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Research Paper

Factors driving land use change and forest distribution on the coastal plain of Mississippi, USA

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HIGHLIGHTS

- Historical aerial photos allow reconstruction of land use history at a Gulf Coast site.
- Land cover change has been synchronized by the lumber boom of the early 20th century.
- A cycle of short-rotation forestry is imposed on the longer cycle of regrowth.
- A wave-front of urban expansion has been replaced by a pattern of nucleation.
- Modern land cover is dictated by proximity to an urban area rather than by regional trends.

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ABSTRACT

Forest distribution is controlled by broad regional trends in land use and by the specific natural and anthropogenic features of a particular site. To separate these influences in landscapes of the Southeastern coastal plain we describe land cover history outside the small city of Hattiesburg, Mississippi, USA, a rural landscape originally occupied by pine savanna and mixed forests. Land cover was recorded at 296 point locations regularly spaced on a 1 km grid. Aerial photographs from 1938, 1958, 1970, 1982, 2000, and 2010 illustrated a progression from open land to pine savanna, Southern Mixed Hardwood Forest (SMF), and built land cover, with low-density residential development encroaching after 1980 – a pattern reflecting broad regional trends in the mid and late 20th century. Examination of point-transitions showed frequent conversion between recent clearcuts and SMF, indicating rapid cycling of small parcels in short rotation forestry, and long-term conversion of abandoned agricultural land to SMF, reflecting regional regrowth following the lumber boom of the early 20th century. Pine savanna declined by introgression of hardwood species rather than by cutting. Logistic regression identified land on floodplains and distant from developed areas as most likely to regenerate as SMF. After 1980 urban expansion was most likely to occur close to existing buildings and arterial roads, suggesting nucleation outside the historical urban core. Thus, modern forest distribution has been decoupled from the natural environmental template. Recent land use changes appear to be driven by proximity to the expanding city rather than regional economic trends.

1. Introduction

Human-generated pattern dominates the landscape matrix of eastern North America, clearly evident in the fine-scale distribution of forest (Forman, 1995). In rural areas land use may be channeled by land form, soils, and land ownership, with land cover often reflecting historical land use rather than current activity. Most studies of land cover change in eastern North America have focused on geologically old and stable regions which are characterized by relatively fertile soils, well-defined topography, deciduous tree species, and long human occupation (e.g. Duram, Bathgate, & Ray, 2004; Foster, 1992; Hall, Motzkin, Siefert, & Burk, 2002; Matlack, 1997a,b). The Atlantic and Gulf coastal plains are comparatively less studied. In the last decades of the twentieth century the Southeastern coastal plain has experienced rapid population growth with attendant changes in land use (Wear & Greis, 2002). Because such changes have the potential to affect natural processes over large areas, there is a need to document land cover change in the region and to understand the factors controlling its spatial distribution. We describe land cover change in an urbanizing area on the coastal plain of southern Mississippi. The region displays a distinctive combination of low relief, rapidly draining soils of poor agricultural quality, fire-shaped forest communities, and a history of resource exploitation. We ask how these features and events have shaped the modern landscape mosaic, and whether principles of land use

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and land cover change observed elsewhere apply to the coastal plain.

Natural communities of the Southeastern coastal plain show a strong upland-lowland contrast caused by rapidly draining soils (Gemborys & Hodgkins, 1971; Titus, 1990). Notwithstanding the modest variation in elevation, the upland-lowland contrast leads to a dendritic distribution of forest types with mixed hardwood forest closely following stream courses in a matrix of upland pine savanna. Widespread cutting in the early 20th century and subsequent plantation forestry have obscured the natural pattern, replacing it with large blocks of managed forest independent of land form (Perkins & Matlack, 2002). In the last three decades there has been a significant increase in the amount of urbanized land in the region (e.g. Gallant, Loveland, Sohl, & Napton, 2004; Griffith, Stehman, & Loveland, 2003; Price, Dorcas, Gallant, Klaver, & Willson, 2006). The biological effects of these landuse changes are not well documented, but observations of natural communities suggest substantial alteration of landscape-scale processes. Landscape fragmentation and widespread fire suppression have reduced fire frequency, causing a shift from pine savanna to mixed pine-hardwood forest over large areas (Batista & Platt, 1997). Plantation forestry appears to influence the spread of pathogens by increasing spatial connectedness and homogenizing landscape structure (Perkins & Matlack, 2002). Changes in land cover have severely affected rain water runoff and erosion, in turn impairing water quality and stressing biological stream communities (Schweizer & Matlack, 2005). Land use change is of particular interest because the region preserves isolated examples of the threatened longleaf pine savanna ecosystem (Landers, van Lear, & Boyer, 1995).

It is important to understand the factors driving these trends at a fine scale because management decisions are made at the level of individual ownership parcels. We document point-changes in land cover using a time series of aerial photographs from 1938 to 2010. Individual point transitions were compared with aspects of the physical, vegetational, and anthropogenic environment to determine the drivers of land-use conversions at various scales. We test the null hypothesis that land use history in a particular study area is shaped by broad regional tends irrespective of local environmental and cultural variation. Our goal is to determine to what extent the peculiar natural and cultural circumstances of the coastal plain have guided land cover change and to identify the scale at which such factors work.

2. Methods

2.1. Study area

The study area was located in Forrest and Lamar Counties, Mississippi (31.31° N, 89.31° W), on the coastal plain of the southeastern United States, ca. 100 kilometers north of the Gulf of Mexico (Fig. 1). The area was well suited to testing our hypothesis because it includes all the principal landuse types of the region, and because extensive historical and photo documentation was available. The climate is subtropical with mild winters and warm, humid summers (National Climate Data Center, 2007). Mean monthly temperatures range from 8.8 °C in January to 27.6 °C in July. The area receives an average annual precipitation of 158 cm from prolonged low-intensity rainfall between late fall and early spring and brief thunderstorms during summer months. Soils are fast-draining ultisols in Pleistocene shoreline terraces (USDA, 1993; Walker, 1994) characterized by sand and sandy loams with a high shrink-swell potential and low agricultural value (USDA Soil Conservation Service, 1993). The area falls within EPA Ecoregion IX; Southeastern Temperate Forested Plains and Hills (Omernik, 1987; Sohl, 2013) close to its southern boundary with the Southern Coastal Plain Ecoregion (Drummond, 2013).

The study area covers ca. 340 km^2, defined by 17 small watersheds draining into the nearby Leaf and Bouie Rivers. Landforms include the flood plains of the Leaf and Bouie Rivers and tributary creeks (ca. 45 m a.s.l.) flanked by gently rolling hills rising to 120 m in the southwestern part of the study area. Natural vegetation has historically been an open, fire-maintained savanna with tree cover consisting almost exclusively of longleaf pine (*Pinus palustris*) in upland sections. The dominant vegetation today is a closed-canopy pine-hardwood forest roughly corresponding to Quarterman and Keever's (1962) Southern Mixed Hardwood Forest, with small amounts of managed pine plantation (largely fast-growing *Pinus taeda* and *P. elliottii*). Human activity has produced a mosaic of forests, agricultural grasslands, lawn, impervious surface, wetlands, and small lakes.

2.2. Local history

Until the late 19th century the study area was sparsely populated, dominated by old-growth pine savanna and bottomland hardwood forest. Between ca. 1890 and 1930, the area experienced rapid deforestation in a period of intensive timber exploitation referred to as the "Southern Lumber Boom" (Williams, 1989). The small city of Hattiesburg (pop. 46,626; US Census, 2011), arose at the east edge of the study area as a transportation hub and milling center for the lumber industry. Timber extraction peaked ca. 1925 and declined rapidly in the economic depression of the 1930s (Williams, 1989). After exhaustion of the timber resource, modest population growth was supported by establishment of a regional hospital, educational facilities including the University of Southern Mississippi, and a military training facility. Lacking the recreational advantages of the Gulf Coast and the established industry of the adjacent Piedmont zone, the Southern Plains lagged in population growth (Napton, Auch, Headley, & Taylor, 2010). While other parts of the country experienced rapid suburban growth in the years following World War II (Garreau, 1991; Platt Boustan, 2007), the study area remained in a state of economic stagnation until the 1960s, when an interstate highway connected the region with urban centers along the Gulf Coast. In the 1970s and 1980s, the local economy shifted from dependence on marginal agriculture to an economy supported mainly by service industries in the small urban area (Hattiesburg Area Chamber of Commerce, 2002). Suburban development accelerated with the construction of arterial roads westward from the town center. In the 1980s and 1990s an influx of senior citizens attracted by the mild climate and affordable living contributed to population increase. On August 29, 2005, the eye of Hurricane Katrina, a strong Category 3 storm, passed directly over Hattiesburg causing extensive destruction to buildings and forests (Stanturf, Goodrick, & Outcalt, 2007).

2.3. Land cover data

Land cover was recorded at 296 sample points on a square grid with a 1000 meter interval. The interval was selected to provide high resolution while exceeding the scale of most management units, thus ensuring spatial independence of point data. Individual points were relocated and examined on aerial photos taken in 1937–1938, 1958, 1970, 1982, 2000, and 2010 covering a period of ca. seventy years. The earliest photos were taken at a scale of 1:18,000 for purposes of petroleum exploration (Tobin Aerial Surveys, San Antonio, TX); photos from 1958 onward were taken in the federal NHAP, NAPP, and Farm Service Agency survey programs at a scale of ca. 1:8000. At all dates individual trees were clearly distinguishable, although grass- and scrubland texture was occasionally problematic in the 1937–1938 photos. At each date,