FARM BOUNDARIES AS AGROECOLOGICAL SYSTEMS

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South-central Pennsylvania, framed by the great folds of the Appalachians to the north and west, by the Mason Dixon Line to the south, and by the rise of hills that bound the lower Susquehanna River to the east, was claimed by settler-farmers of western European descent during the early and mid-eighteenth century. They utilized river and stream valleys to gain access to the fertile lowlands and rich uplands of the region, following in the steps of surveyors to mark farm boundaries with timber fences cut from the cloak of forest. The social and ecological imprint of these boundary structures has endured for hundreds of years.[1]

Today this is a patchy domesticated landscape, a mosaic of farms and forest, fields and ravines, pastoral valleys and resistant ridges. This familiar ground has been partitioned many times, but has remained mostly rural. Dividing the fields and pastures are fencerows, wild hedges, and stone fences—some clearly managed and maintained, others overtaken by forest or removed to make way for progress. Overall, a sense of cultural stability and rootedness prevails, yet ecologically this landscape has been anything but stable. Boundary structures provide historical and ecological insight into how agricultural lands were managed and how they changed. In addition, they have become important

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conservation landforms, especially with regard to pollination systems that support bee-dependent agriculture.

An agroecologist uses conservation, history, ecology, and agriculture to see a working landscape holistically, as narrative. My interest in agricultural boundary structures is rooted in agrarian history, bees, and orchards, and the biogeophysical features related to the human manipulation of the landscape. Indeed, recent research on wild bee populations suggests that hedgerows, tree lines, and other boundary structures—heretofore largely overlooked as historical primary sources—can provide clues to the health and productivity of agricultural lands in the past. These clues provide important new opportunities for historians and other scholars to experience boundary structures as more than simply legal borders or edges of cultivation. But, to paraphrase environmental historian Donald Worster, we must first "get out of doors altogether" and walk them.[2]

Setting the Historical Fence

The earliest settler-farmers initially established boundaries with timber zig-zag or snake fencing or the upturned root masses of stumps hauled from the ground by draft animals. To prepare for cultivation, they collected surface stones and tossed them aside (usually toward boundary edges), stashed them under rail fences, or piled them into large stacks of fieldstone in the center of pastures and hayfields. Subsequent deforestation resulted in severe topsoil loss, exposing hundreds of large stone slabs and thousands of fist-sized rocks per field. The settler-farmers collected these each spring after snowmelt and frost heave. As fertile soils were lost, lower soil horizons were exposed, offering a generation's worth of work to remove weathered shards and blocks of parent rock.[3]

Stone dumps grew into linear landscape features. Rock boundaries created suitable habitat for insects, mammals, reptiles, and amphibians that became associated with the farming way of life: black rat snakes, field rodents, toads, chipmunks, skunks, groundhogs, foxes, and wild bees. Catskills naturalist-farmer John Burroughs later wrote of field edges piled high with country rock, a squirrel's hoarding heaven: pockets of ash seeds, acorns, chestnuts, and beechnuts stashed in crevices and hollows. If forgotten and in the right environment, these sprouted the following summer.[4]

As annual cultivation intensified, erosion by wind and rain removed additional surface soils. Stones, long buried by topsoils and upper horizons, erupted from the land as if by magic. As human hands lifted, carried, and stacked millions of rocks, field boundaries and fencerow dumps grew waist high and many times as wide. By the 1840s waste stone had become a commodity, easily mined from boundary piles for use in foundations, chimneys, well linings, springhouses, and root cellars. Constructing the beautiful Pennsylvania stone fence became the work of industrious farmers and laborers who built from the waste heaps miles of elegant drystack stone boundaries.[5]

Evolving from human-constructed boundaries, fencerows matured as wild hedges, offering shelter to livestock, shading country lanes, and providing habitat to hundreds of animal and plant species associated with meadows, grasslands, and open space. The South-central region, however, has no history with human-constructed hedgerows per se. German, Scot-Irish, and English settler-farmers had no reason to construct them. They created large windbreaks and shelterbelts from uncut strips of forest, which were allowed to grow beyond the stone dumps.[6] Instead, our wild, shaggy, and unkempt hedgerows arose from seed dispersal via birds and mammals over time.

FIGURE 1

Early fences kept free-roaming animals out of cultivated land and gardens. These were essential and regularly maintained. As farming methods improved and regional agricultural markets opened for beef by the mid-1800s, wandering livestock once fenced *out* of gardens and crop fields were now fenced *in*, confined to pasture for fattening on clover and hay. To contain the large animals, the settlers raised the stone fences higher and topped them with post and rail and, later, wire. By the Civil War stone fences were multifunctional hybrid boundaries of post, rail, saplings, and shady oaks that created habitat and wildlife corridors (see Figure 1).[7]

Old World Comparisons

South-central Pennsylvania's wild hedges and forested shelterbelts can be compared to the historic planted hedgerows of Europe. Many agricultural boundaries in the United Kingdom, France, and Germany are hundreds to a thousand years old, constructed of quick-growing trees and shrubs to form a living fence. They demarcated property lines, pastures, and fields, and later enclosed the work of peasants, thereby enforcing political-economic constraints upon the land and its people. Combinations of swale and mound planting, wall building, and shelterbelt construction developed as ways to modify agricultural landscapes to serve the purposes of those who owned or worked the land.[8]

Gone wild and woody, crisscrossing the rural European countryside with over 200,000 documented miles of boundary structures, these landforms are now recognized as important conservation corridors. Sheltering some of the most diverse yet vulnerable habitats and landscapes on the European continent, agricultural boundaries have been subject to increasing pressures from development, highway expansion, and agricultural intensification.[9] During the 1980s and 1990s highway expansions destroyed many treasured hedgerows across Europe and the UK. Farmers, rural heritage historians, and conservation constituents in the UK urged local and national governments to provide regulatory protections, while scientific inventories were conducted to ascertain biodiversity and conservation value. Realizing the critical role agricultural boundary lands serve in biodiversity and ecosystem services, agricultural conservation management committees formed while citizen-science projects continue to monitor species and populations from hedgehogs to bumblebees. Conservation groups have made hedgerow conservation their main concern, working with farmers and landowners to repair and restore hedgerows to ecological fitness. The historic art of hedge-laying has re-emerged as a conservation practice, intervening in the process of natural plant succession to purposely disturb, open, and reinvigorate matured woodland with sun and space. These structures, through their rewilding and protection, serve as important refugia for many of Europe's native plants and animals and today are serve as a centerpiece of conservation farming efforts.[10]

Boundaries in Pennsylvania

A winter bird's-eye Google Earth view of historic farmlands of Adams, Cumberland, Perry, Dauphin, Franklin, Lebanon, York, and Lancaster counties in Pennsylvania reveal mile upon mile of stone fence winding through the fields, scrubland, and re-established woodland where farms are abandoned. Though built at a time when much of this landscape was cleared of forest and the Susquehanna carried large sediment loads of eroded soils to the Chesapeake Bay, many south-central Pennsylvania wild hedges still mark the property lines and field edges of working farms. Where the woods have returned, massive waste-stone heaps and scattered walls, buried under a century of forest regrowth and detritus, can easily be observed through a leafless canopy. Unlike the boundary features in Europe, however, few efforts have been made to document and preserve these structures, though locally

FIGURE 2

some farmers do take great pride in rebuilding and renovating hedges and walls along roadsides and pasture borders as beautiful reminders of centuries of agrarian history on the land (see Figure 2).

Coupled Systems: Boundaries and Bees

Small and mid-sized farms dominate the landscape in south-central Pennsylvania. Many of these farms represent generations of agriculturalists that date back to the early eighteenth century. Today, traditional horse-powered Amish and Mennonite farms nestle alongside conventional mechanized farms. A new wave of young farmers is working to reclaim abandoned or neglected lands. Because of the persistence of farming on this landscape over centuries, boundary structures and semi-wild landforms are plentiful. These structures have aged and in their neglect provide rich habitat for wildlife.[11]

As in Europe, North American agricultural and conservation research has recognized the importance of brushy stone fences, wild hedges, multi-species windbreaks, and shelterbelts to biodiversity. The Natural Resource Conservation Service (NRCS) places emphasis on marginal lands to preserve pollinator diversity.[12] The field of agroecology, in particular, pays close attention to the art and craft of ecological restoration on farms to ensure biodiversity, and thus resilience, within our regional food systems. Biodiversity, one of the many ecosystems services required to sustain a farm, includes insect pollinators, predators of insect pests, soil builders, and decomposers.[13]

From the perspective of agricultural landscape ecology, these south-central Pennsylvania farms represent a "coupled system" where environment and society are explicitly linked together. When one system falters or begins to exhibit increasing variability in function, systems connected to it begin to destabilize, or even uncouple in critical ways. Farmers and scientists are concerned that societal pressures are contributing to a decline of pollinators and affecting bee-dependent agriculture such as tree fruits and berries, hay forage, and vegetable crops.[14] Abundant agroecological research in Europe shows that carefully managed boundary structures have high conservation value with regard to wild native bees.[15] Similarly, recent research in the United States reveals that with the conservation management of agricultural boundary lands, pollination services provided by wild bees can meet and exceed the services of managed honey bees.[16] Therefore, boundary structures—heretofore largely overlooked as a historical primary source—can provide clues to the health and productivity of agricultural lands in the past. To more fully understand how this coupled system works, one must understand the nature of wild bees.

Wild Bees at Work

Regionally adapted (and adaptable) wild native bees are critical to sustaining local agriculture. The wild bee population has declined regionally and globally, due in large part to industrial agricultural intensification, landscape fragmentation in rural areas, and changes in larger environmental systems such as climate.[17] Agricultural landscapes that remain scaled appropriately to their surroundings and retain the valuable edge habitat preferred by native bees are proving critical to bee-dependent agriculture.[18]

Most eastern native bee species rely on clearings caused naturally by blow-downs, agricultural open space, and forest thinning created by logging. Disturbance regimes that favor early and mid-successional plant communities and season-long blossom periods have sites that offer dry soils for digging, rocky strata for cavity dens, and the shrubby scrublands, power line right-of-ways, weedy roadsides, and agricultural boundary structures that provide the rich assemblages of forage plants and nesting sites that maintain vibrant bee communities. Overgrown linear boundary features and abandoned pasture provide necessary wildlife corridors that facilitate the flow of insects and animals to and from woodland patches and forests. Research suggests that up to 30 percent of agricultural lands should be maintained in some form of semi-wild succession to favor wild bees.[19]

My own research shows that old drystack stone fences provide invaluable bee space for colonial nesting species such as bumblebees (*Bombus sp.*) that search out and utilize old rodent nests to house new colonies each spring. Solitary bees, the dominant group of North American native bees, do not establish single queen colonies but nest abundantly and gregariously along semi-wild edges in collective patches of individual ground nests, singly in twigs and brush, or in sun-drenched, sandy, dry soils. Many species prefer log and stump piles along field edges in which to excavate cavity nests and galleries. Solitary bee groups such as mason bees (*Osmia sp.*), large meadow bees (*Anthophora sp.*), leaf cutters (*Megachile sp.*), and wool-carder bees (*Anthidium sp.*) proliferate where stone fences border orchards and crop fields. Once landowners and farmers identify these bee resources, land-management decisions can protect and enhance such features, which would otherwise be overlooked for conservation value.[20]

Neglected plank or wire-and-post fencerows are thick with bee-forage plants where livestock are absent or unable to graze them down. These linear grasslands and shrub thickets develop as a result of perching birds and small mammals consuming fruits and berries, then defecating seeds into stone piles and grass banks from their rail or wire perches. Field rodents, chipmunks, and squirrels cache great numbers of seeds and acorns that, when forgotten, germinate the next season. "Bird-and-squirrel" hedges eventually take the place of rotting or abandoned wooden fences and posts, and are ideal habitat for wild bees. Leaf cutter bees, blue orchard bees, plasterers (*Hylaeus*), polyester bees (*Colletids*), sweat bees (*Halictids*), and miner bees (*Adrena*) make up just a few of the native groups that utilize this woody habitat. Opening a mature wild hedge in places will allow sunlight in and encourage shrubby growth. This process also releases nutrients to the soil, provides fire and post wood, and maintains a disturbance regime that favors early successional plants for season-long forage.[21]

Extensive numbers of wild bee genera utilize patchy, overgrown wild hedges, stone fences, and brushy fencerows of the south-central Pennsylvania region, making old overgrown stone fences and wild hedges home to potentially hundreds of wild bee species throughout a growing season.[22] Most landowners and farmers are astounded by the numbers of wild bees already at work in their fields and gardens. It is easy to dismiss a ragged field edge or wild boundary as unsightly by human standards, but it is enriching and

FIGURE 3

profitable to view the same feature through the eyes of wild bees in search of forage and nesting sites. Attending wild bee workshops, taking pasture walks with farmers, or conducting citizen-science surveys can open entirely new ways of looking at working landscapes (see Figure 3).

Conclusion

Agroecology blends the disciplines of agrarian history, entomology, conservation biology, and landscape ecology. Depending on the focus of the work (in my case agro-pollination systems) cultural and natural history, geography, agricultural policy and economics, rural studies and geology blend and blur the edges of disciplines, like a raggedy old fence line, to broaden our perspectives on the value of linked systems of agriculture and nature.[23]

Like a historian immersed in the primary source literature of agricultural history, the agroecologist plunges into the thickets and wild hedges that cover the old walls to find primary evidence of humans on the land. What is found, along the old rotted post-and-rail pasture boundaries and miles of undulating and scattered stone fences, is the persistence and adaptability of nature. It builds upon the work of generations of farmers, who in clearing land built fences and stacked stone, ultimately enriching and benefiting regional agriculture and biodiversity through their labor.

In a landscape such as south-central Pennsylvania, where agricultural and natural areas are nested within each other, it is important to appreciate the coupled systems of farming and ecosystem services that produce our food. A long-settled farming region such as this contains socioecological systems that have co-evolved over centuries to create a modern tapestry of nature and society. The hundreds of species of wild bees native to this region depend in many ways upon the human management of landscapes and, in turn, we depend upon them for the vast agricultural wealth we harvest from the land. Agroecology is the science of sustainable agriculture. In practice, it builds an understanding of the history and the arts of conservation and stewardship that make our agricultural heritage so enduring and productive.

To provide a solid measure of protection for bee-dependent agriculture in south-central Pennsylvania, we need to take a more proactive approach for maintaining the ecological integrity of the land. Taking cues from the hedgerow conservation movement in Europe and the UK, we should draw upon agrarian history to help us manage agricultural landscapes so that future regional food systems are resilient and sustainable.

NOTES

1. The evolution of the New England stone wall and the Pennsylvania stone fence follow similar developments. Whether forests were consumed as heat wood, fuel for iron furnaces, or building material, the near-total deforestation of the Northeast was complete by the time of the Civil War. Eric Sloane, *Our Vanishing Landscape* (New York: Wilfred Funk, 1955), illustrates the evolution of the stone fence in the Northeast from the colonial era to the rise of the industrial exploitation of eastern forests for iron and ore furnaces from the 1840s through the 1860s. A wonderful set of historical dioramas at the Fisher Museum of the Harvard Forest in Petersham, Massachusetts, meticulously document the clearing of lands and the building of walls in New England; see http://via.lib.harvard.edu/via/deliver/deepLinkResults?kw1=dioramas&index1=Anywhere&repositoryLimit=Harvard%20Forest.
2. Donald Worster, "Doing Environmental History," in *The Ends of the Earth*, ed. Donald Worster (New York: Cambridge University Press, 1989), 289.
3. For a geological and mechanical explanation of how fieldstones became more numerous after initial clearing, and the subsequent use of agricultural lands, see Robert M. Thorson, *Stone by Stone: The Magnificent History in New England's Stone Walls* (New York: Walker and Company, 2002).
4. Charles F. Davis, *Harvest of a Quiet Eye: The Natural World of John Burroughs* (Madison, WI: Tamarack Press, 1976).
5. James T. Lemon, "The Agricultural Practices of National Groups in Eighteenth Century Pennsylvania," *Geographical Review* 56, no. 4 (October 1966): 467–96.
6. Ibid.
7. Charles L. Redman and David R. Foster, *Agrarian Landscapes in Transition: Comparisons of Long-Term Ecological and Cultural Change* (New York: Oxford University Press, 2008).
8. E. J. P. Marshall and A. C. Moonen, "Field Margins in Northern Europe: Their Functions and Interactions with Agriculture," *Agriculture, Ecosystems and Environment* 89, nos. 1–2 (April 2002): 5–21.
9. John Warren, Clare Lawson, and Ken Belcher, *The Agri-Environment* (New York: Cambridge University Press, 2008).
10. UK hedgelaying societies, conservation organizations, citizen-science projects, and restoration consultants abound, where it seems every district has its own local group to monitor and protect these important conservation and cultural structures. The National Hedge Laying Society, sponsored by the Prince of Wales, is Britain's primary professional and advisory group for traditional upkeep and planting methods (www.hedgelaying.org). The Royal Society for the Protection of Birds offers wildlife enthusiasts, farmers, and land owners valuable management advice and contacts for funding restoration efforts (www.rsbp.org.uk). Natural England is an important conservation-government advisory group. National regulations and laws pertaining to hedge row conservation may be found on their website (www.naturalengland.org.uk).

11. Ingolf Steffan-Dewenter and Catrin Westphal, "The Interplay of Pollinator Diversity, Pollination Services and Landscape Change," *Journal of Applied Ecology* 45, no. 3 (June 2008): 737–41.
12. The U.S. Department of Agriculture (USDA) recognized the importance of conserving wild bee habitat as concerns over colony collapse disorder began to pose real economic threats to bee-dependent agriculture. Funding through the 2007 Farm Bill supported pollinator habitat conservation and preservation efforts in cost share programs offered through NRCS. USDA, NRCS, "Pollinator Biology and Habitat," *New England Biology Technical Note*, April 2009.
13. USDA, Agricultural Research Service, "Bee Pastures: Floral Havens Where Pollinators Can Prosper," *Agricultural Research Magazine* 58, no. 7 (August 2010): 20–21; Claire Kremen and Richard Cowling, "Managing Ecosystem Services: What Do We Need to Know about Managing Their Ecology?" *Ecology Letters* 8, no. 5 (May 2005): 468–79; and Barbara Gemmill-Herren, Connal Eardley, John Mburu, Wanja Kinuthia, and Dino Martins, "Pollinators," in *Farming with Nature: The Science and Practice of Ecoagriculture*, ed Sara Scherr and Jeffrey McNeely (Washington, DC: Island Press, 2007), 166–77.
14. In response, pollinator conservation programs are available to farmers through NRCS and a growing public awareness of the importance of pollinators to our food systems is bringing much needed attention to the effects of destabilized agroecosystems in this region. See Gary Paul Nabhan et al., "The Potential Consequences of Pollinator Declines on the Conservation of Biodiversity and Stability of Food Crop Yields," *Conservation Biology* 12, no. 1 (February 1998): 8–17; Zoe G. Davies and Andrew S. Pullin, "Are Hedgerows Effective Corridors between Fragments of Woodland Habitat? An Evidence-Based Approach," *Landscape Ecology* 22 (2007): 333–51; J. D. Holland and L. Fahrig, "Landscape Woody Border Increases Insect Diversity in Alfalfa Fields," in *Hedgerows of the World: Their Ecological Functions in Different Landscapes*, ed. Colin Barr and Sandrine Petit, Proceedings of the Tenth Annual Conference of the International Association for Landscape Ecology, Birmingham University (2001), 167–76.
15. Laura E. Hannon and Thomas D. Sisk, "Hedgerows in an Agri-Natural Landscape: Potential Habitat Value for Native Bees," *Biological Conservation* 142, no. 10 (October 2009): 2140–54; Gillian Lye, Kirsty Park, Juliet Osborn, John Holland, and Dave Goulson, "Assessing the Value of Rural Stewardship Schemes for Providing Foraging Resources and Nesting Habitat for Bumblebee Queens (Hymenoptera: Apidae)," *Biological Conservation* 142, no. 10 (October 2009): 2023–32; Richard F. Pywell, William R. Meek, R. G. Loxton, Marek Nowakowski, Claire Carvell, and Ben A. Woodcock, "Ecological Restoration on Farmland Can Drive Beneficial Function Responses in Plant and Invertebrate Communities," *Agriculture, Ecosystems and Environment* 140, nos. 1–2 (January 30, 2011): 62–67.
16. Robbin W. Thorp, "Bumble bees (Hymenoptea: Apidae): Commercial Use and Environmental Concerns," in *For Non-Native Crops, Whence Pollinators of the Future?*, ed. K. Strickler and J. H. Cane, Entomology Society of America, Thomas Say Publications in Entomology (2003): 21–40; Julianna K. Tuell, John S. Ascher, and Rufus Isaacs, "Wild Bees of the Michigan Highbush Blueberry Agroecosystem." *Annals of the Entomological Society of America* 102, no. 2 (March 2009): 275–87; Rachael Winfree, Neal M. Williams, Jonathan Dushoff, and Claire Kremen, "Native Bees Provide Insurance against Ongoing Honey Bee Losses," *Ecology Letters* 10, no. 11 (November 2007): 1105–13.

17. Nabhan et al., "Potential Consequences of Pollinator Declines."
18. Gemmill-Herron et al., "Pollinators"; Kremen and Cowling, "Managing Ecosystem Services"; G. Philip Robertson and Scott M. Swinton, "Reconciling Agricultural Productivity and Environmental Integrity: A Grand Challenge for Agriculture," *Frontiers in Ecology and Environment* 3, no. 1 (February 2005): 38–46; Winfree et al., "Native Bees Provide Insurance against Ongoing Honey Bee Losses."
19. USDA, "Bee Pastures"; Eric Mader, Matthew Shepherd, Mace Vaughn, Scott Hoffman Black, and Gretchen LeBuhn, *Attracting Native Pollinators: Protecting North America's Bees and Butterflies* (North Adams, MA: Storey Publishing, 2011); Pywell et al., "Ecological Restoration on Farmland"; USDA, "Pollinator Biology and Habitat"; Rachael Winfree, Terry Griswold, and Claire Kremen, "Effect of Human Disturbance on Bee Communities in a Forested Ecosystem," *Conservation Biology* 21, no. 1 (February 2007): 213–23.
20. Long-term native bee surveys conducted by the author in north-central Maryland and south-central Pennsylvania, 2005–2012 on agricultural conservation land undergoing ecological and historic landscape structure restoration in two locations: Eden Mill, Pylesville, MD (hedgerows, windbreaks), and Horn Farm, Hellam Township, PA (stone walls, hedgerows). Under the guidance of doctoral advisors Sam Droege, USGS Wild Bee Lab, Beltsville, MD, and Dr. Charles Curtin, Environmental Studies, Antioch University New England.
21. A farmer in Cumberland County, Pennsylvania, relishes in this approach, describing his biannual spot treatment of brushing-out as "bee-tuning my hedgerows." See also Hannon and Sisk, "Hedgerows in an Agri-Natural Landscape"; Holland and L. Fahrig, "Landscape Woody Border Increases Insect Diversity"; Mader et al., *Attracting Native Pollinators*; Cory S. Sheffield, Peter K. Kevan, Sue M. Westby, and Robert F. Smith, "Diversity of Cavity-Nesting Bees (Hymenoptera: Apoidea) Within Apple Orchard and Wild Habitats in the Annapolis Valley, Nova Scotia, Canada," *Canadian Entomology* 140 (2008): 235–49.
22. A short list includes Colletes (polyester bees), Hylaeus (yellow-faced bees), Adrena (mining bees), Perdita (miner bees), Nomia (alkali bees), Dieunomia (large sweat bees), Agapostemon (green sweat bees), Haliticus (sweat bees), Lasioglossum (sweat bees), Sphecodes (cuckoo bees), Hoplitis (mason bees), Osmia (mason bees), Anthidium (wool carder bees), Stelis (cuckoo bees), Coelioxys (cuckoo bees), Megachile (leafcutter bees), Xylocopa (large carpenter bees), Ceratina (small carpenter bees), Nomada (cuckoo bees), Eucera (long-horned bees), Melissodes (long-horned bees), Peponapis (squash bees), Svastra (sunflower bees), Anthophora (digger bees), Centris (mining bees), Bombus (bumble bees) and of course, feral colonies of Apis (honey bees). Wild bee identification guides and host plants are found in Mader et al., *Attracting Native Pollinators*, and the Xerces Society, *Pollinator Conservation Handbook: A Guide to Understanding, Protecting, and Providing Habitat for Native Pollinator Insects* (2003). I also recommend Stephen L. Buchmann and Gary Paul Nabhan, *The Forgotten Pollinators* (Washington, DC: Island Press 1996), to landowners and workshop attendees who wish to learn more about societal, cultural, and agricultural intersections with pollinators through history.
23. Scherr and McNeely, eds., *Farming with Nature*, and Warren, Lawson, and Belcher, *The Agri-Environment*, are two insightful texts that describe the multidisciplinary aspects of agroecology.