Historical Changes in Forest Cover and Land Ownership in a Midwestern U.S. Landscape

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Environmental history in the Midwestern Corn Belt includes changes through time in landowners and their consequent effect on agricultural and uncultivated land resources. We examined these changes in Israel Township, southwestern Ohio, using archival accounts from the mid 1800s, land-cover maps compiled from 1935, 1956, and 1984 aerial images, and land-ownership records from 1912, 1940, 1968, 1974, 1983, and 1989 parcel maps. Historical records document the clearing of beech-maple forests for agriculture and show the economic contributions of forests to early settlement. Between 1935 and 1984, agricultural lands declined from 84 percent to 78 percent and forests increased from 10 percent to 19 percent. These are slight changes in comparison with the more than 90 percent of the uncultivated lands that experienced transitions among land uses. We document a decline in land-cover diversity, with losses in successional lands and most forest growth localized to lower stream valleys and Hueston Woods State Park. The amount of land in farms (≥3-ha tracts) declined slightly, from 99 percent to 88 percent, but 79 percent of the land showed two to three changes in landowners and 16 percent showed four to five changes over the study period. Parcels with low turnover had the greatest percent of their land in forest, larger mean forest-patch sizes, and the greatest percent gains in forest area. Our results support coordinated efforts focused on factors that influence stable farm ownership and promote a diversity of environmental and economic gains from forests in the rural landscape. *Key Words: agrolandscapes, beech-maple forest, conservation, landscape ecology.*

Historical clearing of forested land for agriculture contributed to broad-scale ecological change and many environmental problems in the United States (Williams 1989; Whitney 1994; Leopold 1999). Soil erosion is recognized as a pervasive environmental problem, because it threatens the food-production capacity of the land and affects water supplies (Pimentel et al. 1995). Although the costs associated with soil erosion generate significant concern, recent debates about its estimated magnitude (Pimentel and Skidmore 1999; Trimble and Crosson 2000) and evidence for reduced erosion rates under improved land management (Trimble 1999a, 1999b) show, more positively, the potential and rationale for soil conservation on agricultural lands. Land strategies that reduce soil erosion can be effective and are essential for sustainable agriculture, supporting their importance in all food security and environmental conservation programs (Brown and Wolf 1984).

Improved management of row-crop agriculture is traditionally a primary focus for erosion control. Contour-farming, strip-cropping, and terracing all help control erosion and prevent gully formation by respecting the topography in a way that reduces water runoff (Crasswell 1993; Olson 1994). Gullies are reclaimed by providing ground cover and constructing small earthen dams to reduce water flow and capture sediment. Conservation tillage systems reduce the physical disruption of the soil attributable to plowing or cultivating crops for weed control. Conservation tillage increases the organic matter in the soil, which in turn improves water-holding capacity. These management techniques reduce erosion by buffering slopes, increasing the retention of soil and nutrients by vegetation, and reducing soil disruption on agricultural fields (Crasswell 1993; Olson 1994). The 1975–1992 sediment accretion rate in the agricultural Coon Creek Basin, Wisconsin was about 6 percent of the rate in the 1930s, a change Trimble (1999a) attributes to improvements in agricultural land management after the 1940s.

Although the management of cultivated lands is of critical importance, evidence suggests that the maintenance of uncultivated lands can also contribute significantly to lower rates of erosion and improved water quality in a watershed (Correll 1991; Barrett 1992). Hedgerows and grassed waterways, for example, serve as managed barriers to wind and water erosion (Forman and Baudry 1984; Barrett, Rodenhouse, and Bohlen 1990; Vought et al. 1995). Regrowth forests are of particular interest as

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functional sinks because they can effectively capture and store nutrients, biomass, sediments, and organic matter as they move downslope in a watershed (Lowrance et al. 1984; Peterjohn and Correll 1984). Woody plants reduce the amount of water flow by intercepting it on the foliage, stems, and litter, and also produce soil-pore spaces for water to infiltrate into the soil rather than run over the surface (Oliver and Larson 1990). Agricultural watersheds with some forests, particularly forest buffer strips along streams, are likely to receive lower sediment levels and less nonpoint source pollution, such as agricultural fertilizer, than are streams without forests (Omernik, Abernathy, and Male 1981; Lowrance et al. 1984; Johnson et al. 1997). By slowing and capturing sediment and nutrients from cultivated lands, forest cover directly impacts soil erosion and sedimentation and potentially creates a positive long-term effect on land productivity and water quality. U.S. policies such as the Conservation Reserve Program that promote forest regrowth on highly erodible lands support the ecological role of forests in agricultural landscapes (Dunn et al. 1993).

The apportionment and distribution of agricultural and uncultivated lands occur as the collective result of decisions by individual landowners. According to Williams (1989), forest landscape formation and change is "individual," with a "collective result" that can be only measured by losses and gains to forest over time. Land transformations between forest and agriculture, though localized in their immediate occurrence, contribute to global environmental changes that are "cumulative" and "systemic" in their effect on geographic patterns and processes (Turner and Meyer 1994; cf. Vitousek 1994 for the global implications of land-cover change). Both space and time dimensions are important to the study of human-environment conditions, especially in relation to how humans use the land and the ecological composition, structure, and function of the resulting landscape (cf. Boyden 1992 for studies in biohistory; e.g., Turner and Butzer 1992 for deforestation in the Americas; Black et al. 1998 for agricultural development in the Poulouse bioregion; Hart 1998 for rural land use; Meyer et al. 1998 for climate change). Farm-level decisions about the use of forest resources and land-use changes between forest and agriculture may be reflected in settlement history and the transfer, breakup, or consolidation of land parcels (Foster 1993; Savisky 1993; Kleinman and Erickson 1995). We present a historical study that focuses on landowners and their relationship with regional forest cover as a first step toward unraveling the complexity of land-use decisions and modifying those decisions to include forest conservation in an agricultural landscape.

Study Area and Purpose

With the rise of the Corn Belt in the midwestern United States, nearly all original forest cover was cleared to make way for row-crop agriculture (Hart 1986; Hudson 1994). In Ohio, for example, settlers cleared nearly 85 percent of the land; this later threatened the land's productivity by increasing erosion rates (Lafferty 1979; Cumo 1997). Our study examines land-cover change in Israel Township, a study area of approximately 93 km^2 (36 mi^2) located in the Upper Four-Mile Creek watershed in Preble County, Ohio (Figure 1). Crop production on private farms persists as a major economic activity, and the three small, unincorporated communities of Morning Sun, Fairhaven, and College Corner have a combined population of under 1,000 (USDA 1992). Hueston Woods State Park (1,416 ha) occurs at the base of the Upper Four Mile Creek watershed and takes up about 10 percent of the total township land area (Figure 1).

The Upper Four-Mile Creek watershed is experiencing a serious erosion problem (Vanni et al. 2001). Row crops comprise about 87 percent of the 260-km^2 watershed and contribute to a total gross erosion of about 400,000 metric tons per year (USDA 1992). This rate places the watershed eighteenth out of seventy-four in the state in cropland acres eroding faster than twice the allowable rate. Acton Lake, a 252-ha eutrophic reservoir formed as part of Hueston Woods State Park at the base of the watershed in 1956, has a sedimentation rate of 57,194 metric tons and an average annual total capacity loss of 0.6 percent (Medley et al. 1995; Vanni et al. 2001). Under a joint plan prepared by the Ohio Department of Natural Resources and the Preble County Natural Resources and Conservation Service (USDA 1992), sediment traps are now being constructed along tributary streams in the Upper Four-Mile Creek watershed and extension services and financial incentives are being provided to farm operators for soil conservation.

Three main tributaries flow south through the watershed to Acton Lake in south-central Israel Township (Figure 1; Vanni et al. 2001). Wisconsin glaciation left the township with gently sloping relief that steepens downstream near the streams and more gradually with the rise of the Camden end moraine just north and east of Morning Sun. Russell and Xenia soils predominate in the township, in association with Fincastle on level uplands (Lerch et al. 1969). These soils are fertile, well drained (Russell) to somewhat poorly drained (Fincastle) deep soils that are underlain by calcareous till and capped with a moderately thick (up to 100 cm) layer of loess. Miami and Celina soils occur to the northeast, mostly on the Camden moraine, and are covered by a thin mantle of loess that is underlain

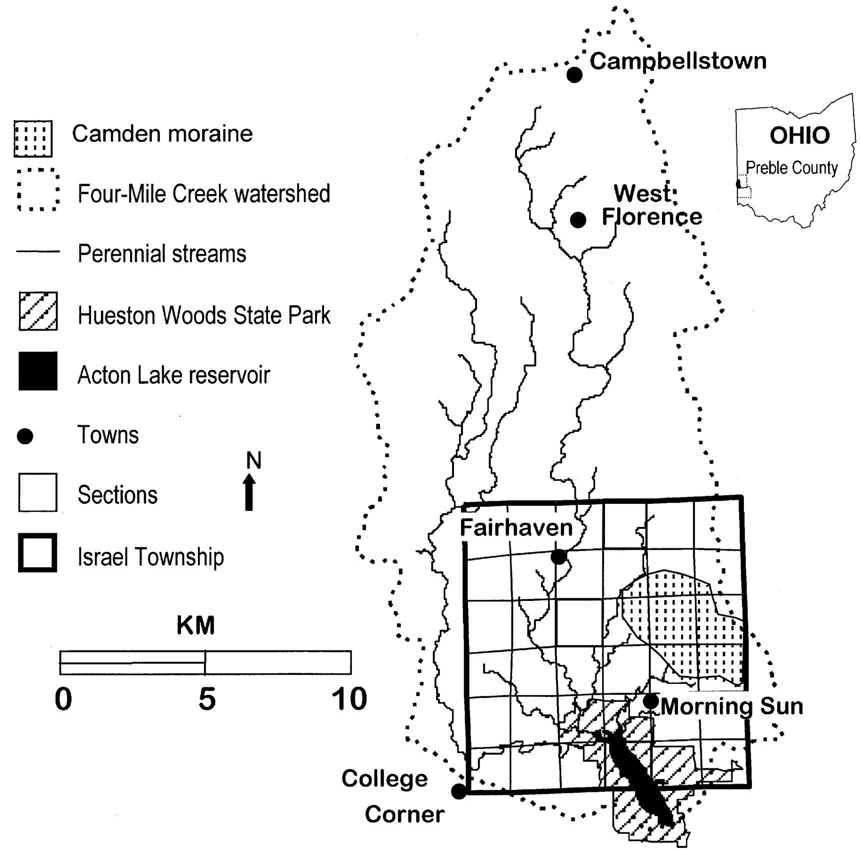

Figure 1. Israel Township, located in the Upper Four-Mile Creek watershed in southwestern Ohio. The township and most of the watershed are located in Preble County, Ohio.

by calcareous till. All of these soils are farmed intensively, and erosion—especially of the silty surface layer—is identified as a major problem. Well-drained Ross soils occur along narrow stream corridors (Lerch et al. 1969).

The environmental history of Israel Township includes changes through time in landowners and their consequent effects on the use and distribution of potential natural vegetation—broadleaf deciduous forests (see Küchler 1964 for North America; Ebinger 1997 for the Midwest). We investigated these changes at regional and farm-level scales by integrating archival descriptive accounts on the activities of European-American landowners from the 1800s with spatial measures of land cover and settlement change after the 1930s. First, our study examines the uses and relative value of forests to the local economy through the historical transformation of the regional landscape to intensive agricultural production and its current challenges for ecological sustainability. Second, measuring the spatial patterns of forest gains and losses in this agricultural landscape, the study focuses locally on relationships with landowners and addresses the question: do the dynamics of land transfers show significant relationships with the amount and landscape patterns of forest cover?

Landownership structure and the rate of turnover in landowners over time is related to changes in attitudes and perceptions on how a land parcel may be managed (cf. Nassauer 1995). Despite the complete transformation of presettlement forest cover with agricultural intensification (Williams 1989), we hypothesized that small areas of remaining forest cover (e.g., farm woodlots) would be more likely to persist on parcels with slow rates of turnover. We predicted that new owners are more likely to make more land-cover changes as they try to mold the property to reflect their beliefs and values, and that landowners that hold onto their property are predicted over time to make fewer changes in land cover. If ownership and forest-cover relationships are identified, they can be used to stratify applied inquiry on *why* different owners choose to use their land differently and to establish conservation strategies that address the consequent influences of different types of owners. The study recognizes the need to integrate historical and spatial perspectives into the analysis of sustainability issues and to reconsider the role forests in this highly modified midwestern agricultural landscape.

Historical Review of Land Management

The *History of Preble County, Ohio* (1881) describes how the first settlers in Israel Township encountered a landscape that was heavily forested, with no clearly discernible patterns imposed by Native Americans (cf. Denevan 1992) or early pioneers. Most of Israel Township was covered by an extensive tract of beech woodland that stretched from the white-oak regions to the south in Hamilton County near Cincinnati, Ohio, and then westward beyond Preble County. These observations concur with the General Land Survey for Israel Township completed between 1799–1800 or prior to European-American settlement. Beech (53 percent), maple (17.4 percent), and ash (13.2 percent) accounted for 83 percent of the 236 witness trees recorded by the surveyors when they mapped the position of section lines in the township (see Butalla 1995). Their survey notes report a forest composition similar to the old-growth beech-maple stand in Hueston Woods State Park, where these same three trees account for 97 percent of the cover in a 1-ha plot (Runkle, Vankat, and Snyder 1984; cf. Braun 1950).

Forests were an obstacle and a resource to the early settlers. The *History of Preble County, Ohio* (1881) presents several accounts of the struggle between the early settlers and the forest. In 1824, Samuel McQuiston proclaimed that the timber was so thick he had to cut away trees to make room for his cabin, which was only 20 square feet ($2\ m^2$). Much of the land was cleared by the ax, by girdling, and by fire. In 1819, Benjamin Morton noted that "[T]he native forest offered a vigorous resistance to the stroke of the woodsman's ax as work of clearing the farm proceeded slowly" (*History of Preble County, Ohio* 1881, 241). Still, the occurrence of high-stature forest identified the relative quality of the land for agricultural production and provided timber and fuel for early settlement.

In the mid- to late 1800s, active sawmills and gristmills marked a time period during which both forest and agricultural resources were of economic importance in the township. In 1874, James Brown was in the sawmill and lumber business with Phillip Murray and Nathan Foster and Murray was the millwright of sawmills on two farms; by 1881, there were stationary mills in Fairhaven and Morning Sun (*History of Preble County, Ohio* 1881). William Ramsey operated the first gristmill, known as the "Corn Cracker," just after 1806. About 1811, Peter Ridenour built a gristmill on the west branch of Four Mile Creek and later joined it with a sawmill operation (*History of Preble County, Ohio*). The 1871 business directories of Morning Sun and Fairhaven include advertisements showing the dual importance of these enterprises: Murray Douglass & Co. Proprietors of Steam Sawmill & Manufacturers of Shingles, Staves; Heading, etc.; Wm. Bell, Proprietor of Sawmill & Manufacturer & Dealer of all kinds of Lumber; Mill on Sec 21 Israel; and U. McDivitt, General Agent for all kinds of Agricultural Implements (Preble County Historical Society 1978). By the mid 1900s, both saw- and gristmills had disappeared from the township, marking a change in the rural economy. The township no longer had an economic supply of timber, and the processing of grain was done at regional centers (e.g., Eaton, the county seat in Preble County). Both the *horizontal* (spatial) and the *vertical* (economic-structural) diversity of the landscape subsequently declined in the study area.

Once the forest was cleared, the fertility of the glacial soils made the region ideal for farming, and the gently rolling land eventually made the region amenable to machine farming. The landscape changed from forest to a mixed landscape of row crops and pasture, and then to a landscape dominated by row-crop production. By 1860, Ohio had become one of the leading corn-producing states, and the region of Illinois, Ohio, Missouri, and Indiana had become known as the Corn Belt (Spencer and Horvath 1963; Hart 1986; Hudson 1994). In the 1912 patrons' directory of Preble County, all thirty-one entries in Israel Township listed their occupation as "Farmer and Stock Raiser" (Preble County Historical Society 1978). By 1964, four principal feed crops (corn, wheat, oats, and hay) occupied more than half the farm acreage, and the sale of livestock and livestock products accounted for approximately half the farm income (Lerch et al. 1969). The environmental history of the Midwest shows a distinct relationship between the early distribution of forest resources and its potential value for other land activities (e.g., Hudson 1994; Ebinger 1997). As an ecoregion, the beech-maple forests of the eastern Corn Belt occur on one of the most productive—and consequently most modified—soil and physiographic settings in North America (Ebinger 1997; Ricketts et al. 1999).

In the fifty years after World War II, intensive cash-grain production replaced mixed-crop and livestock farming, due to the combined effects of new farm technology, economics, and government policy (Hart 1986; Medley et al. 1995). Sitterly (1976) and Birch and Wharton (1982) indicate that in Ohio, the total area of farmland declined after 1940, but the area of harvested grain crops increased after 1954. Intensive cash-grain production put farmers on a "production treadmill," as they adopted new technologies to increase yields and profits (Cochrane 1979). The price of corn stayed relatively the same, while the costs of energy and nutrient supplements increased (Medley et al. 1995). An increase in sown acreage served to maximize returns on investments in machinery, concentrating grain production on fewer and larger farms. The corresponding tenure arrangements through which farmers obtained and used the land also changed, from a predominance of full-owner operators to, now, an abundance of part owners who owned some land and rented some of their land (Hart 1986, 1991). Sitterly (1976) reports that in 1900, about 60 percent of the agricultural land in Ohio was operated by owners who owned all the land (full owners), 29 percent by tenant operators, and less than 10 percent by farmers who owned some and rented some of their land. By 1970, a notable increase had occurred in the number of part owners, to 38 percent, while the number of tenant farmers had decreased to 15 percent and that of full owners to 47 percent of the agricultural land (Sitterly 1976; see also Hart 1991). The ways in which changes in ownership are reflected in the spatial distribution of landowner parcels and corresponding changes in forest cover formed the focus of our spatial analyses in Israel Township. Our findings must be viewed in the context of these regional external factors in the rural economy, how they emerge and change over time, and their consequent effects on land-use practices.

Spatial Data and Methods

Spatial Analysis of Forest Cover, 1935–1984

We measured changes in the distribution of uncultivated lands from three air-photo surveys completed in 1935 (1:13,000), 1956 (1:20,000), and 1984 (1:24,000 from 1:58,000 negatives). Okey (1992) and Butalla (1995) applied a physiognomic classification based on vegetation cover and density to define three land-cover types: forest, successional lands (woodland and old-field/brushland), and hedgerow corridors (Table 1). Since urban land and farm residences comprised only 0.5 percent of the area, they were dropped from the analyses.

The air photos were registered to 1:24,000 base maps for the township, and land-cover patches were digitized through visual interpretation, using the criteria described in Table 1. Each vector-based map was rasterized, using 10 m × 10 m (100 m^2) grid cells as the minimum mapping unit viewed consistently measurable on the air photos for the three time periods. First, we examined the transitions through time in the areas and percentages of different land-cover types. Second, we compared the degree and pattern of fragmentation in forest lands, using the visual interpretation of land-cover maps and GIS measurements of total forest area, patch abundances (#/1000 ha), mean patch areas, and patch shapes. Forest patches bisected by streams or roads were considered single contiguous units. The compactness ratio was calculated to measure patch shapes by dividing the area of a patch by the area of a circle having the same perimeter as the patch, and then taking the square root of this ratio (C varies from 0 to 1; Eastman 1992). These landscape parameters have been shown to influence the structural integrity and ecological functions of forests (e.g., Ryszkowski 1992; Hunter 1999) and potentially their value as a resource in the agricultural landscape (Barrett 1992; Forman 1995).

Spatial Analysis of Land Ownership, 1912–1989

County tax (plat) maps provide a history of ownership that is spatially explicit (see, e.g., Monmonier 1988). Land parcels from 1912, 1940, 1968, 1974, 1983, and 1989 were collected from the Preble County Assessor's Office and from the historical section of the Eaton Public Library, Preble County, Ohio. In order to georegister each parcel map, Butalla (1995) used the roads and township boundary digitized on the compiled 1:24,000 base map. The 1974 plat map, which showed the least distortion, was then registered to the base, and all other parcel maps were digitized in registration with the 1974 map.

Parcel maps were used to identify changes in the: (1) number of landowners; (2) areas of different owner types; (3) mean area of farms; (4) percent land area that changed ownership between time periods; and (5) total turnover. Each owner, identified by their first and last name on the plat maps, was given a unique number that was used to follow ownership changes. For example, we recorded 229 unique owners in 1940 and a total of 682 unique owners

Table 1. Land-Cover Classification for Uncultivated Lands in Israel Township, Ohio, U.S.[a]

Land-Cover Category	Description
Forest	Tree cover at >70% canopy density with a minimum patch length of 130 m and a minimum width of 26 m.
Successional lands	Includes woodland, brushland, and old-field vegetation on abandoned lands. Woodland trees occurred at 5–70% canopy density and were intermixed with shrubs, saplings, and pasture; old-field vegetation exhibited a smooth, even texture, distinguished from grassland by a darker tone; and brushland included shrubs and saplings at a density of 5% or greater. Minimum patch length equaled 130 m, and the minimum width was 26 m.
Hedgerow corridor	Woody linear unit comprised of a single line (e.g., "C"-, "L"-, or "I"-shaped). Branched segments, found on "Y"- or "T"-shaped hedges, for instance, were considered separately for digitizing purposes. These features had a minimum patch length of 130 m and were <26 m wide.

[a]Modified from Okey (1992). Agriculture, including cultivated row crops and pasture, was the dominant land use and formed the background matrix in the township.

through the six time periods (see appendix in Butalla 1995). This numbering system helped to identify owners with more than one parcel and made it possible to track long-term owners and the land area classed as public (e.g., state park, church, cemetery, municipality), farms (sum of owned parcels > 3 ha), and small tracts (sum of owned parcels < 3 ha).

Turnover in landowners was calculated from the overlay of rasterized parcel maps at a grid-cell resolution of 100 m^2, thereby keeping the data consistent with the forest-landscape data. Because each parcel had a unique owner-identification number, the subtraction of different years produced a map of regions with changes in ownership (positive and negative map values) and regions of no change. This procedure was done for consecutive years, calculating the percent of area change for each time period. By adding recoded turnover maps (0 = no change, 1 = change), we compiled a map of total turnover. Some remaining boundary errors, or "slivers of high change," that remained after registration had to be removed because they would have biased the statistics calculated on the forest patches in areas of rapid turnover (Butalla 1995, 29). The problem was resolved by converting all parcel boundaries to nondata and removing the overlay of these lines from the comparison of turnover in land ownership.

Forest-Cover and Landowner Relationships

Forest cover and its structural configuration were compared among areas that experienced different rates of turnover: rapid = parcels that changed ownership four to five times, or about every thirteen to fifteen years; moderate = areas with two to three changes, or about every nineteen to twenty-six years; and slow = areas with one or no recorded changes over at least thirty-eight years. Although the use of first and last names in distinguishing unique owners allowed the study to record within family transfers, it was not possible to confirm the nature of the family ties or distinguish inheritance from sale transfers for each owner on the plat maps. We used these data to examine the hypothesis that forest cover is greater and more stable on parcels with low rates of turnover.

Results

Spatial Analysis of Forest Cover, 1935–1984

Land-cover percentages in Israel Township are typical for the midwestern Corn Belt, with a continued predominance of agriculture throughout the sampling period (Figure 2). The development in the 1950s of the 252-ha reservoir Acton Lake and surrounding 1,416-ha Hueston Woods State Park was correlated with a slight drop in agriculture, from 84 percent in 1935 to 78 percent of the township in 1984, and a corresponding increase in forest cover, from 10 percent to 19 percent. Roughly 47 percent of the total forest area in 1984 occurred in the park, and 50 percent of the increase in forest area over the study period is attributable to growth within the park's boundary. The increase in forest cover is only partially attributable to a loss in agriculture. Successional lands also contribute to the change in forest cover, with a notable drop in their relative cover from 6 percent in 1935 to 3.3 percent in 1984. Hedgerows remained at less than 0.4 percent of the township. Israel Township remains a predominantly agricultural landscape, with only slight changes in the total acreage and, accordingly, the proportions of uncultivated lands.

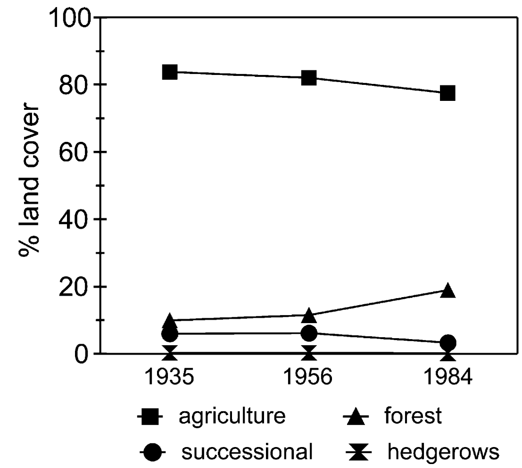

Figure 2. Land-cover percentages for 1935, 1956, and 1984 in Israel Township, Ohio.

Despite a low amount of change in land-area percentages, the transitional dynamics of the landscape were profound. Land-cover changes in Israel Township occurred on 21 percent and 28 percent of the land in the 1935–1956 and 1956–1984 time periods, respectively (Table 2). When only the uncultivated lands are considered, the transitions are much higher. Between 1935 and 1984, 83 percent of the agricultural land remained stable, in contrast to 35 percent of the forest, 12 percent of the successional lands, and 1.6 percent of the hedgerow acreage (Figure 3). Only 6.6 percent of the uncultivated land area stayed in the same land cover for the three time periods, in contrast to 72 percent of the agricultural land. These findings—which consider only changes between the respective endpoints of 1935, 1956 and 1984, not changes between the years—show a high degree of turnover toward and among uncultivated land-cover

Table 2. Transition Matrices Showing the Land-Cover Changes among the Uncultivated (Forest, Successional Lands, Hedgerows) and Agricultural (Row Crops and Pasture) Lands between Two Time Periods, 1935–1956 and 1956–1984

	1956 Land Cover			
1935 Land Cover	Agriculture (7,648)	Forest (1,072)	Successional (575)	Hedgerow (32)
Agriculture (7,812)	7,311	211	263	27
Forest (928)	159	695	73	1
Successional (563)	160	164	238	1
Hedgerow (24)	18	2	1	3
	1984 Land Cover			
1956 Land Cover	Agriculture (7,232)	Forest (1,770)	Successional (304)	Hedgerow (21)
Agriculture (7,648)	6,875	606	149	18
Forest (1,072)	177	847	47	1
Successional (575)	158	310	106	1
Hedgerow (32)	22	7	2	1

Note: All land areas are rounded to hectares (total = 9,327 ha).

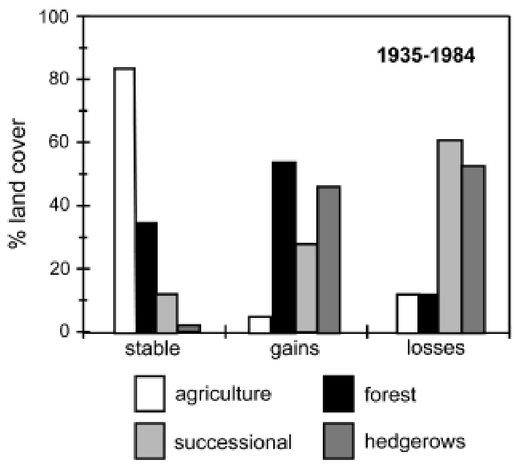

Figure 3. Land-cover stability between 1935 and 1984, showing the percent areas that remained in the same land-cover type (stable) and the amount that a cover type gained or lost.

types. Whereas some of the change in uncultivated lands may be explained by gains in forest area upon the establishment of a protected area and regrowth on successional lands, the transition matrices show that small amounts of land were going in and out of agriculture during the study period (Table 2).

Not only did forest land increase from 928 ha in 1935 to 1770 ha in 1984, but it also became more concentrated in the south-central part of the township and along stream corridors (Figure 4). The configuration of uncultivated lands shows a spatial polarization, designating uplands to agriculture and taking stream corridors out of production. Natural regrowth and the planting of pine plantations in Hueston Woods State Park increased its forest area to about 839 ha by 1984, or nearly half of the total forest area in the township. Approximately 30 to 40 percent of the forest patches had over 50 percent of their land area within

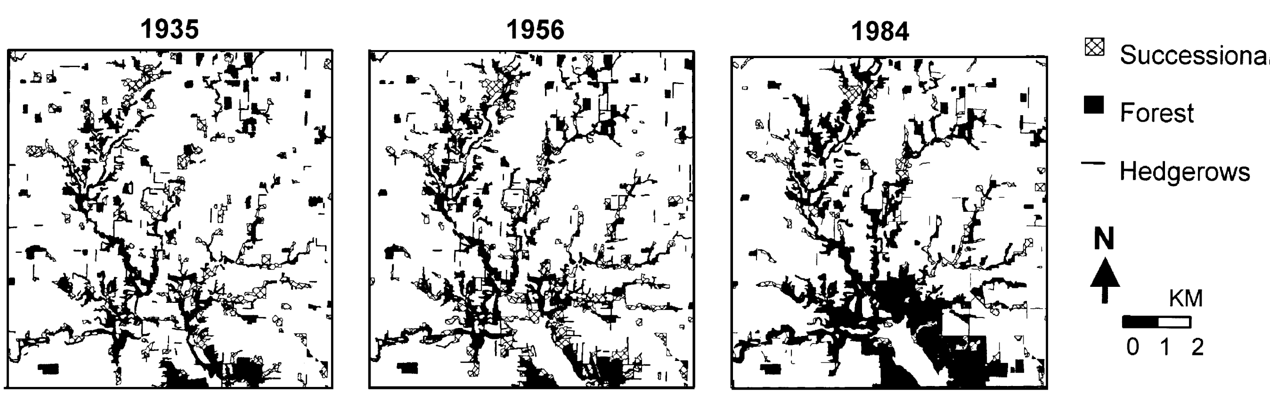

Figure 4. Land-cover types for Israel Township in 1935, 1956, and 1984.

50 m of a stream between 1935 and 1984, and all upland areas stayed in production. Forest patches emerged on the landscape between 1935 and 1956, with an increase in density from 22 to 24 patches per 1,000 ha, and then were either lost or became consolidated, with a decrease to 10 patches per 1,000 ha by 1984. Forest sizes increased by about 304 percent, from a mean of 4.6 ha (s.d. = 12.1, n = 205) in 1935 to 18.6 ha (s.d. = 89.8, n = 93) in 1984, and forest shapes measured by the compactness ratio became more complex, from 0.30 to 0.24. The increased complexity of forest patches may be explained by the consolidation of smaller patches along irregular stream corridors and also a loss of small, more rectangular woodlots from the uplands. The increase in mean forest size through the study period is significant ($T = 2.68$ between 1935 and 1984, prob. < 0.01).

Spatial Analysis of Land Ownership, 1912–1989

Three ownership types—farms ($\geq$3-ha tracts), small tracts ($<$3-ha), and public land—were identified in Israel Township (Figure 5A) when the communities of Fairhaven, Morning Sun, and College Corner were removed from the analysis. In 1912, about 99 percent of the land was classed as farms and 1 percent was in small tracts and public lands combined. Upon the addition of Hueston Woods State Park (1,416 ha) in the 1950s, the percent of land as farm tracts dropped to 88 percent by 1968, and then showed only a slight ($<$1 percent) decline by 1989. Small tracts remained at $<$1 percent, but did show a 100-percent increase, from 0.4 percent in 1968 to 0.8 percent in 1989.

The number of farm owners decreased from 202 in 1912 to 152 in 1989, despite the small change in the land-cover proportions of farms (Figure 5). The most significant change occurred between 1940 and 1968, when the number of farm-tract owners dropped about 30 percent, to a study-period minimum of 143 owners (Figure 5b). Likewise, a corresponding decline occurred in the number of farm parcels, from 213 in 1912 to 160 in 1968, though there were 177 by 1989. The formation of the park (19 parcels) only partially explains the decline in $\geq$3-ha parcels. Consolidation by 1968, mostly from two parcels to one parcel, is evident over most of the township, especially on uplands to the west and east (see Figure 6 for three time periods; see also Butalla 1995 for all six time periods). Since the establishment of the state park in the 1950s, consolidation on the uplands has been coupled with the breakup of parcels, especially around the park boundary and near the main branch of Four-Mile Creek (see Figure 1). Also evident through the time period is an increase in the number of landowners that own two parcels versus one

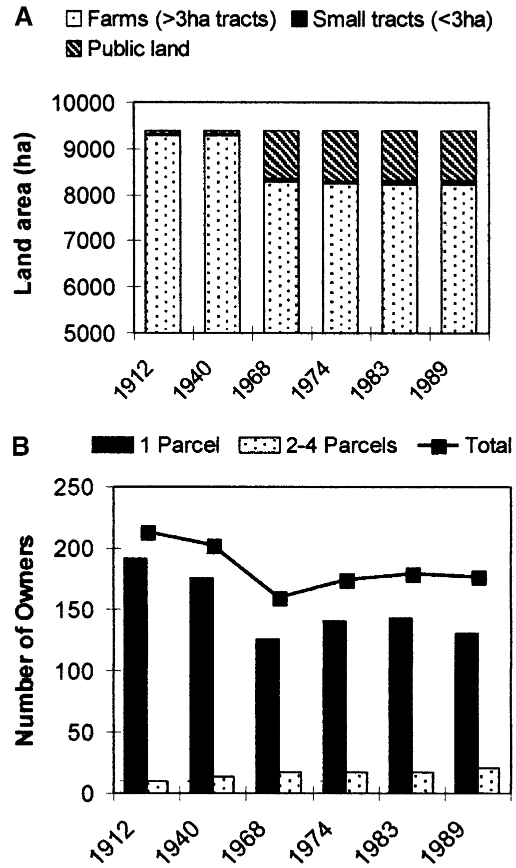

Figure 5. Structure of land ownership, 1912–1989. (A) Change in ownership types; (B) Change in the number of farm ($>$3-ha tract) owners.

parcel, from just less than 5 percent in 1912 to 14 percent in 1989 (Figure 5B). The overall trend was toward increasing the number and size of land units owned by one person or family, but parcels broke up and consolidated at different locations across the township.

Farm parcels showed a significant but low increase in mean areas, from 46 ha (n = 213) in 1912 to a high of 58 ha (n = 160) in 1968, and then a final average of 54 ha (n = 177) in 1989 ($T = 2.25$ between 1912 and 1989, prob. < 0.05). The variability in parcel sizes, however, increased significantly, from a low standard deviation of 29 ha in 1912 to 37 ha in 1968 and 41 ha in 1989 ($F = 2.0$ between 1912 and 1989, prob. < 0.001), a trend that may be attributable to consolidation and parcelization occurring at different locations in the township. The average size of farm parcels for the township was greater than those for the state of Ohio, where Sitterly (1976) measured 90 acres (36 ha) in the first decade of the twentieth century and an increase to 98 acres (39 ha) by 1930.

Despite the seemingly low rates of change in the number of landowners and the mean size of farm parcels, the turnover of landowners in Israel Township was high.

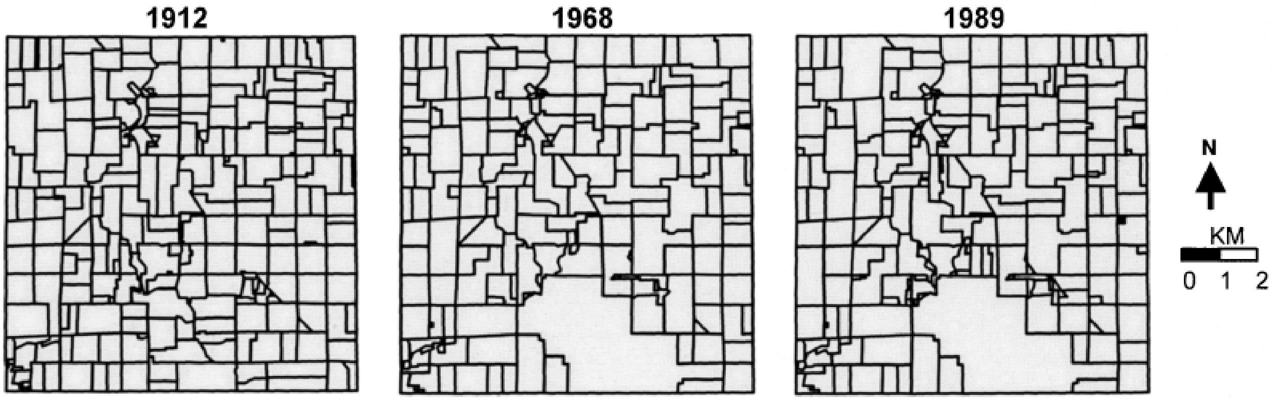

Figure 6. Parcel maps compiled for 1912, 1968, and 1989, showing the consolidation of parcels in the northeast and west and the break-up of parcels along the main stream valley north of Hueston Woods State Park.

Over 85 percent of the land area changed ownership between 1912 and 1940 and between 1940 and 1968. Because these first two intervals were twenty-eight years long, the last three intervals (between 1968 and 1974, 1974 and 1983, and 1983 and 1989) were combined to measure an ownership turnover between 1968 and 1989 that sank slightly but remained high, at 62 percent of the land. During the whole time period, 99.6 percent of the land area changed ownership at least once. The majority of the township experienced moderate turnover (two to three changes; 79 percent), and locations where rates were low (zero changes to one change; 4 percent) and high (four to five changes; 16 percent) were scattered—that is, they showed no interpretable distribution across the township (Figure 7). One might predict at least one ownership change through sale or inheritance during the approximately seventy-seven-year-long time period (low turnover); lands experiencing four or more changes—or changes at least every fifteen years—represent less stable ownership.

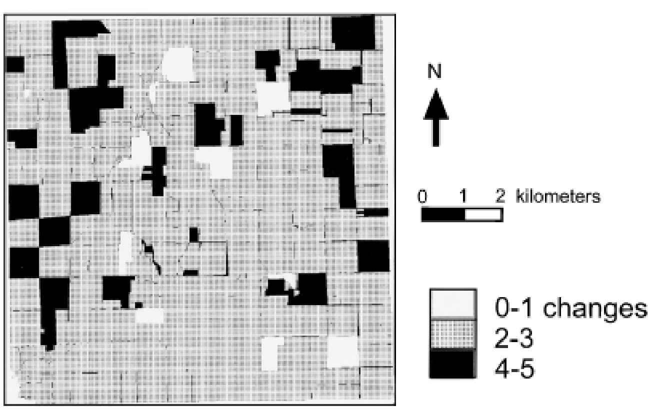

Figure 7. Low (zero changes to one change), moderate (two to three changes), and high (four to five changes) turnover for Israel Township compiled between the years 1912, 1940, 1968, 1974, 1983, and 1989. Black line features represent remaining registration errors between parcel maps and are not included as areas of high turnover.

Forest-Cover and Landowner Relationships

Land areas classed by their turnover rate differ notably in the percentage of their land that is in forest, from about 30 percent on lands of low turnover (zero changes to one change) to 20 percent on lands of moderate turnover (two to three changes) to 12 percent on lands of high turnover (four to five changes; see Figure 8A). Most of the forest area in 1984 occurred on parcels that had experienced moderate turnover since 1912, or changes in ownership every nineteen to twenty-six years (Figure 8A). Hueston Woods State Park, the largest contiguous forest area in the township, occurs where there were two ownership changes (one private owner and then acquisition by the state of Ohio). Together, land areas of moderate turnover comprise 84 percent of the total forest area, in comparison with 7 percent on lands with zero changes to one change (low turnover) and 9 percent on lands that changed four to five times (high turnover). Furthermore, the mean patch sizes of forests were significantly greater on lands with low turnover (5.3 ha; s.d. = 7.1 ha, n = 25) than on lands with high turnover (2.2 ha; s.d. = 3.4, n = 74; T = 3.0, prob. <0.01). Land areas that experienced a larger number of changes have less of their land in forest and smaller patch sizes.

Forest area increased between 1935 to 1984 on all land areas, but the amounts of increase differ in relation to ownership turnover (Figure 8B). The low-turnover category shows the greatest percent change in forest, with a 172-percent increase from 47 ha in 1935 to 127 ha in 1984. The moderate-turnover category had the second largest increase, with a 94-percent increase from 771 ha to

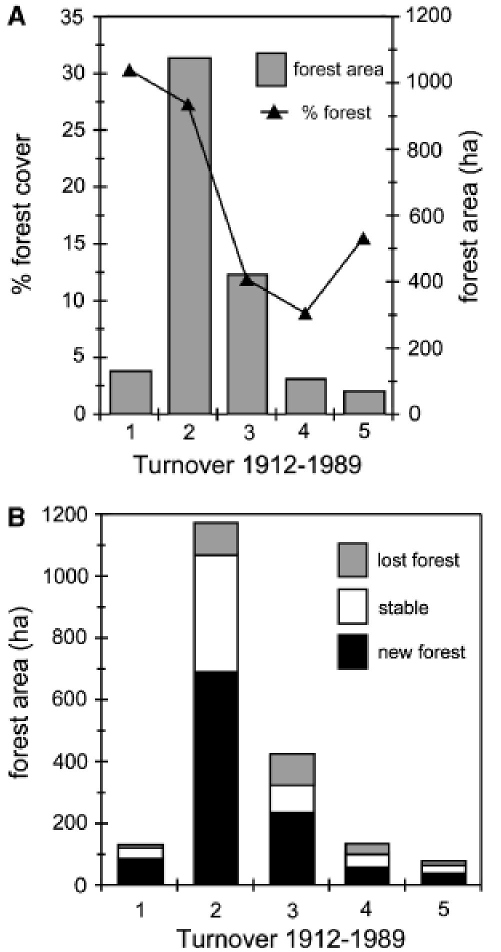

Figure 8. Forest land area by parcels with one to five changes in ownership between 1912 and 1989. (A) Forest area in hectares and the percent forest area by turnover category; (B) Forest area (ha) that remained stable, was lost, or was gained between 1935 and 1984.

1,492 ha. These changes in land area correspond with changes in forest structure. Parcels with low turnover show a significant increase in the mean area of forest patches, from 1.7 ha (s.d. = 2.9, n = 28) in 1935 to 5.3 ha (s.d. = 7.1, n = 25) in 1984 (T = 2.46, prob. <0.01), and the greatest decrease in forest patch density (from 64 to 57/1,000 ha). Forest stability, originally hypothesized to be greater on lands of low turnover, varies little (from 32 percent for low to 41 percent for high; Figure 8B). Lands that experienced greater turnover, however, show higher percentages of forest lost, from <1 percent for areas of low turnover to 14 percent for areas of moderate and 16 percent for areas of high turnover (Figure 8B). Relative gains in forest cover are greatest on lands that experienced fewer changes in ownership, and relative losses are greatest on lands that experienced a greater number of ownership changes.

Discussion

Patterns and Processes in Forest-Agricultural Landscape Change

Agricultural development in Israel Township, Preble County, Ohio led to an overall decrease in forest cover, from the extensive beech-maple forests of the early 1800s, at the time of European-American settlement, to a low of <10 percent by the early 1900s. Because of their occurrence on relatively flat and fertile till plains, beech-maple forests were some of the first forests cleared, and their change to croplands was rapid and complete (Ebinger 1997). Hueston Woods, a 67-ha forest located in Hueston Woods State Park, is the only beech-maple stand known to have remained intact since before 1800 in southwestern Ohio (Braun 1950; Runkle, Vankat, and Snyder 1984). The regional environmental history of Israel Township parallels that documented for the U.S. Corn Belt; indeed, the area we studied lies less than fifty miles west of where the Corn Belt originated with the German-speaking farmers along the Miami River Valley (Hart 1986; Hudson 1994). Agriculture continues to predominate as an economic activity, now on 78 percent of the land area, and showed the least amount of change over the study period. In this agricultural landscape, native vegetation occurs mostly as isolated regrowth patches.

Historical accounts on resource use from the 1800s and spatial analyses of the distribution of uncultivated lands since the 1930s show three important aggregate changes for forests in the township. First, at the scale of individual farms, our results suggest a specialization in land use toward crop production on cultivated lands and the conversion of uncultivated lands to forests. Early records report a decline in the horizontal diversity of economic land uses in Israel Township and a decline in the vertical diversity of economic activities from the production to the processing of agricultural and forest commodities. Between 1935 and 1984, transitional lands—those abandoned from agriculture and in succession toward mature forest—declined, with a consequent decline in landscape diversity. Our results agree with regional studies in the Corn Belt (e.g., Hart 1986; Hudson 1994) and further substantiate trends toward agricultural intensification reported by Medley and colleagues (1995) for Preble County, Ohio and the Upper Four-Mile Creek watershed. The decline in successional lands contrasts with the increase in "other vegetation types" measured in less productive agricultural regions in the U.S. (e.g., Zipperer, Burgess, and Nyland 1990 for upstate New York; Foster 1993 for New England; Savisky 1993 for Georgia in the southeast Piedmont) and for rural landscapes in Europe (e.g., Alard and Poudevigne 1999). Where row-crop agriculture remains productive, lands out of production occur as small farm woodlots in highly modified landscapes (cf. Sharpe et al. 1987; Schwartz 1997).

Second, the study documents a spatial polarization in the configuration of land uses. Forests became increasingly confined to stream corridors and steeply sloped lands along larger, second- and third-order tributaries, while cultivation expanded across the flat uplands. Although Medley and colleagues (1995) showed that forests occupied a larger portion of the lower Upper Four-Mile Creek basin, which includes Israel Township (Figure 1), most of the forest area is localized within the township. Forest growth in Hueston Woods State Park contains about 50 percent of the total forest cover and explains about 50 percent of the increase, but evidence also exists that private landowners removed streamside lands from production over the study period. The study findings show how targeted protection in established parks can lead to considerable changes in regional forest cover, and also highlights the role of topography in defining landscape pattern and its specialization over time (cf. landscape forestry in Boyce 1995; landscape ecology in Forman 1995).

Third, relatively small changes in overall land-cover proportions mask the spatial dynamics of landscape change over the study period. Hedgerows show less than a 20 percent decline in area, but experienced a near 100 percent turnover between 1935 and 1956 and between 1956 and 1984. Less than 10 percent of the uncultivated lands remained in the same land use over the three time periods, documenting the regrowth status of nearly all forest land (see also Muller and Middleton 1994 for the Niagara Region, Ontario). Our findings point to the cumulative importance of land-use decisions by landowners in determining regional patterns in the distribution and structure of uncultivated lands. They also show that land-use decisions are often changed, especially for uncultivated lands. Realizing the dependency of the Corn Belt farm economy on continued high levels of crop production, landowners do show some flexibility in their decisions regarding the amount and configuration of uncultivated land resources. Accordingly, it may be possible to modify decisions for farm-level changes in land cover to have consequent effects on environmental conditions at the broader scale. Factors that influence these farm-level decisions (see, e.g., Camboni and Napier 1993; Salamon et al. 1997) and whether they may be coordinated to promote a diversity of land uses are important considerations for the conservation of resources in highly modified landscapes (Schwartz and van Mantgem 1997; Maguire 1999).

Landowners and Their Aggregate Role in Forest-Landscape Change

Our study examined the degree to which changes in land ownership, particularly the break-up and consolidation of individual parcels, relate to changes in land cover. Private farm operators in Israel Township exert the greatest influence on cumulative changes in land cover: they manage over 80 percent of the land area and just over 50 percent of the forest area in the study region. Thus, of Ohio's total acres of forest, 94 percent are owned by 332,600 private woodland owners (data from Ohio Forestry Association, Inc. 1999). What private farm owners do with their "woodlots" can have profound effects on the quantity and quality of forest resources in the state.

Since 1912, the number of farms has declined by less than 30 percent, and farm size has changed only from 46 to 54 ha. Our results support earlier findings by Hart (1986, 1991) reporting stability in the overall structure of ownership in the Corn Belt. Still, at a finer spatial scale, we did find changes in mean land-parcel sizes, which correspond with changes in the configuration of land ownership. Standard deviations of mean farm sizes went up significantly between 1912 and 1989, a variation that may be explained by small farms near stream basins getting smaller (and possibly out of agriculture) and large farms on flat uplands getting larger (Figure 6). These local trends documented for owned parcels may be further magnified when the land a farm operator rents is also considered. Hart (1986, 1991) explains that most farms in the Corn Belt expanded more by renting lands than by buying; thus, the size of ownership units changed far less than the size of operating units. In the Upper Four-Mile Creek watershed, Medley and colleagues (1995) found from a survey of ninety-nine landowners that 55 percent of the farm operators leased land, thereby increasing their respective farm operations.

Overall, changes in ownership were far more common than long-term stability. Parcels that experienced low turnover (zero changes to one change) had the largest percent of their land area in forest and the largest mean areas of existing forest patches. In contrast, land areas of rapid turnover (four to five changes) had the least amount of land in forest and the smallest mean patch sizes. In general, these results support our hypothesis that parcels with fewer ownership changes tend to show greater support for forest cover. A low number of ownership changes, however, did not correspond with greater stability in the distribution of forests. The differences are better explained by the higher rates of forest gain on land of more stable ownership and higher rates of loss on lands of rapid turnover. Stability in ownership is one factor that shows a positive relationship with the growth of forests and potentially its relative contributions to the sustainability of resources across the agricultural landscape.

Our study emphasized landowners, and how changes in the number and turnover of owners influence forest distribution in the township. Our analyses necessarily mask the possible influences of part owners operating under leased contracts, the comparative effects of land transfers as sales or inheritance, and the complex number of environmental, political, and socioeconomic factors that influence regional stability in farm ownership and forest conservation (e.g., see Olson and Lyson 1999 for farmland preservation). Turnover rates are both high and low in upland and riparian locations, complicating the interpretation of environmental influences on ownership patterns and the tendency for owners to sell or not sell their property. A survey of six farm operators in Preble County on the opportunities and constraints for farmland preservation identified food production, environmental quality, and quality of life as three important reasons to protect farmland (Boone 2000). Decisions that allow for forest growth may be more common among landowners who hold on to their properties and are more likely to consider the long-term sustainability of these lands.

One might predict from our findings that economic incentives that promote full and stable ownership of farmland could be used to support the effective growth and distribution of forests across the agricultural landscape. Unlike the case with agricultural lands to the north and west, the Conservation Reserve Program (CRP), which subsidizes the enrollment of steeply sloped land from cultivation (Dunn et al. 1993), and the Wetland Conservation provision (Swampbuster) in the Food Security Act since 1985 have had little to no importance, respectively, in our study area. For example, only one farm in Israel Township enrolled land under CRP, mostly explained by the low occurrence of suitably "unproductive" lands and the high incomes obtained from lands in production (unpublished data from the U.S. Natural Resources Conservation Service in Preble County, Ohio). Federal assistance programs such as the Forest Stewardship Program and Stewardship Incentives Program provide cost-sharing subsidies for farmers that want to participate in improved forest-management techniques (Garrett and Buck 1997; Hicks 1998; NRC 1998). In addition, under state programs such as the Ohio Forest Tax Law, forest owners can seek lower land taxes under an approved forest-management plan. These plans are underutilized by farm landowners because they do not add benefits to those farm landowners already receive for their agricultural land (e.g., Current Agricultural Use Value Assessment [CAUV]). On the contrary, programs that support farmland preservation can also provide support for a diversity of conservation activities on those lands. For instance, the Farmland Protection Program (Federal Agriculture Improvement and Reform Act 1996; USDA n.d.) is a voluntary program implemented by the U.S. Natural Resources Conservation Service that provides support for local farmland protection programs to purchase conservation easements or other interests (USDA 2000). Our study does suggest a need to consider ownership changes, and the factors influencing a change in ownership when introducing and implementing these types of protection programs.

Roles and Value of Forest Vegetation in an Agricultural Landscape

Over much of the environmental history of Israel Township, forests competed directly with agriculture. The density and stature of the beech-maple forests were obstacles to settlement and, at the same time, indicators of high soil fertility and harbingers of high crop production. Despite the rapid and complete clearing of most timber resources, it is worth noting the mid- to late 1800s, when both timber and agricultural products were processed and marketed in the region. Historically, timber resources and some nontimber resources helped support a diverse rural economy in the American Midwest (Perlin 1989; Williams 1989). Hueston Woods State Park captures some of the legacy of that history, preserving one old-growth stand that was owned and protected by the Hueston family for more than 100 years and hosting the annual sugar-maple festival that educates the public on the extraction and production of syrup from the forest (Runkle, Vankat, and Snyder 1984).

Crop yields in the Corn Belt continued to rise for quite a while before the impacts of soil erosion and the costs of subsidies began to question their economic sustainability (Leopold 1999). Early efforts at conservation focused on the fertility management of croplands for still higher yields (McIsaac 1994; Cumo 1997). Sustainability became a more public concern in the 1980s and was a focus of the Food Security Act of 1985 (McIsaac 1994). The emphasis was on low-input, more diverse agroecosystems, which would increase net incomes on farms (Barrett 1990) and lessen the impacts of nonpoint pollution and soil loss (McIsaac 1994; Barrett, Barrett, and Peles 1998). Landscape changes showed a rising interest in the ecological value of riparian forest buffers and other conservation corridors (Dunn et al. 1993; Vought et al. 1995; Henry et al. 1999).

Despite the ongoing debate over the estimates and magnitude of soil erosion associated with agricultural practices (Pimentel et al. 1995; Pimentel and Skidmore 1999; Trimble and Crosson 2000), improved land-use practices on agricultural landscapes are helping to keep the soil in the watershed (Trimble 1999a, 1999b). Working in the Marshall's Branch watershed, the most eastern tributary of the Upper Four-Mile Creek watershed (see Figure 1 in Israel Township), Lucas (1998) found that three first-order basins with greater than 25 percent of a 100-m stream buffer in forest had nitrate concentrations below the average calculated for seven first-order basins. The targeted protection of riparian corridors, using forest or another uncultivated land use (see, e.g., Trimble 1997), can have a positive effect on reducing erosion and needs local support on productive farms. Moreover, our results show a marked decline by the 1980s in parcel sizes along the lower stream corridors, suggesting that these areas may no longer be functioning farms and are changing to nonfarm residential developments (cf. Kleinman and Erickson 1992). A survey by the U.S. Natural Resources Conservation Service classifies the study area in Preble County as having high quality for agriculture production and high threat for urban conversion (American Farmland Trust 1996; for hot spots of change, see Gobster, Haight, and Shriner 2000).

Without an economic return, the conservation of forests in productive agricultural landscapes remains problematic. Several opportunities are now emerging that might provide greater support for the restoration of forests into "nature-farm plans" (see Smeding and Joenje 1999 for the Netherlands). One is a clear emphasis in the ecological literature on the need to manage biodiversity at the landscape level in the form of diverse agrolandscapes (Barrett, Barrett, and Peles 1998; cf. Hendricks, Stobbelaar, and van Mansvelt 2000 on landscape coherences). The landscape patterns of Israel Township reflect the environmental services of uncultivated lands to the protection of lower riparian zones, but the economic value of timber and nontimber resources in agroforestry systems (Leakey 1998) and the contributions of some extensification to the conservation of biological diversity are also important considerations (see, e.g., Dunn et al. 1993 on Wisconsin; Schwartz and van Mantgem 1997 on highly fragmented landscapes; Black et al. 1998 on the Poulouse Bioregion in Northwestern U.S.; Kristensen 1999 on Denmark; Smeding and Joenje 1999 on the Netherlands).

The study region occurs in an ecoregion that ranks low as a priority for conservation because "[h]abitat loss is nearly complete" and it has [n]o habitat blocks of significant size" (Ricketts et al. 1999, 165 on the Southern Great Lakes forest). The chronic habitat loss that characterizes the midwestern U.S. supports a redirection of nature conservation beyond the protection of remnant stands such as Hueston Woods to the restoration of many small uncultivated land patches and the participation of private landowners in that process (Schwartz and van Mantgem 1997; Elfring 1989 on land trusts; Rhoads et al. 1999 on stream naturalization). For example, the Three-Mile Valley Conservation Trust is one citizen group working with private landowners to restore natural vegetation along Four-Mile Creek below Acton Lake (see Figure 1). Landowner-focused initiatives would work to ensure a more equitable distribution of forested lands across the region and thus provide a source of woodland products and environmental services to more landowners (Leakey 1998). Finally, the Global Climate Change Treaty will continue to put pressure on industrial operations and promote a reexamination of rural landscapes as potential carbon sinks (see, e.g., Lal et al. 1999; Hoover et al. 2000). Not only will forest resources sequester carbon from the atmosphere, but managed small-scale forestry operations may be coordinated to provide a sustainable source of biomass energy (Dovring 1994). According to Collins and Qualset (1998, preface), "[T]here are examples of agriculture practices that enhance biodiversity and one of the great challenges for the next century will be to discover additional ways for achieving complementarity of food, fiber, and energy production and biodiversity." Forests deserve reconsideration as a valued resource for the agricultural economy of the Corn Belt region in the midwestern United States.

Conclusion

> When land does well for its owner, and the owner does well by his land; when both end up better by reason of their partnership, we have conservation. When one or the other grows poorer, we do not. (Leopold 1999, 161)

In his classic 1939 (1999, 164) essay, "The Farmer as Conservationist," Aldo Leopold emphasized that conservation should go beyond preventing practices that are shown to degrade productivity and should become a "positive exercise of skill and insight." Whether that skill should be directed toward the management of semieconomic land uses, such as farm woodlots in the Corn Belt, is a question that continues beyond Leopold's work in the 1930s. Our historical and spatial analyses in Israel Township identify a more positive approach to conservation that reconsiders the economic and ecological contributions of forests to this agricultural landscape and better understands relationships between landowners and the patterns and processes of landscape change when promoting local participation in a diverse land-use agenda. While our study showed little change in the land that is devoted to agriculture, the growth of forests on lands with low ownership turnover and its loss in regions of rapid ownership turnover suggest a connection between farm stability and resource sustainability. Of particular concern is the amount of owned land now under lease in a region that is predicted to rise in land value for urban development (American Farmland Trust 1996). Our study supports the current movements in farmland preservation authorized under the U.S. Farmland Protection Program (Federal Agriculture Improvement and Reform Act 1996; USDA n.d.) and, at the state level, under support for agriculturalq5 easements (e.g., Ohio State Bill 223 in Gebhardt 1999). These policies guide the provision of financial incentives, which maintain land in agriculture or under a diverse land-management plan that supports agricultural and forest resources. Current initiatives in the Upper Four-Mile Creek watershed are providing farm operators with incentives to achieve an aggregate decline in soil erosion, which focuses on cultivated lands but does include the maintenance of uncultivated conservation corridors (sensu Henry et al. 1999). These incentives are producing positive outcomes on water quality in the region (Renwick, Vanni, and Headworth 2000). Clearly, if sufficient financial incentives can be provided for the creation of diverse agrolandscapes, then the economic value of forests will re-emerge as an important conservation enterprise and will help define the future for this important agricultural region.

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