest their living from a stingy and variable environment will rarely overlook the opportunity to improve their security and food supply. The limits to local knowledge must also be emphasized. Indigenous cultivators knew their own environment and its possibilities remarkably well. But they of course lacked the knowledge that such tools of modern science as the microscope, aerial photography, and scientific plant breeding could provide. They often lacked, as did many cultivators elsewhere, the technology or the access to technology that make, say, large-scale irrigation schemes and highly mechanized agriculture possible. Like peasants in the Mediterranean Basin, China, and India, they were capable of damaging their ecosystem, even if low population densities had thus far spared them from making this mistake.[66] But if most agricultural specialists had appreciated how much the indigenous farmer *did* know, had appreciated her practical, experimental temper and willingness to adopt new crops and techniques when they met local needs, such specialists would have concluded, with Robert Chambers, that "indigenous agricultural knowledge, despite being ignored or overridden by consultant experts, is the single largest knowledge resource not yet mobilized in the development enterprise."[67]

The Institutional Affinities of High-Modernist Agriculture

The willful disdain for local competence shown by most agricultural specialists was not, I believe, simply a case of prejudice (of the educated, urban, and Westernized elite toward the peasantry) or of the aesthetic commitments implicit in high modernism. Rather, official attitudes were also a matter of institutional privilege. To the degree that the cultivators' practices were presumed reasonable until proven otherwise, to the degree that specialists might learn as much from the farmer as vice versa, and to the degree that specialists had to negotiate with farmers as political equals, would the basic premise behind the officials' institutional status and power be undermined. The unspoken logic behind most of the state projects of agricultural modernization was one of consolidating the power of central institutions and diminishing the autonomy of cultivators and their communities vis-à-vis those institutions. Every new material practice altered in some way the existing distribution of power, wealth, and status; and the agricultural specialists' claims to be neutral technicians with no institutional stake in the outcome can hardly be accepted at face value.[68]

The centralizing effects of Soviet collectivization and ujamaa villages were perfectly obvious. So are those of large irrigation projects, where authorities decide when to release the water, how to distribute it, and what water fees to charge, or of agricultural plantations, where the workforce is supervised as if it were in a factory setting.[69] For colonialized farmers, the effect of such centralization and expertise was a radical de-skilling of the cultivators themselves. Even in the context of family farms and a liberal economy, this was in fact the utopian prospect held up by Liberty Hyde Bailey, a plant breeder, apostle of agricultural science, and the chairman of the Country Life Commission under Theodore Roosevelt. Bailey declared, "There will be established in the open country plant doctors, plant breeders, soil experts, health experts, pruning and spraying experts, forest experts, recreation experts, market experts, . . . [and] housekeeping experts, . . . [all of whom are] needed for the purpose of giving special advice and direction."[70] Bailey's future was one organized almost entirely by a managerial elite: "Yet we are not to think of society as founded wholly on small separate tracts, of 'family farms,' occupied by persons who live merely in contentment; this would mean that all landsmen would be essentially laborers. We need to hold on the land many persons who possess large powers of organization, who are managers, who can handle affairs in a bold way: it would be fatal to the best social and spiritual results if such persons could find no adequate opportunities on the land and were forced into other occupations."[71]

In spite of these hopeful pronouncements and intentions, if one examines carefully many of the agricultural innovations of the twentieth century—innovations that seemed purely technical and hence neutral —one cannot but conclude that many of them created commercial and political monopolies that inevitably diminished the autonomy of the farmer. The revolution in hybrid seeds, particularly corn, had this effect.[72] Since hybrids are either sterile or do not breed "true," the seed company that has bred the parents of the hybrid-cross has valuable property in hybrid seed, which it can sell every year, unlike the open-pollinated varieties which the farmer can select himself.[73]

A similar but not identical centralizing logic applied to the high-yielding varieties (HYVs) of wheat, rice, and maize developed over the past thirty years. Their enormous impact on yields (an impact that varied widely by crop and growing conditions) depended on combining a massive response to nitrogen application with short, tough stalks that prevented lodging. Realizing their potential yield required abundant water (usually via irrigation), large applications of commercial fertilizer, and the periodic application of pesticides. Mechanization of field preparation and harvesting was also promoted. As with hybrids, the lack of biological diversity in the fields meant that each generation of HYVs was likely to succumb to infestations of fungus, rust, or insects, necessitating the purchase of new seeds *and* new pesticides (as the insects built up resistance). The resulting biological arms race, which plant breeders and chemists believe that they can continue to win, is one that puts the cultivator increasingly in the hands of public and private specialists. As with the truly democratic aspects of Nyerere's policies, those elements of research and policy that might threaten the position of a managerial elite tended either not to be explored at all or, if explored, to be "selected against" in policy implementation.

The Simplifying Assumptions of Agricultural Science

> This attempt at total control is an invitation to disorder. And the rule seems to be that the more rigid and exclusive is the specialist's boundary, and the stricter the control within it, the more disorder rages around it. One can take a greenhouse and grow summer vegetables in the wintertime, but in doing so one creates a vulnerability to the weather and to the possibility of failure where none existed before. The control by which a tomato plant lives through January is much more problematic than the natural order by which an oak tree or a titmouse lives through January.
> —Wendell Berry, *The Unsettling of America*

Most of the elements of state development programs have not been merely the whims of powerful elites. Even villagization in Tanzania had long been the subject of apparently sound agroeconomic analysis. Schemes for the introduction of such new crops as cotton, tobacco, groundnuts, and rice as well as plans for mechanization, irrigation, and fertilizer regimens had been preceded by lengthy technical studies and field trials. Why, then, have such a large number of these schemes failed to deliver anything like the results foreseen for them? A closely related question, which we will address in the next chapter, is why so many successful changes in agricultural practices and production have been pioneered, not by the state, but by the autonomous initiative of cultivators themselves.

The Isolation of Experimental Variables

The record shows, it seems to me, that a substantial part of the problem lies in the systematic and necessary limitations of scientific work *whenever* the ultimate purpose of that work is practical adoption by a diverse set of practitioners working in a large variety of conditions. That is, some of the problems lie deeper than the institutional temptations to central control, the pathologies of administration, or the penchant for aesthetically satisfying but uneconomic show projects. Even under the best of circumstances, the laboratory results and the data from the experimental plots of research stations are a long country mile from the human and natural environments where they must ultimately find a home.

The normal procedure in scientific agricultural research has historically been to focus almost exclusively on crop-by-crop experiments designed to test the impact of variations in inputs on yields. More recently, other variables have come under scrutiny. Thus experiments might test yields under different soil and moisture conditions or determine which hybrids resisted lodging or ripened in a way that facilitated machine harvesting. Ecologically conscious research has often proceeded in the same fashion: by isolating one by one the variables that might contribute, say, to biological resistance of a certain variety of fruit to a particular pest.

The isolation of a very few variables—ideally just two, while controlling all others—is a key tenet of experimental science.[74] As a procedure, it is both valuable and necessary to scientific work. Only by radically simplifying the experimental situation is it possible to guarantee unambiguous, verifiable, impersonal, and universal results.[75] As a pioneer in chaos theory has put it: "There is a fundamental presumption in physics that the way you understand the world is that you keep isolating its ingredients until you understand the stuff you think is truly fundamental. Then you presume that the other things you don't understand are details. The assumption is that there are a small number of principles that you can discern by looking at things in their pure state—this is the truly analytic notion—and somehow you put these together in some more complicated ways when you want to solve more *dirty* problems. *If you can.*"[76] In agricultural research, controlling for all possible variables except those under experimental scrutiny required normalizing assumptions about such things as weather, soils, and landscapes, not to mention normalizing assumptions, often implicit, about farm size, labor availability, and the desires of cultivators. "Test-tube research," of course, most closely approximated the ideal of controls.[77] Even the experimental plot on a research station, however, was itself a radical simplification. It maximized the degree of control "within a small and highly simplified enclosure" and ignored the rest, leaving it "totally out of control."[78]

It is easy to see how monoculture and attention to quantitative yields would fit most comfortably within this paradigm. Monoculture eliminates all other cultivars that might complicate the design, while concern with quantitative yields avoids the thorny measurement problems that would arise if a particular quality or taste were the objective. The science of forestry is easiest when one is interested only in the commercial wood from a single species of tree. The science of agriculture is easiest when it is a question of the most efficient way of getting as many bushels as possible of one hybrid of maize from a "normalized" acre.

A progressive loss of experimental control occurs when one moves from the laboratory to the research plot on an experimental station and then to field trials on actual farms. Richards notes the unease such a move aroused among researchers in West Africa, who were anxious about making their research more practical yet concerned about any relaxing of experimental conditions. After discussing how the farms selected for trials ought to be relatively homogeneous so that they would respond in uniform ways to the experimental results, the researchers went on to lament the experimental control that they they lost by leaving the research station. "It may be difficult," they wrote, "to plant at all locations within a few days and almost impossible to find farm plots of uniform soil." They continued, "Other types of *interference*, such as pest attacks or bad weather, may affect some treatments and not others."[79] This is, Richards explains, a "salutary reminder of one of the reasons why 'formal' scientific research procedures on experimental stations, with the stress on controlling all variables except the one or two under direct investigation, 'miss the point' as far as many small-holders are concerned. The main concern of farmers is how to cope with these complex interactions and unscheduled events. From the scientist's point of view (particularly in relation to the need to secure clear-cut results for publication), on-farm experimentation poses a tough challenge."[80]

To the extent that science is obliged to deal simultaneously with the complex interactions of many variables, it begins to lose the very characteristics that distinguish it as modern science. Nor does the accumulation of many narrow experimental studies add up to the same thing as a single study of such complexity. This is not, I must repeat, a case against the experimental techniques of modern scientific research. Any extensive, on-farm research study that did not reduce the complexity of interactions might be able to show, as farmers can, that a set of practices produced "good results": say, high yields. But it would not be able to isolate the key factors responsible for this result. The case that I am making instead recognizes the power and utility of scientific work, within its domain, *and* recognizes its limitations in dealing with the kinds of problems for which its techniques are ill suited.

Blind Spots

Returning once again to the case of polyculture, we can see why agronomists might have scientific as well as aesthetic and institutional grounds for opposing polycropping. Complex forms of intercropping introduce *too many variables* into simultaneous play to offer much chance of unambiguous experimental proof of causal relations. We know that certain polycultural techniques, particularly those combining nitrogen-fixing legumes with grains, are quite productive, but we know little about the precise interactions that bring about these results.[81] And we find problems in teasing out causation even when we confine our attention to the single dependent variable of quantitative yields.[82] If we relax this restriction of focus and begin to consider a wider range of dependent variables (outcomes), such as soil fertility, interactions with livestock (fodder, manuring), compatibility with family labor supply, and so on, the difficulties of comparison rapidly become intractable to scientific method.

The nature of the scientific problem here is strongly analogous to that of complexity in physical systems. The elegantly simple formulas of Newton's laws of mechanics make it relatively easy to calculate the orbits of two heavenly bodies once we know their respective masses and the distance between them. Add one more body, however, and the calculation of orbits resulting from the interaction becomes far more complex. When there are ten bodies interacting (this is the *simplified* version of our solar system),[83] no orbits ever exactly repeat themselves, and there is no way to predict the long-term state of the system. As each new variable is introduced, the number of ramifying interactions to be taken into account grows geometrically.

It does not stretch the facts too far, I think, to claim that scientific agricultural research has an elective affinity with agricultural techniques that lie within reach of its powerful methods. Maximizing the yields of pure-stand crops is one technique where its power can be used to best advantage. Insofar as its institutional power has permitted, agricultural agencies, like scientific foresters, have tended to simplify their environments in ways that make them more amenable to their system of knowledge. The forms of agriculture that conformed to their modernist aesthetic and their politico-administrative interests also happened to fit securely within the perimeter of their professional scientific vocation.[84]

What of the "disorder" outside the realm of the experimental design? Extra-experimental interactions can in fact prove beneficial when they strengthen the desired effect.[85] There is no a priori reason for anticipating what their effects might be; what is significant is that they lie wholly outside the experimental model.

Occasionally, however, these effects have been both important and potentially threatening. A striking example from the years between 1947 and 1960 was the massive, worldwide use of pesticides, the most infamous of which was DDT. DDT was sprayed to kill mosquito populations and thereby reduce the many diseases that the pests carry. The experimental model was largely confined to determining the dosage concentrations and application conditions required for eradicating mosquito populations. Within its field of vision, the model was successful; DDT did kill mosquitos and dramatically reduced the incidence of endemic malaria and other diseases.[86] It also had, as we slowly became aware, devastating ecological effects, as residues were absorbed by organisms all along the food chain, of which humans are of course also a part. The consequences of the use of DDT and other pesticides on soil, water, fish, insects, birds, and fauna were so intricate that we have not yet gotten to the bottom of them.

Weak Peripheral Vision

Part of the problem was that the side effects were constantly ramifying. A first-order effect—say, the decline or disappearance of a local insect population—led to changes in flowering plants, which changed the habitat for other plants and for rodents, and so on. Another part of the problem was that the effects of pesticides on other species were examined only under experimental conditions. Yet the application of DDT was under *field* conditions, and as Carson pointed out, scientists had no idea what the interactive effects of pesticides were when they were mixed with water and soil and acted upon by sunlight.

That awareness of these interaction effects came from *outside* the scientific paradigm itself is both interesting and, I think, diagnostic. It began, in particular, when people gradually came to realize that the songbird population had suffered a radical decline. Public alarm at what was *not* happening anymore outside their kitchen windows led, eventually (through scientific research), to a tracing of how DDT concentrations in the organs of birds led to fragile eggshells and reproductive failure. This finding in turn stimulated a host of related inquiries into the effects of pesticides and ultimately to legislation banning the use of DDT. In this case, as in others, the power of the scientific paradigm was achieved partly by its exclusion of extra-experimental variables that have often circled back, as it were, to take their revenge.

The logic of agroeconomic analysis of farming efficiency and profits also wins its power by a comparable restriction of the field of focus. Its tools are used to best advantage in examining the microeconomics of the farm as a firm. On the basis of its necessary simplifying assumptions about factor costs, inputs, weather, labor use, and prices, it can show how profitable or unprofitable it might be to use a particular piece of machinery, to buy irrigation equipment, or to raise one crop rather than another. Studies of this kind and also of marketing have tended to demonstrate the economies of scale achievable by large, highly capitalized, and highly mechanized operations. Outside this narrow perspective are hundreds of considerations that are necessarily bracketed, in a manner similar to that used in experimental science. But here, in agroeconomic analysis, the human agents adopting this view have the political capacity, in the short run at least, to make certain that they are not held economically responsible for the larger "extra-firm" consequences of their logic. The pattern in agriculture in the United States was clearly outlined by a rogue economist testifying to Congress in 1972.

> Only in the past decade has serious attention been given to the fact that the large agricultural firm is . . . able to achieve benefits by externalizing certain costs. The disadvantages of large scale operation fall largely outside the decision-making framework of the large farm firm. Problems of waste disposal, pollution control, added burdens on public service, deterioration of rural social structures, impairment of the tax base, and the political consequences of a concentration of economic power have typically not been considered as costs of large scale, by the firm. They are unquestionably costs to the larger community.
>
> In theory, large scale operation should enable the firm to bring a wide range of both costs and benefits within its internal decision-making framework. In practice the economic and political power that accompanies large scale provides constant temptation to the large firm to take the benefits and pass on the costs.[87]

In other words, although the business analysts of the agricultural firms have weak peripheral vision, the political clout that such firms possess both individually and collectively can help them avoid being blindsided.

Shortsightedness

Nearly all studies purporting to evaluate decisions of interest to farmers are experiments that last one or at most a few seasons. Implicitly, the logic behind a research design of this kind is that the long-run effects will not contradict the short-run findings. The question of the time horizon of research is directly relevant even to those for whom the maximization of yields is the holy grail. Unless they are exclusively interested in immediate yields, no matter what the consequences, their attention must be directed to the issue of sustainability or to Hicksian income. Perhaps the most significant practical division is thus not between those who would design agricultural policy with cultural and social goals in mind (such as the preservation of the family farm, the landscape, or diversity) and those who want to maximize production and profit, but rather between productionists with a short view and productionists with a long view. After all, concern about soil erosion and water supply was motivated less often by regard for the environment than by regard for the sustainability of current production.

The relatively short-run orientation of crop studies and farm economics works to exclude even those long-run results of interest to the productionists. Many of the claims for polyculture, for example, assert its superiority over the long haul as a system of production. A polycropping trial of twenty or more years, as Stephen Marglin has suggested, might well reach conclusions that are quite different from those derived from a trial that lasts a season or two.[88] It is not at all implausible that the process of open pollination and selection by farmers, as opposed to hybridization, might have developed cultivars roughly equal in yield to the best hybrids and superior to them in many other respects, including profitability.[89] The paper profits of scientific, monocropped forests, we now realize, were achieved at considerable cost to the long-term health and productivity of the forest. One would have supposed that since most farms are family enterprises, there would have been more studies of cropping and firm economics that took as their analytical unit of time the entire family cycle of one generation.[90]

Nothing in the logic of the scientific method itself seems to require that a short-run perspective prevail; rather, such a perspective seems to be a response to institutional and perhaps commercial pressures. On the other hand, the need to isolate a few variables while assuming everything else constant and the bracketing of interaction effects that lie outside the experimental model are very definitely inscribed in scientific method. They are a condition of the formidable clarity it achieves within its field of vision. Taken together, the parts of the landscape occluded by actual scientific practice—the blind spots, the periphery, and the long view—also constitute a formidable portion of the real world.

The Simplifying Practice of Scientific Agriculture

Some Yields Are More Equal Than Others

Modern agricultural research commonly proceeds as if yields, per unit of scarce inputs, were the central concern of the farmer. The assumption is enormously convenient; like the commercial wood of scientific forestry, the generic, homologous, uniform commodities thus derived create the possibility both of quantitative comparisons between the yield of different cultivation techniques and of aggregate statistics. The familiar tabulations of acres planted, yields per acre, and total production from year to year are usually the decisive measure of success in a development program.

But the premise that all rice, all corn, and all millet are "equal," however useful, is simply not a plausible assumption about any crop unless it is *purely* a commodity for sale in the market.[91] Each subspecies of grain has distinctive properties, not just in how it grows but in its qualities as a grain once harvested. In some cultures, certain varieties of rice are grown for use in certain distinctive dishes; other varieties of rice may be used only for specific ritual purposes or in the settlement of local debts. Some of the complex considerations that go into distinguishing one rice from another in terms of their cooking properties alone can be appreciated from Richards's observations about how the considerations are weighed in Sierra Leone.

> A phrase like "it cooks badly" is often a catch-all for a range of properties connected with storage, preparation and consumption, going well beyond subjective questions of "taste." Is the variety concerned well-adapted to local food processing techniques? Is it readily peeled, milled, and pounded? How much water and fuel does it require in cooking? How long does it keep, prior to cooking and once cooked? Mende women claim that improved swamp rices are much less palatable than the harder "upland" rices when served up a second time. With the right kind of rice, it is possible to cut down the number of times it is necessary to cook during busy periods on the farm. Since cooking sometimes takes up to 3–4 hours per day (including the time taken to husk rice, prepare a fire and collect water) this is a factor of no small importance when labour is short.[92]

So far, we have considered only the husked grain. What if we broaden our view to take in the rest of the plant? At once we see that there is a great deal more to be harvested from a plant than its seed grains. Thus a Central American peasant may not be interested only in the number and size of the corn kernels she harvested. She may also be interested in using the cobs for fodder and scrub brushes; the husk and leaves for wrappers, thatch, and fodder; and the stalks as trellises for climbing beans, as fodder, and as temporary fencing. The fact that Central American farmers know of many more maize varieties than do their counterparts in the Corn Belt of the United States is partly related to the uses to which different varieties are put. Maize may also be sold in the market for any of these purposes and thus prized for qualities other than its kernels. The same story could, of course, be told about virtually any widely grown cultivar. Its various parts from various stages of growth may come in handy as twine, vegetable dyes, medicinal poultices, greens to eat raw or to cook, packaging material, bedding, or items for ritual or decorative purposes.

Even from a commercial point of view, then, the plant is not simply its grain. Nor are all grains of all subspecies and hybrids of maize and rice equal. The yield of seeds by weight or volume may therefore be only one of many ends—and perhaps not the most important one—for a cultivator. But once scientific agriculture or plant breeding begins to introduce this enormous range of value and uses into its own calculations, it is once again in the Newtonian dilemma of the ten heavenly bodies. And even if it were able to represent some of this complexity in its models, these usages are subject to change without notice.

Experimental Plots Versus Actual Fields

All environments, as we noted earlier, are intractably local. There is always what we might call the translation problem in converting the generic, standardized High Church Latin which emanates from labs and experimental stations into the vernacular of the local parish. Standardized solutions to field preparation, planting schedules, and fertilizer requirements always have to be adjusted when they are applied to, say, a stony, low-lying, north-facing field which has just grown two crops of oats. Agricultural scientists at research stations and extension agents are very much aware of this translation problem, as are specialists in any applied science. The question is always how to discover and convey findings so that they will be helpful to farmers. As long as the findings or solutions are not simply imposed, the farmer must decide if they meet his needs.

Like cadastral maps, the experimental plots of agricultural research stations cannot begin to represent the diversity and variability of farmers' fields. The researchers must operate on the basis of standard, normal-range assumptions about soil, field preparation, weeding, rainfall, temperature, and so on, whereas each farmer's field is a unique concatenation of circumstances, actions, and events, some of which are knowable in advance (soil composition) and some of which are out of anyone's hands (the weather). The *interactions* among these and other variables are at least as important as the status of each; thus the effects of an early monsoon on rocky soil that has just been weeded are different from those of an early monsoon on waterlogged land that has not been weeded.

The averages and normalizations of experimental work obscure the fact that an average weather year or a standard soil is a statistical fiction. As Wendell Berry puts it:

> The industrial version of agriculture has it that farming brings the farmer annually, over and over again, to the same series of problems, to each one of which there is always the same generalized solution, and therefore, that industry's solution can be simply and safely substituted for his solution. But that is false. On a good farm, because of weather and other so-called variables, neither the annual series of problems nor any of the problems individually is ever quite the same two years running. The good farmer (like the artist, the quarterback, the statesman)

> must be master of many possible solutions, one of which he must choose under pressure and apply with skill in the right place at the right time.[93]

Soil, although it is not as capriciously variable day by day as the weather, is often exceptionally variable within the same field. The essential simplifications of agricultural science require, first, that soil be sorted into a small number of categories based on acidity, nitrogen levels, and other qualities. For analyzing the soil of a single field, the practice is to gather bits of soil from several parts of the field and to combine them in the sample to be analyzed so that it will represent an average. This procedure implicitly recognizes the substantial variation in soil quality over a given field. The recommended fertilizer application may therefore not be right for *any* part of the field, but compared to applications derived from other formulas, it will be "less wrong," on average, for the field as a whole. Once again, Berry cautions us against these generalizations: "Most farms, even most fields, are made up of different kinds of soil patterns and soil sense. Good farmers have always known this and have used the land accordingly; they have been careful students of the natural vegetation, soil depth, and structure, slope and drainage. They are not appliers of generalizations, theoretical or methodological or mechanical."[94] When, to the complexity and variation of the soil conditions, we add the practice of polyculture, the obstacles to a successful application of a general formula become virtually insurmountable. The knowledge we do have of the limits on some plants' tolerance of temperature and moisture does not ensure that they will necessarily thrive within these limits. The typical plant is "awfully finicky about just where and when it will grow, under exactly what conditions it will germinate," as Edgar Anderson explains. "The vastly more intricate business of which plants they will and will not tolerate as neighbors and under what conditions, has never been looked into except in a preliminary way for a few species."[95]

Indigenous farmers are exceptionally alert to microfeatures of terrain and environment that are important to cultivation. Two examples from Richards's analysis of West Africa will serve to illustrate the small details that are simply too minute to be visible within a standardizing grid. Among the bewildering variety of small-scale, local irrigation practices, Richards classifies at least eleven different kinds, some with subvariations. All depend directly on locally specific details of topography, soil, flooding, rainfall, and so on, with the type of irrigation used depending on whether the area is a seasonally flooded delta, saucer-shaped depression with poor drainage, or an inland valley swamp. These small "schemes," which take advantage of the existing possibilities of the landscape, are a far cry from vast engineered schemes in which no effort is spared to modify the landscape in conformity with the engineering plan.

Richards's second example shows how West African farmers used a rather simple but ingenious choice in what strain of rice to plant to help them cope with a local pest. Mende farmers on one area of Sierra Leone had, against the textbook advice on the varieties of rice to be preferred, selected a variant of rice with long awns (beard or bristles) and glumes (bracts). The textbook reasoning was probably that such varieties were lower yielding or that the awns and glumes would simply add more chaff that would have to be winnowed after threshing. The farmers' reasoning was that the long awns and glumes discouraged birds from eating the bulk of their rice before it ever made it to the threshing floor. These details about microirrigation and the damage caused by birds are vital for local cultivators, but such details do not and cannot appear on the high-flying mapping of modern agricultural planning.

Many critics of scientific agriculture have claimed not only that it has systematically favored large-scale, production-oriented monoculture but that its research findings are of at best limited use, since all agriculture is local. Howard argued for a fundamentally different practice, basing it on two premises. The first was that experimental plots could not yield helpful results.

> Small plots and farms are very different things. It is impossible to manage a small plot as a self-contained unit in the same way as a good farm is conducted. The essential relation between livestock and the land is lost; there are no means of maintaining the fertility of the soil by suitable rotations as is the rule in good farming. The plot and the farm are obviously out of relation; the plot does not even represent the field in which it occurs. A collection of field plots cannot represent the agricultural problem they set out to investigate. . . . What possible advantage therefore can be obtained by the application of higher mathematics to a technique which is so fundamentally unsound?[96]

Howard's second premise is that many of the most important indications of a farm and a crop's health are *qualitative:* "Can a mutually interacting system like the crop and the soil, for example, dependent on a multitude of factors which are changing from week-to-week and year-to-year, ever be made to yield quantitative results corresponding to the precision of mathematics?"[97] As Howard sees it, the danger is that the narrow, experimental, and exclusively quantitative approach will succeed in completely driving out the other forms of local knowledge and judgment possessed by most cultivators.

But Howard and others, it seems to me, miss the most important abstraction of experimental work in scientific agriculture. How can we define how useful this research is until we know the ends to which cultivators will put it? Useful for what? It is at the level of human agency where scientific agriculture constructs its greatest abstraction: the creation of a stock character, the Everyman cultivator, who is interested only in realizing the greatest yields at the least cost.

Fictional Farmers Versus Real Farmers

Not only are the weather, the crops, and the soil complex and variable; the farmer is, too. Season by season and frequently day by day, millions of cultivators are pursuing an innumerable variety of complicated goals. These goals and the shifting mix between them defy any simple model or description.

Profitable production of one or more major crops, the usual standard of agricultural research, is obviously one purpose shared by most cultivators. It is instructive, nevertheless, to observe how deeply mediated this goal is by other purposes that may indeed usurp it altogether. The complexities I suggest below merely scratch the surface.

Each farm family has its unique endowment of land, skills, tools, and labor, which greatly constrain how it farms. Consider only one aspect of labor supply: a "labor-rich" farm with many able-bodied young workers has options in growing labor-intensive crops, in planting schedules, and in developing artisan sidelines that are not easily available to "labor-poor" farms. Furthermore, the same family farm will go through several stages in the course of a family cycle of development.[98] Farmers who migrate out for wage work during part of the year may plant crops of early or late maturity or crops requiring little care in order to accommodate their migratory schedule.

As we saw earlier, a particular crop's profit may be tied to more than just its yield in grain and the cost of producing it. The stubble of a crop may be crucial as fodder for livestock or waterfowl. A crop may be vital because of what it does to the soil in rotation with other crops or how it assists another crop with which it is interplanted. A crop may be less important for its grain that for what it supplies, in raw material, for artisanal production, whether that material is sold in the market or used at home. Families who live close to the subsistence line may choose their crops, not on the basis of their profitability, but on the basis of how steady their yields are and whether they can be eaten if their market price plunges.

The complexities thus far introduced could, at least in principle, be accommodated within a drastically modified, neoclassical notion of economic maximization, even though it would be too elaborate to model easily. Once we add such considerations as aesthetics, rituals, taste, and social and political considerations, this is no longer the case. There are any number of perfectly rational but noneconomic reasons for wanting to grow a certain crop in a certain way, whether because one wishes to maintain cooperative relations with neighbors or because a particular crop is linked to group identity. Such cultural habits are perfectly compatible with commercial success, as the experience of the Amish, Mennonites, and Hutterites demonstrates. As long as we are pointing to the high level of abstraction of "the farm family" for whom scientific agricultural research does its work, we should note that, in much of the world, an understanding of the practices in use on almost any farm will require distinguishing the purposes of the various members of the family. Each family enterprise is, on closer inspection, a partnership—albeit typically unequal—with its own internal politics.

The units of "farmer" and "farm community" are, finally, every bit as intricate and fluid as the weather, soil, and landscape. Mapping them is even more problematic than, say, analyzing the soil. The reason, I think, is that while the farmer's expertise may occasionally fail him in assessing his own soil, we will not doubt the farmer's expertise in knowing his own mind and interests.[99]

Just as the buzzing complexity and plasticity of customary land tenure practices cannot be satisfactorily represented in the straitjacket of modern freehold property law, so the complex motives and goals of cultivators and the land they farm cannot be effectively portrayed by the standardizations of scientific agriculture. The schematic representations so important for experimental work can and have produced important new knowledge, which, suitably adapted, has been incorporated into most agricultural routines. But such abstractions, again like those of freehold tenure, are powerful misrepresentations that usually circle back to influence reality. They operate, at a minimum, to generate research and findings most applicable to farms that meet the description of their schematization: large, monocropped, mechanized, commercial farms producing solely for the market. In addition, this standardization is typically linked to public policy in the form of tax incentives, loans, price supports, marketing subsidies, and, significantly, handicaps imposed on enterprises that do not fit the schematization, which systematically operate to nudge reality toward the grid of its observations. The effect is nothing like the shock therapy of the campaigns for Soviet collectivization or ujamaa villages, which relied more on sticks than carrots. But over the long haul such a powerful grid can, and does, change the landscape.

Two Agricultural Logics Compared

If the logic of actual farming is one of an inventive, practiced response to a highly variable environment, the logic of scientific agriculture is, by contrast, one of adapting the environment as much as possible to its centralizing and standardizing formulas. Thanks to the pioneering work of Jan Douwe van der Ploeg, it is possible to spell out how this logic works for potato cultivation in the Andes.[100]

Van der Ploeg calls indigenous potato cultivation in the Andes a "craft."[101] The cultivator begins with an exceptionally diverse local ecology and aims at both successfully adapting to it and gradually improving it. Andean farmers' skills have allowed them to achieve results that are quite respectable in terms of narrow productionist goals and extraordinarily so in terms of reliability of yields and sustainability.

The typical farmer cultivates anywhere from twelve to fifteen distinct parcels as well as other plots on a rotating basis.[102] Given the great variety of conditions on each plot (altitude, soil, history of cultivation, slope, orientation to wind and sun), each field is unique. The very idea of a "standard field" in this context is an empty abstraction. "Some fields contain only one cultivar, others between two and ten, sometimes interplanted in the same row or with each in its own row."[103] Each cultivar is a well-placed bet in its niche. The variety of cultivars makes for local experimentation with new crosses and hybrids, each of which is tested and exchanged among farmers, and the many landraces of potatoes thus developed have unique characteristics that become well known. From the appearance of a new variety to its substantial use in the fields takes at least five or six years. Each season is the occasion for a new round of prudent bets, with last season's results in terms of yield, disease, prices, and response to changed plot conditions having been carefully weighed. These farms are market-oriented experiment stations with good yields, great adaptability, and reliability. Perhaps more important, they are not just producing crops; they are reproducing farmers and communities with plant breeding skills, flexible strategies, ecological knowledge, and considerable self-confidence and autonomy.

Compare this "craft-based" potato production with the inherent logic of scientific agriculture. The process begins with the definition of an ideal plant type. "Ideal" is defined mainly, but not only, in terms of yields. Professional plant breeders then begin synthesizing the strains that might combine to form a new genotype with the desired characteristics. Then, and only then, are the plant strains grown in experimental plots in order to determine the conditions under which the potential of the new genotype will be realized. The basic procedure is exactly the reverse of Andean craft production, where the cultivator *begins* with the plot, its soil, and its ecology and then selects or develops varieties that will likely thrive in this setting. The variety of cultivars in such a community is in large part a reflection of the variety of both local needs and ecological conditions. In scientific potato growing, by contrast, the point of departure is the new cultivar or genotype, in service of which every effort is made to transform and homogenize field conditions so that the field meets the genotype's specific requirements.

The logic of beginning with an ideal genotype and then transforming nature to accord with its growing conditions has some predictable consequences. Extension work essentially becomes the attempt to remake the farmer's field to suit the genotype. This usually requires the application of nitrogen fertilizer and pesticides, which must be purchased and applied at the right moment. It usually also requires a watering regimen that in many cases only irrigation can possibly satisfy.[104] The timing of all operations for this genotype (planting, cultivating, fertilizer spreading, and so forth) are spelled out carefully. The logic of the process—a logic not even remotely realized on the ground—is to transform the farmers into "standard" farmers growing the required genotype on similar soils and leveled fields and according to the instructions printed right on the seed packages, applying the same fertilizers, pesticides, and amounts of water. It is a logic of homogenization and the virtual elimination of local knowledge. To the degree that this homogenization is successful, the genotype will likely succeed in terms of production levels in the short run. Conversely, to the degree that such homogenization is impossible, the genotype will fail.

Once the job of the agricultural specialist is defined as one of raising all farmers' plots to the uniform condition that will realize the new cultivar's promise, there is no further need to attend to the great variety of conditions—some of which are unalterable—on actual farmers' fields. Rather than have the facts on the ground muddy a simple, unitary research issue, it was more convenient to try to impose a research abstraction on the fields (and lives) of farmers. Given the intractable ecological variety of the Andes, this was a nearly fatal step.[105] Rarely have agricultural specialists asked themselves, as did the Russian S. P. Fridolin well before the revolution, whether they might not be working from the wrong angle: "He realized that his work was actually harming the peasants. Instead of learning what local conditions were and *then* making agricultural practice fit these conditions better, he had been trying to 'improve' local practice so that it would conform to abstract standards."[106] It is little wonder that scientific agriculture tends to favor the creation of large artificial practices and environments—irrigation schemes, large and leveled fields, the application of fertilizer by formula, greenhouses, pesticides—all of which allow a homogenization and control of nature within which "ideal" experimental conditions for its genotypes can be maintained.

There is, I think, a larger lesson here. An explicit set of rules will take you further when the situation is cut-and-dried. The more static and one-dimensional the stereotype, the less the need for creative interpretation and adaptation. In the Andes, van der Ploeg implies, the "rules" attached to the new potato were so restrictive that they could never be successfully translated to the great variety of local farming vernaculars. One of the major purposes of state simplifications, collectivization, assembly lines, plantations, and planned communities alike is to strip down reality to the bare bones so that the rules will in fact explain more of the situation and provide a better guide to behavior. To the extent that this simplification can be imposed, those who make the rules *can* actually supply crucial guidance and instruction. This, at any rate, is what I take to be the inner logic of social, economic, and productive de-skilling. If the environment can be simplified down to the point where the rules do explain a great deal, those who formulate the rules and techniques have also greatly expanded their power. They have, correspondingly, diminished the power of those who do not. To the degree that they do succeed, cultivators with a high degree of autonomy, skills, experience, self-confidence, and adaptability are replaced by cultivators following instructions. Such reduction in diversity, movement, and life, to recall Jacobs's term, represents a kind of social "taxidermy."

The new potato genotype, as van der Ploeg shows, usually fails, if not immediately, within three or four years. Unlike the ensemble of indigenous varieties, the new cultivar thrives within a narrower band of environmental conditions. *Many* things, in other words, must go right for the new cultivar to produce well, and if *any* of these things goes wrong (too much hot weather, late delivery of fertilizer, and so forth), the yields suffer dramatically. Within a few years the new genotypes "become incapable of generating even low levels of production."[107]

In practice, however, the vast majority of Andean cultivators are neither purely traditional cultivators nor mindless followers of the scientific specialists. They are, instead, crafting unique amalgams of strategies that reflect their aims, their resources, and their local conditions. Where the new potatoes seem to fit their purposes, they may plant some, but they may interplant them with other cultivars and may substitute dung, or plow in green manure (alfalfa, clover), rather than apply the standard fertilizer package. They are constantly inventing and experimenting with different rotations, timing, and weeding techniques. But because of the very particularity of these thousands of "in-field experiments" and the specialists' studied inattention to them, they are illegible, if not invisible, to scientific research. Farmers, being polytheists when it comes to agricultural practice, are quick to seize whatever seems useful from the epistemic work of formal science. But the researchers, trained as monotheists, seem all but incapable of absorbing the informal experimental results of practice.

Conclusion

The great confidence that high-modernist agriculture has inspired among its practitioners and partisans should not surprise us. It *is* associated with unparalleled agricultural productivity in the West and with the power and prestige of the scientific and industrial revolutions. Little wonder, then, that the tenets of high modernism, as talismans of the true faith, should have been carried throughout the world uncritically and indeed with the conviction that they lighted the way to agricultural progress.[108] I believe that this uncritical, and hence unscientific, trust in the artifacts and techniques of what became codified as scientific agriculture was responsible for its failures. The logical companion to a complete faith in a quasi-industrial model of high-modernist agriculture was an often explicit contempt for the practices of actual cultivators and what might be learned from them. Whereas a scientific spirit would have counseled skepticism *and* dispassionate inquiry into these practices, modern agriculture as a blind faith preached scorn and summary dismissal.

Actual cultivators in West Africa and elsewhere should more accurately have been understood as lifelong experimenters conducting in-field seasonal trials, the results of which they incorporated into their ever-evolving repertoire of practices. Inasmuch as these experimenters were and are surrounded by hundreds or thousands of other local experimenters with whom they share research findings and the knowledge of generations of earlier research as codified in folk wisdom, they could be said to have instant access to the popular equivalent of an impressive research library. Now it is also undeniably the case that they carry out most of their research without the proper experimental controls and are therefore prone to drawing false inferences from their findings. They are also limited by what they can observe; microprocesses only visible in the laboratory necessarily escape them. Nor is it clear that the ecological logic that seems to work well on a single farm over the long haul will at the same time produce sustainable aggregate results for an entire region.

That said, it is also the case, however, that West African cultivators have at their disposal a lifetime of careful, local observation and the fine-grained knowledge of the locality that no research scientist can hope to duplicate for the same terrain. And let us not fail to note what kind of experimenters these are. Their lives and the lives of their families depend directly on the outcomes of their field experiments. Given these important positional advantages, one would have imagined that agricultural scientists would have paid attention to what these farmers did know. It was their failure to do so, Howard claims, that constitutes the great shortcoming of modern scientific agriculture: "The approach to the problems of farming must be made from the field, not from the laboratory. The discovery of the things that matter is three quarters of the battle. In this the observant farmer and labourer, who have spent their lives in close contact with nature, can be of greatest help to the investigator. The views of the peasantry in all countries are worthy of respect; there is always good reason for their practices; in matters like the cultivation of mixed crops they themselves are still the pioneers."[109] Howard credits most of his own findings about soil, humus, and root action to a careful observation of indigenous farming practice. And he is rather disdainful of agricultural specialists who "do not have to take their own advice"—that is, who have never had to see their own crop through from planting to harvest.[110]

Why, then, the *unscientific* scorn for practical knowledge? There are at least three reasons for it, as far as I can tell. The first is the "professional" reason mentioned earlier: the more the cultivator knows, the less the importance of the specialist and his institutions. The second is the simple reflex of high modernism: namely, a contempt for history and past knowledge. As the scientist is always associated with the modern and the indigenous cultivator with the past that modernism will banish, the scientist feels that he or she has little to learn from that quarter. The third reason is that practical knowledge is represented and codified in a form uncongenial to scientific agriculture. From a narrow scientific view, *nothing* is known until and unless it is proven in a tightly controlled experiment. Knowledge that arrives in any form other than through the techniques and instruments of formal scientific procedure does not deserve to be taken seriously. The imperial pretense of scientific modernism admits knowledge only if it arrives through the aperture that the experimental method has constructed for its admission. Traditional practices, codified as they are in practice and in folk sayings, are seen presumptively as not meriting attention, let alone verification.

And yet, as we have seen, cultivators have devised and perfected a host of techniques that do work, producing desirable results in crop production, pest control, soil preservation, and so forth. By constantly observing the results of their field experiments and retaining those methods that succeed, the farmers have discovered and refined practices that work, without knowing the precise chemical or physical reasons why they work. In agriculture, as in many other fields, "practice has long preceded theory."[111] And indeed some of these practically successful techniques, which involve a large number of simultaneously interacting variables, may never be fully understood by the techniques of science. We turn, then, to a closer examination of practical knowledge, a kind of knowledge that high modernism has ignored to its peril.