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Four centuries of forest clearance and regeneration in the hinterland of a large city

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Abstract. In the last 350 years, forests of eastern North America have experienced widespread clearance and regrowth with local variation in timing and extent determined by patterns of human land use. This paper describes the history of forest in the hinterland of a large city (Wilmington, Delaware) surrounded by fertile soils and having access to a navigable estuary. Forests were cleared between 1650 and 1780 to accommodate shifting cultivation of cereal crops and to provide fuelwood for nearby cities. Proximity to urban markets supported a vigorous agricultural economy through the 19th century and delayed widespread forest regeneration. Reforestation began on a large scale following the local decline of agriculture 1920–1940. In the late 20th century, forest competes for land with suburban housing. Although a similar sequence has occurred throughout eastern North America, the study area is unique in that a larger proportion of original forest was cleared and reforestation began much later than in other regions. Today, the history of land use is evident in the high proportion of young, successional forest and the very small area of long-established forest.

Key words. Agricultural history, conservation, forest ecology, forest fragmentation, forest succession, fuelwood, land use history, suburbanization.

INTRODUCTION

In the last 350 years, eastern North America has experienced widespread forest clearance, a period of open landscape, and extensive forest regeneration. These events roughly correspond to the arrival of European settlers, cultivation to supply urban markets, and land abandonment following the decline of eastern agriculture. In the late 20th century, second-growth forest has become the dominant vegetation on unmanaged land from southern Ontario to northern Florida. Because some forms of disturbance cause very long-lived changes in community structure, the impact of historical land use may still be evident in modern forests (Rackham, 1975; Peterkin & Game, 1984; Whitney & Foster, 1988; Matlack, 1994b). It is safe to say that very little forest in east-temperate North America has escaped human influence (Williams, 1989); most eastern forest has been very severely affected.

Human influence has not been uniform across the continent, however. The character and timing of forest clearance varied by region according to the accessibility of forests to urban markets, the capital and technology available to entrepreneurs, the value of wood as lumber or fuelwood, and the motivation of humans in occupying a site (Cronon, 1983, 1991; Williams, 1989; Perlin, 1991; Foster, 1992). Regeneration of forest varied, in turn, according to the value of crops that could potentially be grown at a site, the relative ease in getting them to market, and the attraction of alternative lands, usually to the west (e.g. Raup, 1966; Hart, 1980, Loeb, 1989). All regions have not been treated alike, and it is instructive to see how the local history of land use has determined the distribution of forest in a particular area.

Within a stand, community structure varies according to the character of historical activity at the site, whether it be agriculture, lumbering, hunting, suburban development, recreation, or some combination of these. Ecological studies show that historical land use has had a variety of lasting effects in forest communities (e.g. Wales, 1972; Peterken & Game, 1984; McSorley, 1993; Matlack, 1994b), although such work is necessarily limited in its scope. Through an understanding of cultural and economic history, the biologist can generalize local ecological findings to the vegetation of an entire region. In addition to providing insights into community structure, such an approach has value in managing forest diversity: the better we understand historical effects in forest communities, the better we can anticipate the long-term consequences of modern management.

The present study uses documentary sources to reconstruct the history of forest near a large city in the eastern United States. As such, it provides a human context for purely botanical studies reported elsewhere (Matlack, 1994a,b). Timber has never been a major commercial resource in the study area (Jones, 1926; Coleman *et al.*, 1984), so there are few records available bearing directly on forests. Instead, forest history is inferred from the history of agriculture, the principal land use since European

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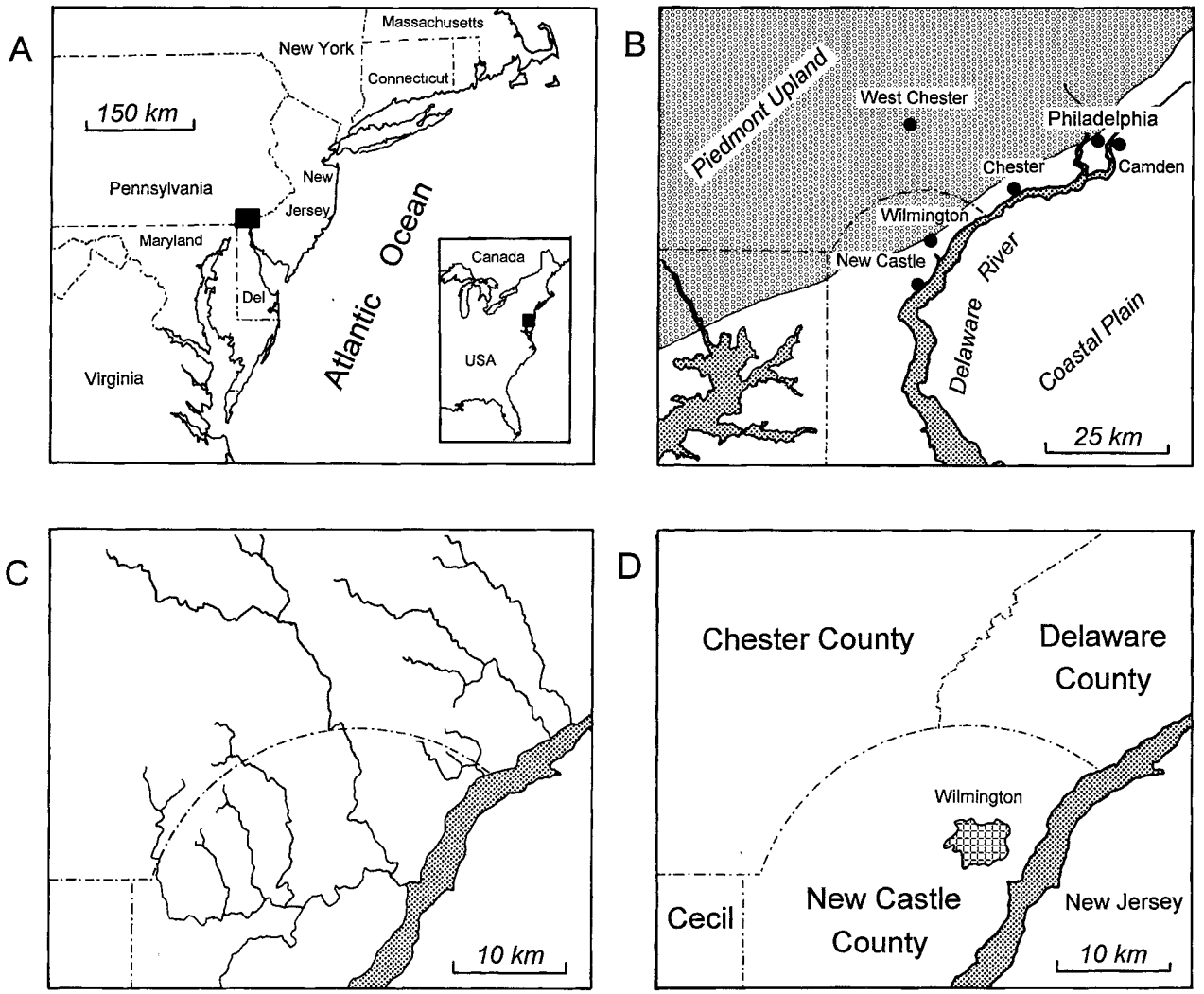

FIG. 1. Location of the study area. A, The east coast of the United States; the study area is indicated by the black rectangle. B, Principal colonial towns in the lower Delaware River Valley. The shaded area to the northwest is the Piedmont Plateau; the light area to the southeast is the Coastal Plain. C, Principal streams flow southward through the Piedmont Plateau, then eastward across the coastal plain to the Delaware River. D, The study area, showing modern counties.

settlement. Agricultural records are supplemented by legal documents and the accounts of travellers. In the late 19th century, quantitative records became available, primarily in the decennial U.S. census and the more-frequent Census of Agriculture.

STUDY AREA

The study focuses on an area of low, rounded hills and steep-sided stream valleys adjacent to the Delaware River and *c.* 120 km from the Atlantic Ocean (Fig. 1a). The area is conveniently defined as the land laying within 20 km of the city of Wilmington, Delaware (39°42′ N lat.; 75°32′ W long.), roughly corresponding to the city's agricultural and commuting hinterland. The work is primarily concerned with the Piedmont physiographic province (Fig. 1b), although examples are drawn from the nearby coastal plain when appropriate. The study area loosely corresponds to the area surveyed by aerial photography by Matlack (1996).

The general landform is a highly eroded plateau (the Piedmont penneplain) cut by steep-sided stream valleys draining north-to-south into the Delaware River and its tributaries (Fig. 1c; Fenneman, 1938). Upland soils are well-drained silty loams in the Glenelg-Manor-Chester and Neshaminy-Glenelg associations (Soil Conservation Service, 1959, 1970, 1973) considered to be of moderate to high agricultural value.

The climate can be described as humid-continental moderated by proximity to the Atlantic Ocean (NOAA, 1993). Winter weather is determined by cold continental air masses approaching from the west and northwest; summer weather is dominated by warm, humid bodies of air moving north along the Atlantic coast. Monthly mean temperatures range from −1 to 26°C. The area receives *c.* 120 cm of precipitation distributed throughout the year.

Natural vegetation consists of a winter-deciduous

hardwood forest dominated by oaks and hickories. The American chestnut (*Castanea dentata* Marsh., Borkh.) was a prominent member of the tree community until the early 20th century when its numbers were very much reduced by a fungal pathogen (1910–1930). There is a sparse subcanopy of flowering dogwood (*Cornus florida* L.) and suppressed individuals of canopy species. Light-demanding species such as *Fraxinus americana* L., *Liriodendron tulipifera* L. and *Prunus serotina* Ehrh. occupy canopy gaps and play an important role in colonizing abandoned agricultural land. The area has a diverse and luxuriant understory similar to that of the southern Appalachians or the mixed mesophytic forests of the Ohio Valley (Stone, 1945).

The study area was colonized by the Dutch and Swedish in 1630–1650, and annexed by the English in 1664. The first European settlement in the area was the village of New Castle (founded 1651; Fig. 1b), a grain shipping port on the Delaware River. Its commerce was gradually lost to the milling and shipping town of Wilmington, 10 km northeast (incorporated 1730). Wilmington was, in turn, overshadowed by the city of Philadelphia, 35 km northeast (laid out in 1690) which had become by 1740 the largest city in North America. This hierarchy of size and commercial importance has endured to the late 20th century. The study area now includes parts of New Castle County in the state of Delaware; Cecil County, Maryland; and Chester and Delaware Counties in Pennsylvania (Fig. 1d).

THE HISTORY OF FOREST IN THE WILMINGTON HINTERLAND

Significant human impact on forests began with the arrival of European settlers, who initially cleared trees for subsistence farming but soon switched to cash crops. With land clearance for export-oriented agriculture, and to meet the fuelwood demands of nearby colonial cities, most forests in the region were removed by 1800. The region remained in agriculture throughout the 19th century precluding the regeneration of forests and maintaining a very low forest coverage. Local agriculture eventually declined in the early 20th century due to rising labour costs and competition from western states. Most modern forest has arisen since that time, and, in the late 20th century, there is a moderately high coverage of young second-growth woodland. In recent decades, there has been extensive suburban development in the region but, as yet, this has caused only a minor impact on forests.

In this discussion, I have divided the regional history of forests into five stages roughly corresponding to the shifting economic and demographic demands on the land: Clearance of forests for agriculture and fuelwood (*c.* 1630–1780), economic distress arising from overpopulation and soil depletion (*c.* 1780–1820), a period of agricultural transition dependent on proximity to urban markets (*c.* 1820–1920), the decline of regional agriculture and regeneration of forests between the World Wars (*c.* 1920–1950), and the recent expansion of suburbia into the rural landscape (*c.* 1950–1990).

Clearance of forests (1630–1780)

Aboriginal peoples are known to have moved through the area (Coleman *et al.*, 1984), but they left no recognizable traces in the vegetation. Sediment cores collected in nearby New Jersey (Russell, 1980) and the northern Chesapeake Bay (Brush & Davis, 1984) show little grass pollen and only modest sediment deposition before the European period, suggesting that aboriginal forest clearance was at most very limited in the region. Archaeological evidence supports this conclusion. Local tribes appear to have lived exclusively by foraging and there is no evidence of cultivation before contact with European cultures (M. L. Becker, pers. comm.).

Europeans settled first along the Delaware River and its tidal creeks, but soon moved onto the Piedmont upland where they cleared small areas of forest for subsistence agriculture (Jones, 1926). The Delaware Valley constituted 'New Sweden', the North American outpost of the Baltic empire of Sweden, and most early colonists originated in Sweden or Finland. At the time, forests had long been cleared in Britain and western Europe (Perlin, 1991; Jordan & Kaups, 1990), and woodcraft was not among the skills English colonists brought to the New England and Virginia colonies. By contrast to England, Sweden and Finland remained largely forested. Jordan (1986) argues that the Scandinavian experience of woodmanship prepared Swedes and Finns to take advantage of the densely forested land beside the Delaware River and determined the manner in which they cleared forest and used forest products. Indeed, punishment for unlawful clearance of forest was the reason why many Finns originally came to New Sweden.

The Finnish forest lifestyle was structured around isolated homesteads in small forest clearings (Jordan, 1986). In remote northern and eastern Scandinavia, Finns practised a shifting cultivation based on killing trees in a small area, burning to open the understory and release mineral nutrients, and cropping at short intervals until soil fertility declined. This form of cultivation was also widely practised in New Sweden (in contrast to neighbouring English colonies; Kalm, 1770; Jordan, 1986). Later, under English rule, economic conditions favoured continuation of the Finnish mode of agriculture. With a chronic shortage of labour but relatively cheap land, pre-revolutionary farming was conducted on an extensive rather than intensive basis (Jones, 1926; Jordan & Kaups, 1989). Farm plots shifted often as local fertility of the forest soil was exhausted; no effort was made to maintain fertility with manure, crop rotation, or fallowing. Tree stumps were simply left in the fields.

Forest clearance was greatly increased by the prosperous cereal export trade. Swedish and Finnish settlers initially planted rye and barley, but soon adopted wheat as a cash crop. Wheat was recognized as a regional speciality by 1700 (Coleman *et al.*, 1984), promoted by the fertility soils and easy shipment from ports on the Delaware River. By 1800, the Delaware Valley was one of the premier wheat producing regions in the world, shipping wheat to the other American colonies and to Europe through the ports of Wilmington, Philadelphia, New Castle, and smaller towns on the Delaware estuary (Coleman *et al.*, 1984). Although the

greatest volume of wheat came from the coastal plain, intensity of cultivation was greater in the Piedmont zone which had a higher population density, a smaller average farm acreage, and a greater proportion of land under cultivation (Garrison, 1988). Benefiting from proximity to ports and mills, farms in the Piedmont focused more closely on market production than did the more remote farms of southern Delaware (Garrison, 1988; Herman, 1988). The large volume of wheat produced, the high population density, and the widespread practice of shifting cultivation imply that forest was cleared over large sections of the study area.

Another force driving forest clearance was the use of wood for commercial and domestic heating (Williams, 1989, pp. 77–80). Philadelphia was the largest city in North America between 1750–1800 and Wilmington was a considerable colonial town, creating an enormous local demand (Coleman *et al.*, 1984). The bulk of firewood and the poor condition of colonial roads made it unprofitable to haul wood more than 40–50 km to market (Williams, 1989, p. 78), so all wood for the two cities must have come from within a 50 km radius. The entire study area lies within 20 km of Wilmington, and most of the area is within 50 km of Philadelphia. Whereas clearance for cultivation was more-or-less restricted to level land, all forests were vulnerable to fuel-wood gathering. Forests in the study area must have been severely affected.

In addition to agriculture and heating, small industry made local demands on forests. Iron furnaces operated near the study area at Chester, Hopewell, and Hibernia, Pennsylvania, and at Iron Hill, Delaware. All relied on charcoal as fuel. The furnace at Hopewell (1771–1883) consumed 5000–6000 cords per year (Lewis & Huggins, 1983; 1 cord = a stack of cut wood 3.6 m^3). Similar operations in Vermont obtained *c.* 30 cords of wood per acre of mature forest (Rolando, 1991) so, assuming a 40-year cycle of forest regeneration, the Hopewell furnace required a forest hinterland of *c.* 7330 acres (29.7 km^2) corresponding to a circle of 3.8 miles (6.1 km) diameter. In addition to iron furnaces, lime kilns consumed firewood on Pike Creek and elsewhere in New Castle County. Boat and ship building consumed wood around shipyards at Chester, Pennsylvania and Wilmington, Delaware (Kalm, 1770; J. Gardner, pers. comm.).

A valuable snapshot of forest conditions in the mid-18th century is provided by Peter Kalm, a botanical explorer and student of Linneus. Kalm was sent to the Delaware Valley in 1748 by the Royal Swedish Academy of Sciences to discover useful plants that might be imported to Scandinavia (Kalm, 1770). His journal suggests considerable local variation in the extent of forest clearance. Commenting on the land between Philadelphia and Wilmington, he wrote 'The greater part of the country is covered with several kinds of deciduous trees ... In some places little glades opened' (p. 82). By contrast, the land east of Philadelphia towards Princeton, New Jersey was more open: 'As these parts were sooner inhabited by Europeans than Pennsylvania, the woods were likewise more cut away, and the country more cultivated so that one might imagine himself to be in Europe' (p. 119).

In a general description of the Delaware Valley he confirms the continued use of shifting, low-capital agriculture. Referring to the method of cultivation in small forest openings,

> 'This easy method of getting a rich crop has spoiled the English and other European inhabitants, and induced them to adopt the same method which the Indians make use of; that is, to sow uncultivated grounds, as long as they will produce a crop without manuring, but to turn them into pastures as soon as they can bear no more, and to take in hand new spots of ground, covered since time immemorial with woods ... In a word, the corn fields, the meadows, the forests, the cattle &C are treated with great carelessness by the inhabitants. We can hardly be more lavish of our woods in Sweden and Finland than they are here: their eyes are fixed upon present gain, and they are blind to futurity [sic]' (p. 300).

(Note: Kalm's connection of shifting cultivation with Native Americans is almost certainly wrong; see above.) With regard to the cultivation of wheat near the northeastern edge of the study area (October 1748):

> 'Wheat was now sown everywhere. In some places, it was already green having been sown for weeks before. ... Great stumps of the trees which had been cut down, are everywhere seen on the fields, and this shews [sic] that the country has been lately cultivated' (p. 90).

Although extensive forests evidently remained in the Wilmington hinterland at the time of his visit, clearance was well underway and there are numerous hints of an impending wood shortage. Sapling fences were advocated for restraining pigs because they required little wood (p. 89); the zig-zag 'worm' fences were criticized because they were extravagant of wood (p. 229). Kalm concluded of the lower Delaware Valley,

> '... one may imagine how the forests will be consumed and what sort of an appearance the country will have forty or fifty years hence, in case no alteration is made; especially as wood is really squandered away in great quantities, day and night all the winter or nearly one half of the year, for fewel [sic]' (p. 229).

Wood shortages (1780–1820)

The predictions of Peter Kalm were born out. Very little forest remained in the Wilmington hinterland by 1800 (Fig. 2). Several indirect lines of evidence suggest almost complete removal of forests. First, a general shortage of wood is revealed in legal records from the nearby coastal plain, somewhat south of the study area. In contracts between landlords and tenant farmers, there is often language explicitly protecting timber on the rented property. For example, the landowner John Dickinson stipulated in a lease to tenant William White (October 1781, in Siders *et al.*, 1991).

> 'No timber or Wood to be cut for Rails, Fencing or Repairs but in the swamps, or between the new Ground

FIG. 2. 'Perspective view of the Country between Wilmington and the Delaware, Taken from the Hill S.W. of the Academy' (detail). From *Columbia* magazine (June 1788). The view shows the very high degree of forest clearance near the city (Courtesy of the Library Company of Philadelphia).

> now stubble Field and Chamber's point ... No wood to be cut for firewood but dead wood in the land to be cleared. No trees to be deadened under any pretence [sic] whatever except the land to be cleared and no Trees fit for Rails or Timber to be deadened even there.'

Dickinson was equally stern with his other tenants (Garrison, 1988). The shortage of timber also manifested itself in disputes over the need to fence in roaming pigs. In a petition before the state legislature of Delaware (1797, in Herman, 1988) coastal plain farmers listed reasons why free-ranging pigs should be restrained:

> 'The scarcity of timber in this district has, at length, become so general and so serious, as that fences calculated to prevent the depredations of Swine, cannot be made and maintained without destroying, in a great degree, the very little rail timber; or annually purchasing from New Jersey at a dear rate, tens of thousands of cedar-rails, which might be dispensed with, were Swine not suffered to run at large ...'

The very small area of surviving forest was also evident in a shortage of fuel wood. In the last decade of the 18th century, the cost of firewood in Philadelphia was so high that it became economical to import coal from Britain to meet domestic heating needs (Reynolds & Pierson, 1942), and the city remained predominantly coal-heated throughout the 19th century (Sargent, 1884; Williams, 1989).

It is useful to view the forests of the Wilmington hinterland in terms of von Thunnen's (1838) model of 'the isolated state', in which the use of land surrounding a market town is dictated by the relationship between the market value of produce and the cost of growing and transporting it to market. A product difficult to transport due to its bulk or perishable nature will give the greatest net profit when produced near the market; products easily stored and transported should be produced on land at a greater distance. Colonial Wilmington served as a market for regionally produced timber, wheat, and dairy products. Dairying was concentrated close to the city (Garrison, 1988) in Chester, Delaware and northern New Castle Counties (which also served the Philadelphia market), probably because spoilage made the cost of transport very high relative to market value. Wheat was a far less perishable commodity, and Wilmington's wheat hinterland extended all the way to York and Lancaster Counties of Pennsylvania (60–120 km west; Coleman *et al.*, 1984) consistent with von Thunnen's expectation. Wilmington did not actually consume most of this wheat, but merely shipped it to a wider market which included many European cities.

Owing to its great bulk and weight, wood had a very high transport cost. von Thunnen (1838) assumed that prudent farmers would try to minimize transport costs by planting trees close to the market, outside the dairying zone but well within the cereal-growing zone. This did not happen in the Wilmington hinterland, doubtless because (as Peter Kalm repeatedly observed) the early American settlers did not measure up to Northern European standards of prudent farming. Instead, forests were cleared to the limits of profitable transport and cleared land was devoted to wheat or pasturage. This 'lack of concern for futurity' (Kalm, 1770) was characteristic of all colonial communities (Cronon, 1983; Williams, 1989), eventually pricing locally

produced firewood beyond the reach of urban dwellers. Because the populations of Wilmington and Philadelphia continued to expand despite the fuelwood shortage, the logic of the market stressed alternative sources of fuel (i.e. European coal) and more complete exploitation within the nearby hinterland. Small scraps of forest surviving near the city would become metaphorical gold mines, as John Dickinson's leases suggest.

Quantitative estimates of forest cover are not available, but by 1775 it was said that the Philadelphia area was as bare of trees as southern England, which had been denuded over the previous 200 years by a booming iron industry (Williams, 1989, p. 78; Perlin, 1991). We can assume that forest cover within the study area was reduced to very low levels, possibly no more than isolated clusters of trees around buildings and in other protected areas. It is probably reasonable to assume <1% forest cover in 1800.

Agricultural transition (1820–1920)

The early nineteenth century was a period of agricultural upheaval in the Wilmington hinterland, mirroring economic changes in other Atlantic coastal states (e.g. Hart, 1980; Loeb, 1989; White, Worthen & Stiles, 1990; Foster, 1992). Ecological and financial crises led to extensive out-migration among the rural poor and forced agricultural reform among large landowners. Agriculture survived as a viable industry around Wilmington, however, and its changing character did not lead to an increase in forest cover, which remained low throughout the 19th century. The age structure of modern forests was largely determined by this continued agricultural vitality.

Around 1820, the wheat economy of the Delaware Valley began a long decline precipitated by economic force beyond the control of local farmers. Critical events included the economic depression of 1819 and the conclusion of the Napoleonic wars, which reduced European demand for wheat and increased European competition with American producers (Jones, 1926). In 1815–1827, the English 'corn laws' were strengthened to restrict foreign (i.e. American) imports, and maintain a high price for domestic wheat on the English market. A more serious source of competition was the rich arable land along the Ohio River, which eventually surpassed the study area in cereal production (Jones, 1926).

Other causes of the decline originated within the Delaware Valley. Rapid population growth in the 18th century created unsustainable pressure for subdivision of existing farms and cultivation of marginal sites (Jones, 1926). Without crop rotation, fertilizer, or fallowing, soil exhaustion began to be noticed *c.* 1790 (Coleman *et al.*, 1984). The agricultural reformer James Tilton observed (1789, in Garrison, 1988), 'Hitherto we have depended chiefly on the freshness and richness of our soil, but manure is now more necessary and more used than formerly'. Seeing no opportunity in the Wilmington hinterland, much of the rural population migrated westward. The distribution of Swedish surnames in county records in the Midwest (Jordan, 1986) suggests that by 1820 large numbers of Delaware farmers had moved to the uncleared land of the Ohio Valley. Today, a survey of place names in states bordering the Ohio River reveals several New Castles, Camdens, Newarks, Wilmingtons, and Delawares again suggesting Delaware Valley origins.

The paradigm for the collapse of a single-crop economy is the rapid decline of cotton in the Piedmont zone of Georgia *c.* 1900 (Hart, 1980). In Georgia, a drop in cotton prices produced great economic distress in the rural population, leading to widespread abandonment of farm land and regeneration of forest. For several reasons, the decline of wheat did not lead to this degree of distress in the Wilmington hinterland, farmland was not widely abandoned, and forests were not allowed to regenerate.

First, new crops and new forms of cultivation were adopted, allowing the continuation of agriculture as an important industry. At the beginning of the 19th century, Delaware Valley land owners were becoming conscious of agrarian reform in Europe (Herman, 1987; Siders *et al.*, 1991). Agricultural improvement societies were formed in the study area such as The Agricultural Society of the County of New Castle (founded 1819), or the Philadelphia Society for Promoting Agriculture (1785) which still meets. These societies pursued improvements such as crop rotation, mechanization, and manure application 'with an evangelical zeal' (Herman, 1987). As a result, agriculture gradually switched from a shifting, spatially extensive mode to a fixed, labour- and capital-intensive mode. Breaking with their pioneer past, Chester, Delaware, and New Castle Counties developed reputations as progressive and productive farming areas in the second half of the 19th century (Coleman *et al.*, 1984).

The impact of this realignment is clearly seen by examining the Agricultural Census of 1924. The 1920's form a convenient break between the agricultural practices of the 19th century and new forms of land use that emerged in the 20th century. Data are admirably summarized in a series of national maps compiled by Baker (1931). The whole country is presented here to show the relationship between the Delaware Valley and competing agricultural regions in the East, Midwest, and California (Fig. 3).

By the mid 1800s, the Delaware Valley had lost its pre-eminence in wheat production. In 1840, the region was still self-sufficient in wheat, but by 1860 it achieved a deficit, importing 15 M bushels from the West in that year (Colman *et al.*, 1984). By 1924, wheat culture had shifted decisively to the west, centring in the Dakotas, Nebraska, Kansas and Oklahoma where it was supported by irrigation (Baker, 1931; Fig. 3a). Although modest amounts of wheat continued to be produced in the Wilmington hinterland into the 20th century (Fig. 6a), acreage was much below levels of the early 19th century.

In the place of wheat, the Wilmington hinterland switched to market gardening of fruits and vegetables, a major industry throughout the Middle Atlantic region (Fig. 3b). Despite the general shift of agricultural production to the Midwest, the Delaware Valley and adjacent areas continued to lead the nation in such crops as sweet corn and tomatoes. The Delaware Valley also remained strong in dairy products (Fig. 3c). The national centre of dairy production had shifted to Minnesota, Wisconsin, and northern New York State at the end of the 19th century, but the Delaware

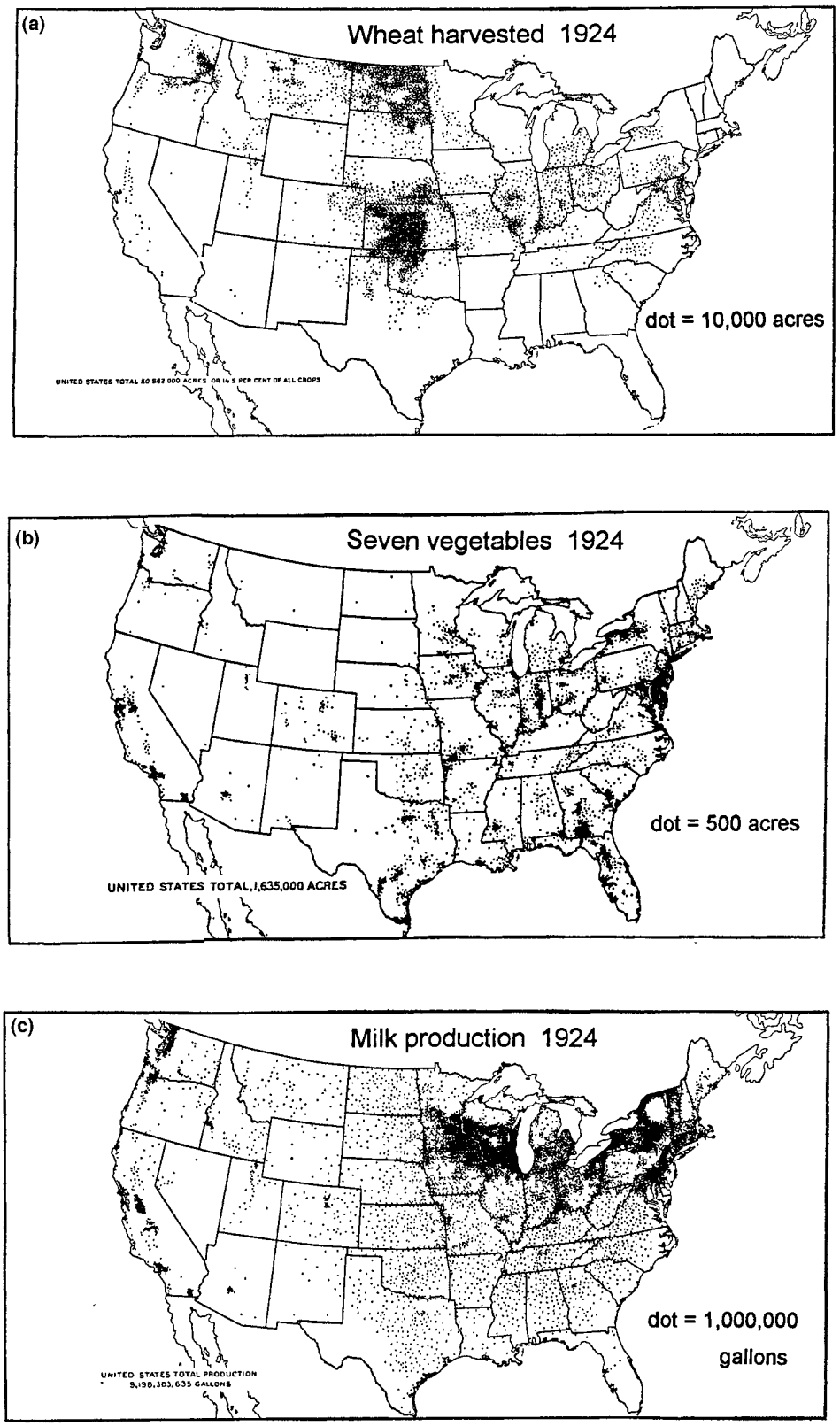

FIG. 3. The distribution of various forms of agriculture as shown by the 1924 Census of Agriculture, including wheat (3a), vegetable production (3b), and dairying (3c). Although wheat has shifted westward to irrigated lands, vegetable production and dairying remain strong in the Delaware Valley. Maps are modified from Baker (1931).

Valley and adjacent counties in Pennsylvania remained the principal dairying area on the Atlantic seaboard. Indeed, dairying overtook fruit and vegetables as the principal agricultural activity in New Castle County from 1910 to 1940 (Brizzolara, 1989).

The successful transition to fruits and vegetables depended upon the proximity of large urban markets. Despite the agricultural depression of the early 19th century, the urban population of the study area continued to grow (Coleman *et al.*, 1984). Well into the 20th century, the majority of the nation's population still lived in the Northeastern cities (Fig. 4a), to which the Wilmington hinterland had good access. Proximity to the urban market was no particular advantage in the case of wheat (a durable, easily transported form of produce; Cronon 1991), but it was critical in the marketing of Delaware Valley fruits, vegetables, and dairy products. To apply von Thunnen's (1838) model, improvements in transportation in the early 19th century vastly expanded the hinterland in which it was profitable to grow nonperishable crops such as wheat, for which transport time was not an issue. However, without a dramatic increase in transport speed, long-distance movement of perishable crops remained impossible and their production was restricted to the area adjacent to the urban market.

As a result of the study area's favoured location, agricultural land values remained high into the early 20th century. Indeed, land values were higher than anywhere east or south of the Ohio Valley (Fig. 4b). Potentially profitable land remained in production and very little was abandoned to forest. This was in sharp contrast to the rest of the eastern United States, where large areas of agricultural land had reverted to forest in the mid- and late-19th century (Fig. 4c). Matlack (1997) uses historical aerial photographs to arrive at an estimate of 5% forest cover in 1890, a proportion supported by contemporary landscape photographs (e.g. Fig. 5). In such views, forest appears to be restricted to gullies and steep slopes, areas of low agricultural value. These isolated stands were used as sources of lumber and fuel by the rural population (L. H. Wilkinson, pers comm.). Level sections remained treeless, however, as they had been in 1800.

Decline of agriculture and the regeneration of forest 1920–1950

In the early 20th century, agriculture began to decline in the Wilmington hinterland. Farmland dropped out of production and forests began to increase in area, following the rest of the eastern United States by 20–100 years (Raup, 1966; Williams, 1989; Glitzenstein *et al.*, 1990; Smith, Marks & Gardescu, 1992). The reasons for this decline appear complex, perhaps in part because recent changes provide only a limited historical perspective. On the other hand, recentness permits us to take advantage of two resources not available for earlier periods: First, quantitative data are available, and, second, many individuals who experienced these events are still alive and can provide useful insights.

The Census of Agriculture (Department of Commerce, 1890–1990) shows the continued decline of wheat production to the late 20th century (Fig. 6a). Vegetables, long the mainstay of agriculture around Wilmington, peaked during the Second World War (Fig. 6b). This peak may reflect an advantage to local producers caused by restricted transportation during the war (E. F. and A. S. Matlack, pers. comm.). Dairying showed a gradual decline through the 20th century (Fig. 6c), with overall production in inverse proportion to the degree of urbanization in the respective counties.

Factors contributing to the decline of agriculture were both national and local in origin. At the level of the national economy, agriculture entered a depression following the boom period 1900–1920, and prices for farm produce did not recover until the 1940s (Craf, 1952, p. 432; Greenleaf, 1968, p. 309). Despite the advantages of their location, farmers in the Wilmington hinterland were not immune to the national trend. The slump in agricultural prices limited the wages that could be offered to farm labour, reducing the attractiveness of farm employment relative to work in nearby industry. Whereas proximity to urban centres had been an advantage in marketing produce, it was a liability in competition for labour.

With advances in transport technology in the late 19th century, the advantages of market proximity were lost. Electrical refrigeration and the internal combustion engine made it possible to move perishable produce rapidly over long distances, eliminating distance almost entirely as a factor determining prices of produce (Cronon, 1991). By the early 20th century, the Delaware Valley was obliged to compete with states such as Florida and California in production of fruit and vegetables.

The Great Depression of 1929–1940 capped this list of rural misfortunes. Apparently milk had been a luxury item in many urban households. With the Depression, urban milk consumption dropped *c.* 40% (Brizzolara, 1989), a blow the Delaware Valley dairy industry never recovered from. Farms collapsed in all counties of the Wilmington hinterland (Fig. 7a), punctuating a decline in number throughout the 20th century. The decline in farm number was accompanied by an overall decline in farm area (Fig. 7b).

During this period, much debt-ridden farm land was purchased for country retreats by wealthy city dwellers, a process observed in rural areas elsewhere in the Northeastern states (Loeb, 1989; Glitzenstein *et al.*, 1990). Many bankrupt farms in the study area were combined into large estates, notably by the descendants of E. I. DuPont, an industrialist who settled near Wilmington in 1802 to take advantage of the abundant water power (Brizzolara, 1989). Although these estates were situated in the countryside, the capital that supported them was purely urban in its origins, signalling the effective transition of the regional economy to industry. Some estate owners continued to farm as a form of recreation (Brizzolara, 1989), but much land was allowed to regenerate to forest. Both within and outside the large estates early successional forest became a common habitat type (GRM pers. obs.).

Most modern forest has arisen during and since this period of agricultural depression. Forest regeneration began on rocky hill tops and steep slopes (Matlack, 1997), reflecting

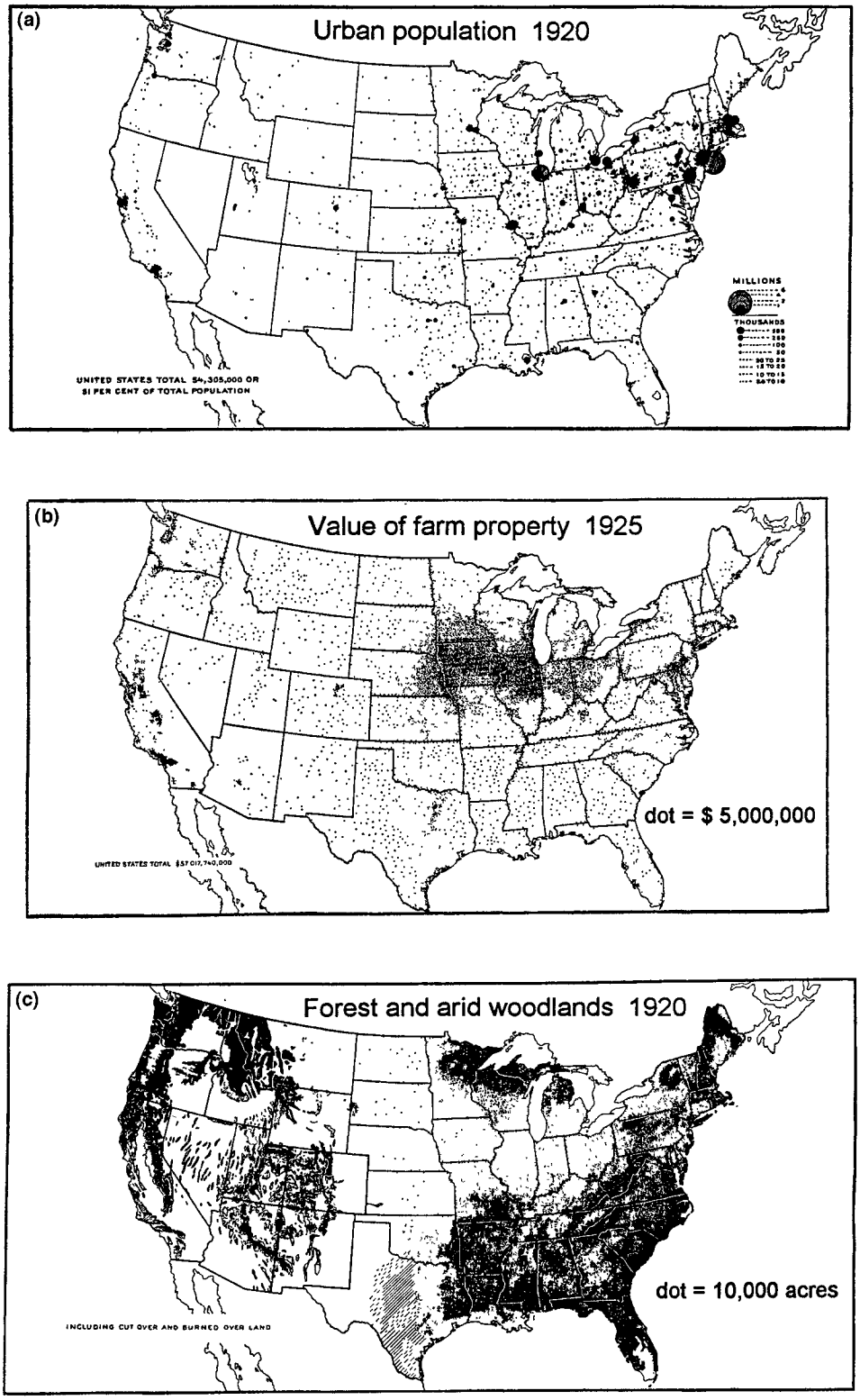

FIG. 4. Factors influencing land use in the Delaware Valley as shown by the Census of Agriculture of 1924: (4a) the populations of towns and cities, (4b) value of agricultural land, and (4c) forest coverage. Proximity to urban markets maintained high agricultural land values in the Wilmington hinterland, preventing abandonment to forest. Maps are modified from Baker (1931).

FIG. 5. Forest coverage in the Wilmington hinterland *c.* 1907, a landscape photograph taken on the Piedmont plateau near the Brandywine River *c.* 10 km north of Wilmington. The ground is covered with snow. (Photograph by Wills Passmore, used by kind permission of Ms. Joanne Passmore.)

their low agricultural value (J. O. Passmore, L. H. Wilkinson, pers. comm.). Slopes were undesirable for cultivation because they were prone to erosion; they were often used instead as pasture for dairy cattle (J. O. Passmore, N. T. Dempsey, pers. comm.). It has been suggested that slopes were less easily tilled by early tractors than by horse teams, and that the shift to mechanical cultivation caused sloping fields to be abandoned earlier (Baker, 1931), but there is disagreement on this point among farmers practicing at the time (J. O. Passmore, L. H. Wilkinson, pers. comm.). There is no disagreement that level ground was preferred for agriculture, however, even before the arrival of tractors.

Two other technological changes in the 1920–1940 period also contributed to regeneration of forest: first, the rural transition from firewood to heating oil reduced cutting pressure on farm woodlots. Second, the gradual replacement of horses by trucks and automobiles reduced the need for land in pasture and silage production (J. O. Passmore, N. T. Dempsey, E. F. Matlack, pers. comm.).

Suburbanization (1950–1990)

In the mid-20th century, another form of land use began to occupy large sections of the Wilmington hinterland: suburban housing. Early in the century population growth had been concentrated in urban areas (Fig. 8a), but in mid-century urban populations stabilized and eventually began to decline. In contrast to urban areas, the rural population continued to rise rapidly due to migration of the middle class to newly built suburbs (Fig. 8b). Expansion of suburbs more than balanced the loss of rural population caused by the demise of agriculture and the decline in farm number. Because population data were collected at the scale of townships, we can examine growth in the study area very closely: sections of the study area in Chester and Delaware Counties grew modestly, but the portion in New Castle County has grown explosively (Fig. 8c), more than doubling between 1950 and 1960 (+104% in the area outside the Wilmington city limits). This pattern of expansion was typical of suburban growth outside northeastern cities in the post-war period (Jackson, 1985), but unusual in its rapid pace (D. Ames, pers. comm.).

Suburbanization favoured areas to the northeast and west of Wilmington, spreading initially along principal highways and later filling between them. In topographic terms, residential development was largely restricted to level, upland sites recently retired from agriculture (Matlack, 1997). Development generally avoided slopes and flood plains, and, hence, had little impact on forests of the study area. Building on flood plains was discouraged by

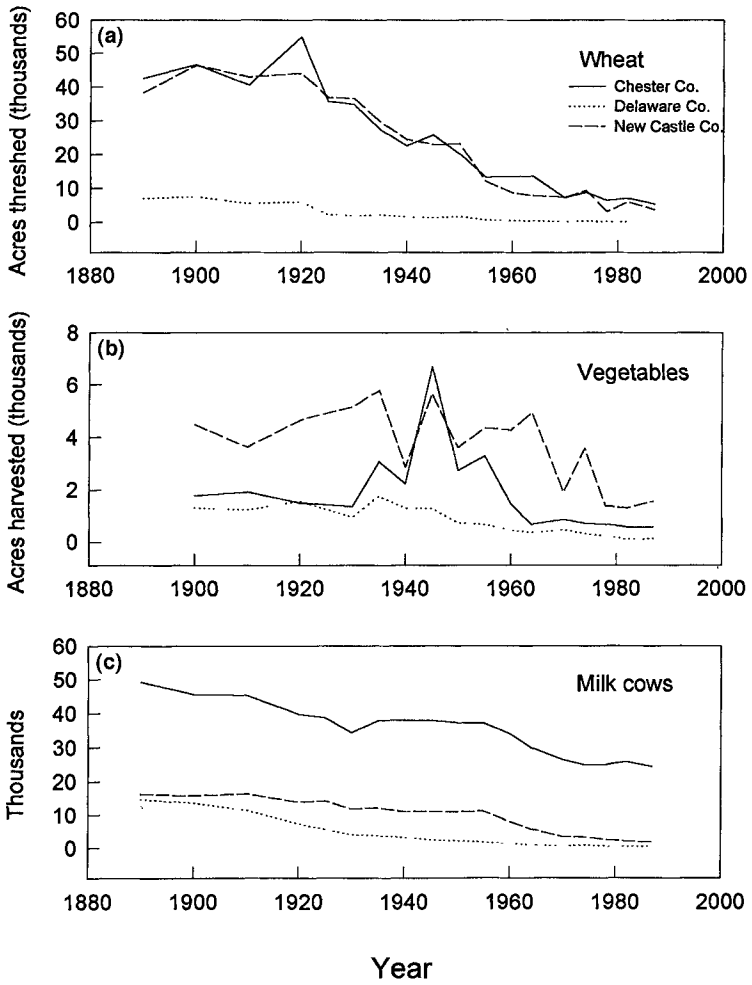

FIG. 6. The decline of agriculture in the Wilmington hinterland 1890–1987 (Department of Commerce 1890–1987): (a) acres in wheat production in Chester, Delaware, and New Castle Counties; (b) total acres in vegetable production; (c) dairying, indicated by the number of milk cows.

injunctions against excessive runoff and stream sedimentation and by the difficulty in obtaining federal flood insurance for such sites (Tourbier & Westmacott, 1974). Steep slopes were avoided by home builders because they presented engineering problems not encountered on flat sites (Soil Conservation Service, 1970).

Postwar suburban homes were far more modest than the great pre-war estates but they reflected a similar environmental philosophy: a desire to live away from the city in the peaceful, healthful rural landscape (Jackson, 1985; Stilgoe, 1988). In pursuing this end, suburbanites caused the transformation of the agricultural landscape to one dominated by vast expanses of low-density single family housing (Fig. 9a,b). Suburbanization raised real estate values in nearby undeveloped land (Fig. 7c), providing incentive for the remaining farmers to sell their fields (N. T. Dempsey, pers. comm.). The practical impact of suburban growth on forests may be the maintenance of high rural land values, which insured that land would not remain unused long enough for forest to become established.

The economic pressure on land values has not been continuous, however, and intervals of low value have allowed recruitment of the modern forest. In 1950, 42% of fallow fields in the Wilmington hinterland had been abandoned from agriculture >20 years earlier, long enough for tree seedlings to become established (Matlack, 1997). By 1990, inflation-corrected land values had risen (Fig. 7c) and the proportion of long-term abandoned land had dropped to 4.8%, indicating a faster turnover of land uses and providing less opportunity for recruitment of forest. Thus, the mid-century episode of forest recruitment appears to have ended. As yet, little forest has been cleared for suburban development (Matlack, 1997), but considering the rapid spread of suburbia and the small amount of agricultural land still available for building, it seems likely that forest will soon be used.

DISCUSSION

Over the course of 350 years, the agricultural geography of the Wilmington hinterland has changed fundamentally several times. Notwithstanding the passage of centuries, the

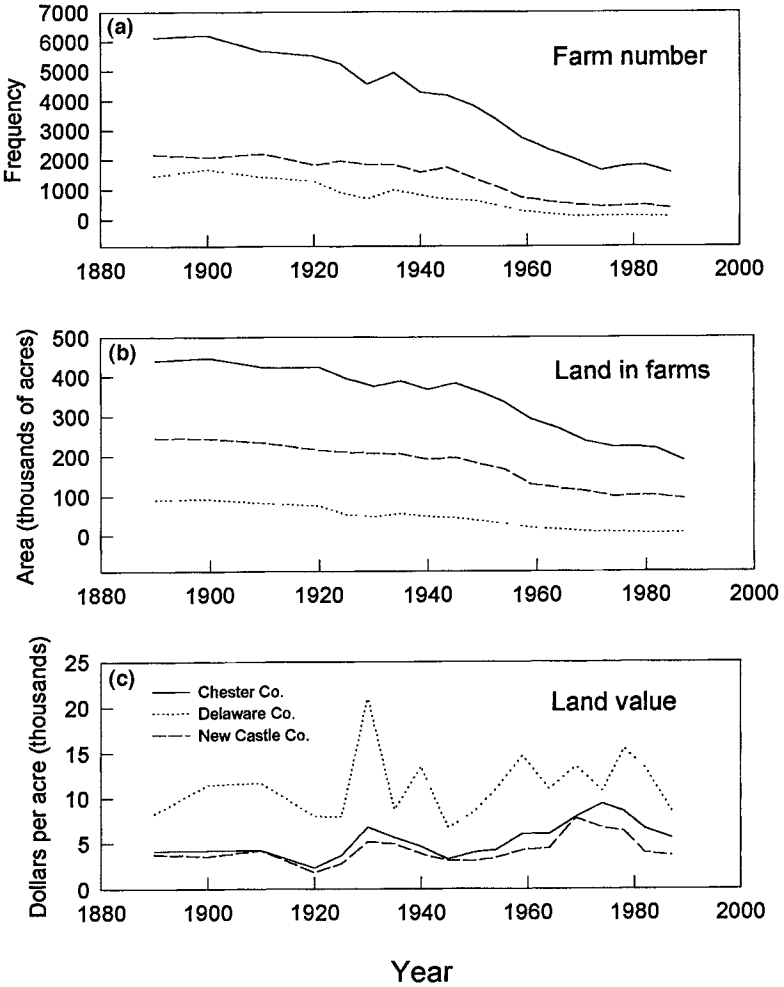

FIG. 7. Disposition of farms in New Castle County, Delaware, and Chester and Delaware Counties of Pennsylvania 1890–1987. Fig. 7a shows the total number of farms in the respective counties. Fig. 7b presents the acreage of land in agriculture, and Fig. 7c indicates the mean price of farm land and buildings expressed in 1993 dollars. Data from the US Department of Commerce Census of Agriculture (1890–1987).

impact of these events is still evident in the character of modern forests. Three agricultural phases have been particularly important. First, in the 18th century spatially extensive modes of cultivation and a heavy demand for fuel wood caused forest vegetation to be reduced to a very low proportion of the landscape. Second, easy access to large markets (both local and foreign), and a booming population within the study area, caused much of the deforested land to be ploughed, removing any traces of forest vegetation. Finally, the continued vitality of local agriculture prevented widespread forest regeneration until very recently. Although this sequence of events was common to much of the eastern United States (Hart, 1980; Williams, 1989; Glitzenstein *et al.*, 1990; Foster, 1992; Smith *et al.*, 1993), the study area appears to be unique in the very high degree of forest clearance and the very recent onset of regeneration.

Forest in the late 20th-century is probably very little like the early forest the Swedes and Finns encountered. Although superficially satisfying the definition of 'forest', modern stands are much altered in their community structure and composition. Most of the existing forest is young and, hence, dominated by shade-intolerant successional tree species such as tulip (*Liriodendron tulipifera*) and ash (*Fraxinus americana*), species that would have only appeared in isolated gaps before forest clearance. Stands are characterized by high stem densities and uniformly young age distributions.

Cultivation of the soil has created some of the most persistent environmental changes. Because most modern forest arises from previously ploughed land, forest soils lack the vertical structure and probably the chemical properties of the pre-European soils (Daniels, Amos & Baker, 1983; GRM, pers. obs.). Cultivation has also removed the pit-and-mound microtopography that provides habitat for many forest understory species (Beatty, 1984; Peterson & Pickett, 1990; Matlack, 1997).

The spatial distribution of modern forest has been determined by patterns of land abandonment following agriculture or small-scale logging. Most modern forest exists in fragments of 30–60 ha separated by 10s–100s of metres

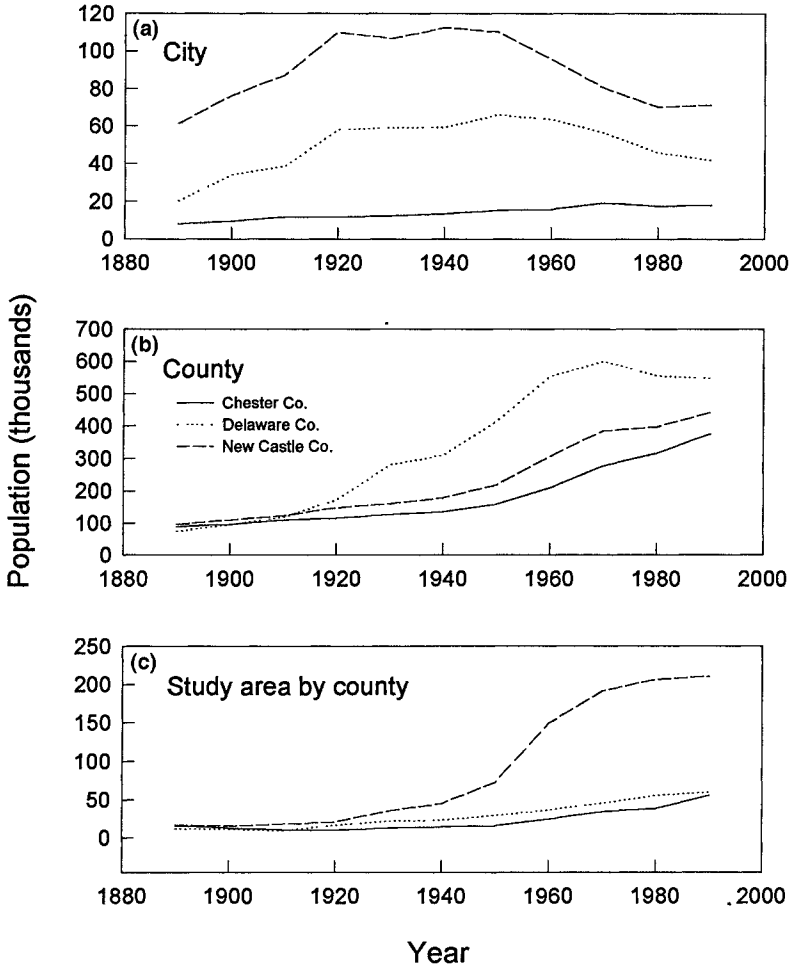

FIG. 8. Rural population trends in the hinterland of Wilmington, Delaware. Fig. 8a indicates the populations of the principle urban centres in or near the study area. Fig. 8b shows the total populations of the three largest counties in the study area (compare with 8a). Fig. 8c presents population growth in the townships that make up the study area, presented by county. Data are from the US Department of Commerce Census of Population (1890–1990).

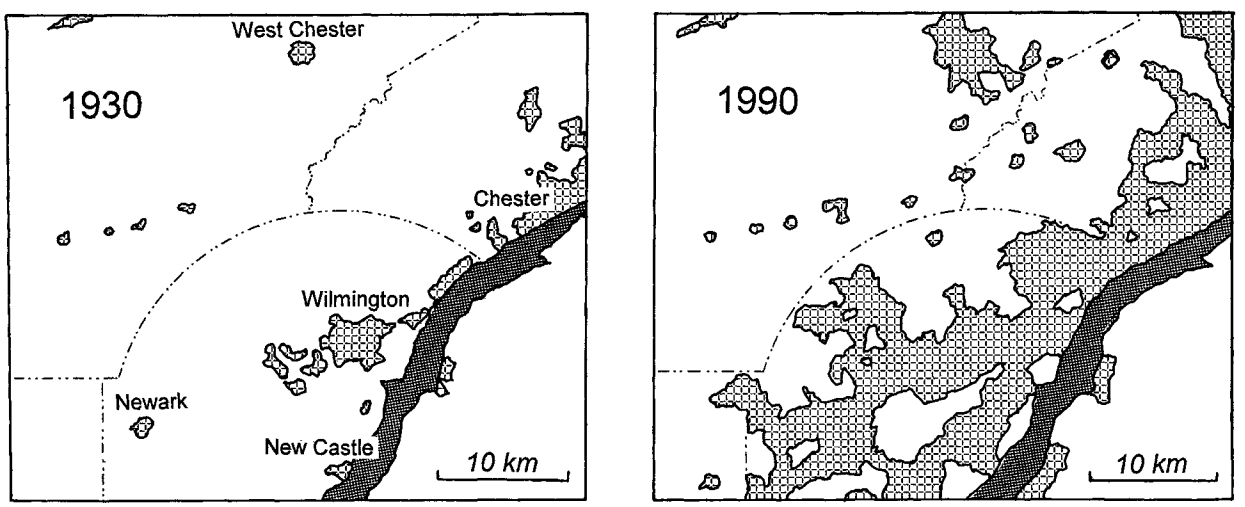

FIG. 9. Suburban development in the hinterland of Wilmington, Delaware 1930–1990. The cross-hatched area indicates the extent of developed land in 1930 and 1990, respectively.

(Matlack, 1994b, 1997). These stands tend to be narrow and highly invaginated, so, despite their size, most forest lies within the zone of altered microclimate near a forest edge (Matlack, 1993, 1994a, 1997). Very little interior forest remains in the modern landscape. It has also been suggested (Matlack, 1994b) that the spatial separation of regenerating stands discriminates against plant and animal species with weak dispersal abilities. Indeed, most forests in the study area are species-poor relative to those few stands which have escaped cultivation.

The environmental consequences of economic and agricultural history have been profound, but they are not widely recognized. Forest has usually been a default condition of the Eastern landscape. To appreciate historical changes in forest communities one must often infer their presence from the more-noticed forms of land use. Considered unremarkable for 350 years, the forest of the Wilmington hinterland has changed remarkably in that time. One wonders if Peter Kalm would recognize it now.

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