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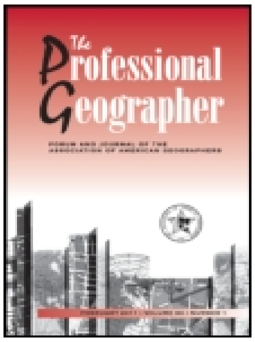


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# Having It Both Ways? Land Use Change in a U.S. Midwestern Agricultural Ecoregion*

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Urbanization has been directly linked to decreases in area of agricultural lands and, as such, has been considered a threat to food security. Although the area of land used to produce food has diminished, often overlooked have been changes in agricultural output. The Eastern Corn Belt Plains (ECBP) is an important agricultural region in the U.S. Midwest. It has both gained a significant amount of urban land, primarily from the conversion of agricultural land between 1973 and 2000, and at the same time continued to produce ever-increasing quantities of agricultural products. By 2002, more corn, soybeans, and hogs were produced on a smaller agricultural land base than in 1974. In the last quarter of the twentieth century, ECBP ecoregion society appeared to have "had it both ways": more urbanization along with increased agricultural output. **Key Words: Eastern Corn Belt Plains, increased agricultural output, urbanization.**

城市化被直接连结至农业土地面积的减少, 并因此被认为是对粮食安全的威胁。儘管用来生产粮食的土地面积已然减少, 但粮食产出的变化却经常被忽略。东部玉米种植带 (ECBP) 是美国中西部重要的农业区域。该区域在 1973 年至 2000 年间, 主要透过农地变更, 使得城市土地面积显着成长, 但却也同时不断创造农产品产量的增加。与 1974 年相较之下, 2002 年之际, 有更多的玉米、大豆和食用猪产自于较小型的农业基地。二十世纪的最后二十五年, ECBP 的生态区域社会似乎能够"两者兼得": 更多的城市化, 同时伴随着农业产出的增加。 关键词: 东部玉米种植带, 增加的农业产出, 城市化。

La urbanización ha sido directamente vinculada a la reducción del área de las tierras agrícolas, y en tal condición se la considera como amenaza para la seguridad alimentaria. Aunque el área de tierra utilizada para producir alimentos ha disminuido, lo que con frecuencia se pasa por alto son los cambios ocurridos en la productividad agrícola. Las Planicies del Cinturón Oriental del Maíz son una región agrícola importante del Medio Oeste de los EE.UU. Esta región se ha ganado un espacio significativo de terreno urbana, primariamente con la conversión de tierra agrícola entre 1973 y 2000, a la vez que continuaba produciendo volúmenes cada vez más grandes de productos agrícolas. Para el 2002, más soya, maíz y cerdos fueron producidos sobre una base de tierra agrícola más pequeña que la de 1974. Parece que durante el último cuarto del siglo XX, en la eco-región plana del Cinturón Oriental del Maíz concurrieron las dos cosas: más urbanización simultáneamente con una mayor productividad agrícola. *Palabras clave: Planicies del Cinturón Oriental del Maíz, aumento de productividad agrícola, urbanización*

Urbanization is one of the major land cover transformations humans have wrought upon the Earth. During the twentieth century this anthropogenic action accelerated. The United States is no exception—its population reached an estimated 316 million by 2013, of which 80 percent lived in urban and other built-up lands in and around metropolitan areas (U.S. Census Bureau 2012).

Americans find many advantages in living in or near metropolitan areas, although urbanization has been shown to have a number of negative externalities. Increased amounts of developed land cover can deplete downstream water quality and quantity, air quality, and wildlife habitat; alter land surface–atmosphere interactions such as increasing greenhouse gas emissions; fragment nearby working rural landscapes; and change local societies and land use perceptions (e.g., Berry 1990; Thomas and Howell 2003; Burian and Pomeroy 2010; Heisler and Brazel 2010; Jenerette and Alstad 2010; Santosa 2010; Shepherd et al. 2010; Slemp et al. 2012). Urbanization also reaches far beyond its local hinterlands as higher density settlement draws on land use resources at various scales using processes such as agriculture, forestry, and mining to maintain itself. These other land uses can also create or augment negative externalities brought on by urbanization such as the loss of biodiversity (Czech, Krausman, and Devers 2000), erosion and sedimentation (James 2011), and toxic waste production (Kavanaugh 1996). Agriculture, in particular, has caused deforestation (Mountford 2000), wetland loss (Vileisis 1997), and nutrient impairments of waterways (Power 2010).

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Urbanization in the United States, however, tends to impact agricultural landscapes in greater amounts and is perceived to be a threat to farming (Sorensen, Greene, and Russ 1997). Agricultural land was the leading source of new developed (built-up) land in the conterminous United States between 1973 and 2000 (Auch, Drummond, et al. 2012). Farming on the metropolitan fringe can become more complex and friction between rural and urban land uses can result (Lopez, Adelaja, and Andrews 1988; Kelsey and Singletary 1996; Daniels 2000; Thomas and Howell 2003). An important question then becomes this: Does urbanization pose a threat to U.S. food production, now or any time in the foreseeable future?

U.S. farmland loss to urbanization has been lamented in the media and by advocacy groups (Kneeland 1981; Sorensen, Greene, and Russ 1997; Mitchell 2001; Grady and Tsouderos 2004; Heinricht 2004; Campbell 2006; Erbé 2010) and raised as an issue of concern in numerous scholarly articles (e.g., Alig, Kline, and Lichtenstein 2004; Thompson and Prokopy 2007; Guzy et al. 2008) but often only in passing and under a broad assumption that a decline in agricultural land equates to a decline in agricultural production. This raises an important question: What quantity of agricultural land is needed to satisfy domestic and global markets of agricultural output? Nizeyimana et al. (2001) noted that this debate had been ongoing for three decades. Their emphasis was that urbanization was disproportionally impacting the most productive soils of the country. Greene and Stager (2001) also noted concern over greater conversion of "prime" cropland across the country, as well as others (Hasse and Lathrop 2003; Petrov and Sugumaran 2009) in regions as diverse from each other as New Jersey and Iowa. Imhoff, Bounoua, DeFries, et al. (2004) explored a different issue, namely, that urbanization of the most "productive" land has reduced both ecological net primary production and agricultural potential. None of these studies, however, discussed changes in increased agricultural *production* in the late twentieth century—one of the leading stories of recent U.S. agricultural land use (Hart 2003a).

Amundson, Guo, and Gong (2003), in discussing soil diversity in the United States and the societal value of undisturbed soils, stated that such a value "must include the value of present farmland in rapidly urbanizing areas, since the loss of this land increases the pressure to agriculturally develop native landscapes elsewhere" (481). This conclusion assumes a near steady state of agricultural production and implies that cropland loss in one location necessitates the creation of new cropland elsewhere. Greene and Stager (2001) also emphasized "replacement" cropland, positing that rangelands in the Western United States were being converted to replace prime farmland lost to urbanization elsewhere, although little evidence was offered in support of this teleconnection. In all of these studies, increased agricultural productivity was never mentioned, and the need for replacement cropland appears far from certain.

In the broader theory of land change science (Rindfuss et al. 2004), our work and arguments are rooted in von Thünen's model of the urban–rural land use continuum (Hall 1966; O'Kelly and Bryan 1996). Changing functional and economic aspects of agro-food geography (Pierce 1994; Hart 2003a; Watts, Ilbery, and Maye 2005) and the continued fragmentation of land at the urban–rural fringe (Theobald 2001; Thomas and Howell 2003; Irwin and Bockstael 2007) creates unique opportunities for places and regions to grow specialty and locally consumable foods (Kloppenburg, Hendrickson, and Stevenson 1996; Giombolini et al. 2011) not normally found in surrounding rural areas dominated by row crops, small grains, or large-scale livestock production.

Although Pollan (2008), and those who promote carbon- and fossil fuel–free agricultural production, would strongly disagree with our thesis, the past seventy years (and foreseeable future) of large-scale, agricultural production cannot be ignored (Hart 2001) and should be better understood. We, in fact, argue that growing urban populations rely on the continued expansion of large-scale production agriculture and access to supermarket foods (Smoyer-Tomic, Spence, and Amrhein 2006), in that specific urban situations might not afford residents the opportunity to become "locavores" (Burros 2007; Blake, Mellor, and Crane 2010) due to constraints of land, time, money, or other resources (including personal choice). Increased reliance on foods stemming from large-scale production agriculture prompts this question: Can both increased urbanization and increased agricultural productivity coexist?

This theoretical notion was examined using land use and land cover (LULC) change analysis in the Eastern Corn Belt Plains (ECBP) ecoregion between 1973 to 2000; this area has experienced substantial increases in developed land cover (a surrogate for urbanization) while it has had continued increases in agricultural output (Figure 1). As part of this aspect of the research, we also examined the sampled areas of agriculture to developed land conversions against specific spatially explicit biophysical conditions to test whether higher quality land for farming was being transformed in relationship to all land. We then analyzed the agricultural production of the region's leading commodities during nearly the same study period (1974–2002). We end the article with a discussion of our results and interrogate the issue(s) of regional agricultural sustainability with respect to increased urbanization.

## Data and Methods

The data used for this study come from four main sources. First, LULC change estimates come from the U.S. Geological Survey's (USGS) Land Cover Trends project. Second, socioeconomic data related to population, housing, and employment come from the U.S. Census Bureau decadal Census of Population and Census of Housing. Third, agricultural production values come from the Census of Agriculture (U.S. Census

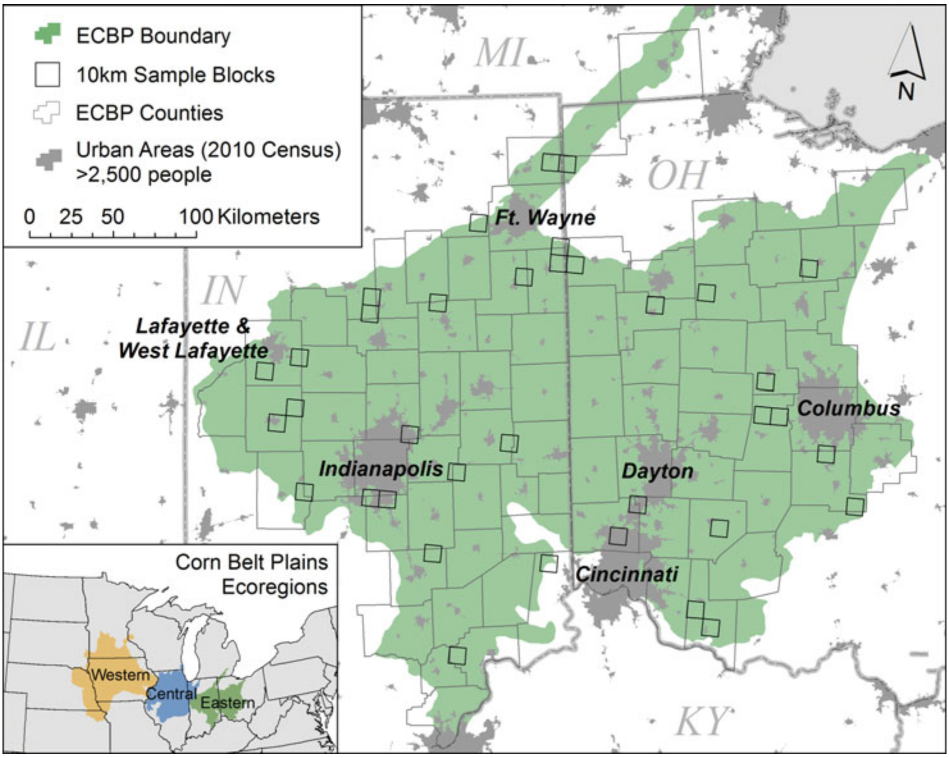


**Figure 1** *Locations of the seventy-seven counties, urban areas, and sample blocks of the Eastern Corn Belt Plains (ECBP) ecoregion. Source: Sample block and ecoregion data were obtained from the U.S. Geological Survey Land Cover Trends project; all other data were obtained from the U.S. Census Bureau (see* http://www.census.gov/cgi-bin/geo/shapefiles2010/main*). (Color figure available online.)*



Bureau 1974–1992; National Agricultural Statistics Service [NASS] 1997–2002).[1] Finally, the cropping capabilities of the ecoregion's land area were acquired from the U.S. Department of Agriculture's (USDA) SSURGO soils database (USDA 2009).

The Land Cover Trends project was designed to better understand recent conterminous U.S. LULC change at regional and national scales (Loveland et al. 2002). The methodology used multitemporal sources of Landsat satellite imagery, a regionalization by U.S. Environmental Protection Agency (EPA) ecoregions (Omernik 1987; U.S. EPA 1999), and a statistical sampling strategy (Stehman, Sohl, and Loveland 2003). Ecoregion estimates of LULC change in the ECBP were derived from the thirty-six sample "blocks" found in Figure 1.[2] The ECBP had nine LULC classes that followed a modified Anderson Level I classification scheme (Anderson et al. 1976). Most prevalent in the ECBP were agriculture,[3] forest, and developed.[4] Beyond more standard estimates of rates and areal extent of LULC change, areas identified as "agriculture to developed" were further analyzed using geographic information system intersection with the USDA's spatially explicit cropping capability database to investigate the quality of the land being converted. Socioeconomic and agricultural data were gathered at the county scale and aggregated up to the ecoregion. A county was assigned to the ECBP if it or a majority of its area were contained within the ecoregion (see Figure 1).

## Land Cover Change Results

Results from the USGS Land Cover Trends analysis of the ECBP ecoregion highlight the dynamics of the region's changing LULC from 1973 to 2000. The most prevalent land cover change in the ECBP ecoregion during the study period was indeed agriculture to developed land conversion at a normalized rate of 0.16 percent of the ecoregion per year. Land Cover Trends estimates that 3,708 km$^2$ (±1,726 km$^2$) of agricultural land was converted directly to developed land use (Table 1). The 1992 to 2000 interval was the most dynamic for this type of change, accounting for 1,760 km$^2$ (±896 km$^2$) or 0.26 percent per year. The interval with the least agriculture to developed change was between 1980 and 1986, with 324 km$^2$ (±159 km$^2$) or 0.06 percent of the ecoregion per year.

During the study period, most of the land converted from agriculture to developed land cover was of high-quality cropping capability (Class 2), but this was almost identical to the percentages of the ecoregion as a whole in that capability class (Table 2). The only exception was a small amount that was converted from

***Table 1*** *The top five individual land use and land cover changes between 1973 and 2000 in the Eastern Corn Belt ecoregion*

| Individual LULC changes | Area changed (km$^2$) | Margin of error (± km$^2$) | Percentage of all changes |
|---|---|---|---|
| Agriculture to developed | 3,708 | 1,726 | 66.4 |
| Forest to developed | 403 | 303 | 7.2 |
| Agriculture to grassland or shrubland | 388 | 134 | 7.0 |
| Agriculture to mechanically disturbed | 206 | 152 | 3.7 |
| Forest to agriculture | 171 | 45 | 3.1 |
| All others | 710 | N/A | 12.7 |

*Note:* LULC = land use and land cover.

the least capable land in the ecoregion (Class 7) that had been included in land identified as agricultural land cover. Such land typically has a high degree of slope and poorer soils for building construction, which likely result in less of this soil class being converted to developed uses.

Agricultural lands in the ecoregion were also converted to grassland or shrubland (388 km$^2$, ±134 km$^2$), with another 206 km$^2$ (±152 km$^2$) changed from agriculture to mechanically disturbed land (Table 1). This latter change often occurred within metropolitan areas where large, ongoing construction projects were captured in the remotely sensed imagery. Most of these mechanically disturbed conversions ultimately became developed land uses. Minor conversions from agricultural land included to mining, water, and forest (229 km$^2$ combined, ±51 km$^2$; part of the "other" change found in Table 1). The only noticeable source of new agricultural land created was an estimated 171 km$^2$ (±45 km$^2$) gained from forest. Overall, agricultural land in the ECBP decreased from 80.2 percent (±3.2 percent) in 1973 to 75.0 percent (±4.6 percent) in 2000.

Over time, there was highly suitable land for farming in the ecoregion that was not in agricultural land cover or had not been converted to developed lands. To evaluate how much, we compared the sample-based land covers[5] to the USDA cropping capability data for the best cropping land and found that a majority of the ecoregion's land was already in agricultural or developed land uses by 1973 (Table 3). Because agriculture to developed land cover was the leading change in the ecoregion, the percentages of these cropping capability classes in either agriculture or developed use did not show substantial shifts by 2000 (Table 3). Most of the potential agricultural land left in the ecoregion was Class 2 land lying under either forest or grassland and shrubland land covers, with a small amount of Class 3 in the same condition. This "reserve" agricultural land amounted to approximately 12 to 13 percent of the ecoregion using the sample-based estimates.

## Socioeconomic Changes: Urban Growth

Changes in socioeconomic variables reflect the increase of developed land in the ecoregion (Figure 2). The ECBP gained approximately 1.2 million people from 1970 to 2000, yielding a population of over 8.1 million. The number of occupied housing units increased by just over 1 million during the same time and the employment sectors gained about 1.5 million jobs.

National demographic changes created an increased demand for more per capita housing units (Gober 1981; Hanlon, Short, and Vicino 2010). Mean household size for the ecoregion declined from 3.2 persons in 1970 to 2.5 in 2000, a greater reduction in household size than was found in other areas such as the Northern Piedmont ecoregion of the northeast urban corridor, which experienced a change from 3.2 to 2.7 (Auch, Napton, et al. 2012).



***Table 2*** *U.S. Department of Agriculture cropping capability proportions of the Eastern Corn Belt Plain ecoregion (total ecoregion vs. sample based) and the proportions of identified agriculture land cover conversion to developed land*

| USDA cropping capability classes (from best to least) | Total ecoregion (120-m pixel resolution): Percentages of total | Sample-based ecoregion (60-m pixel resolution): Percentages of total | Agriculture to developed LULC change vs. cropping capability classes (sample-based, 60-m resolution): Percentages of total |
|---|---|---|---|
| Class 1 | 0.1 | > 0.1 | 0.1 |
| Class 2 | 94.0 | 95.1 | 95.7 |
| Class 3 | 4.9 | 3.6 | 4.1 |
| Class 4 | 0.1 | 0.0 | 0.0 |
| Class 7 | 0.9 | 1.3 | 0.1 |

*Note:* USDA = U.S. Department of Agriculture; LULC = land use and land cover.

***Table 3*** *U.S. Department of Agriculture cropping capability proportions of the Eastern Corn Belt Plain ecoregion (total ecoregion) and the proportions of land covers and cropping capability Classes 1 through 4 (sample-based ecoregion)*

| | | **Sample-based ecoregion (60-m pixel resolution)** | | |
|---|---|---|---|---|
| **Total ecoregion (120-m pixel resolution): Percentages of total** | | **Class 1: Agricultural or developed** | **Class 1: Forest or grass/shrub** | **Class 1: All other land covers** |
| 0.1 | 1973 | 98.0 | 2.0 | 0.0 |
| 0.1 | 2000 | 98.0 | 2.0 | 0.0 |
| | | **Class 2: Agricultural or developed** | **Class 2: Forest or grass/shrub** | **Class 2: All other land covers** |
| 94.0 | 1973 | 86.1 | 13.0 | 0.9 |
| 94.0 | 2000 | 86.3 | 12.5 | 1.2 |
| | | **Class 3: Agricultural or developed** | **Class 3: Forest or grass/shrub** | **Class 3: All other land covers** |
| 4.9 | 1973 | 81.2 | 17.3 | 1.5 |
| 4.9 | 2000 | 80.3 | 18.0 | 1.7 |
| | | **Class 4: Agricultural or developed** | **Class 4: Forest or grass/shrub** | **Class 4: All other land covers** |
| 0.1 | 1973 | 0.0 | 0.0 | 0.0 |
| 0.1 | 2000 | 0.0 | 0.0 | 0.0 |

The geographic distribution of these socioeconomic changes had distinctive patterns within the ecoregion (Figure 3). The top twelve counties for population gain accounted for 84.8 percent of the population growth. In Ohio, this group included three Cincinnati suburban-exurban counties, the Columbus core, and two of Columbus's metropolitan counties. The Indianapolis core, three Indianapolis suburban-exurban counties, and the Fort Wayne and Lafayette/West Lafayette core counties were included in Indiana. The county with the largest population loss was the Cincinnati core.

Counties changing most with respect to occupied housing units and employment included many of the just listed counties but also several other urban core counties that were still experiencing gains in these variables. The leaders for occupied housing unit gains included the Cincinnati core and three of its suburban-exurban counties, along with Columbus's core and one of its suburban-exurban counties. Dayton's core county was also included in the leading Ohio counties. In Indiana, Indianapolis's core and two of its suburban-exurban counties, as well as the Fort Wayne and Lafayette/West Lafayette counties, were again the

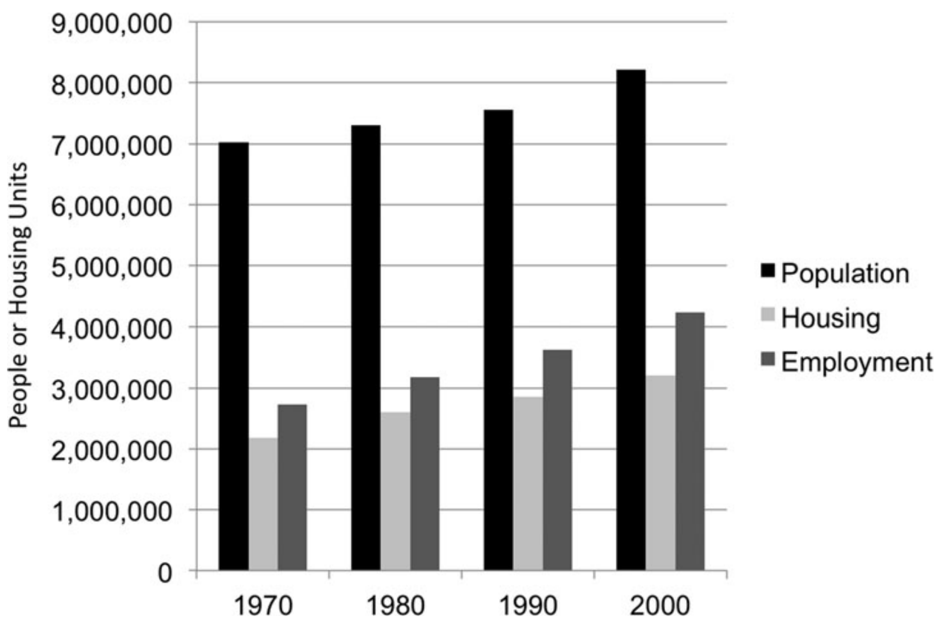


**Figure 2** *Changes in population, housing, and employment. Source: U.S. Census Bureau (1972, 1973, 1983a, 1983b, 1992, 1993, 2002).*

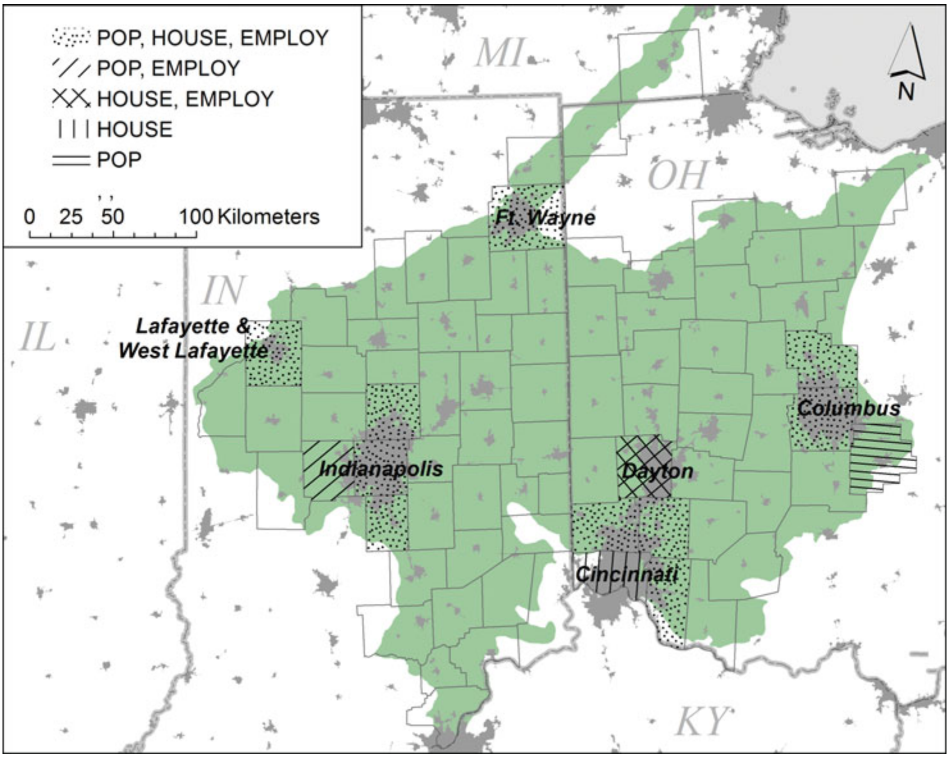


**Figure 3** *Counties that experienced the greatest increases in population (POP), housing units (HOUSE), and employment (EMPLOY). Source: U.S. Census Bureau (1972, 1973, 1983a, 1983b, 1992, 1993, 2002). (Color figure available online.)*

leaders. The group for growth in employment was almost identical to the top gainers in occupied housing units with the exception that the Cincinnati core fell out and an Indianapolis suburban-exurban county was added.

The preceding patterns in metropolitan growth are similar to conditions found by others for contemporary U.S. urbanization, whether in common processes of change (Jackson 1985; Muller 1986; Lewis 1995; Knox 2008; McDonald 2008; Hanlon, Short, and Vicino 2010) or in specific regions (Miller and Johnson 1990; Clark et al. 2003; Auch, Napton, et al. 2012). The ECBP gained population, occupied housing units, and employment that manifested into more developed land in the ecoregion. This additional urbanization should have produced less agricultural output if the perception that "increased development is a threat to farming" was, in fact, true. In reality, ECBP farmers increased their agricultural output as the amount of available agricultural land diminished.

## Agricultural Changes: Increased Production of Leading Commodities

Many of the counties that make up the ECBP ecoregion, especially those in southwestern Ohio, were considered the "first" Corn Belt counties. Their agricultural potential was discovered in the 1750s by land speculators working for the Ohio Company who proclaimed it was "the best agricultural land that any American had yet described" (Hudson 1994, 32).

Corn Belt agriculture has changed over the past century. When O. E. Baker defined the extent of the Corn Belt in the late 1920s, and again when the USDA defined its boundary in 1950, they did so based on a practice of farming where corn was grown in rotation with oats, a hay crop, and possibly wheat with the primary purpose of the farmer being not to produce copious amounts of corn for sale but instead to feed and fatten hogs and beef cattle (Laingen and Craig 2011). Cash-grain farming, which is today the primary agricultural endeavor, where corn and (predominantly) soybeans are grown in rotation, emerged from the Grand Prairie region of Illinois and western Indiana in the 1960s and spread throughout the rest of the Corn Belt by the 1970s. This practice continues today, and the farmers of the ECBP rely more on these two crops than on any other agricultural activity (Figure 4).

The ECBP ecoregion produced 8.5 percent of the nation's corn in 1974, and even though that proportion dropped to 7.3 percent by 2002, overall production more than doubled (8.4 to 18.4 million tonnes[6]). During our study period only one county in the ECBP lost corn production: Indianapolis's core. On average, each county in the ECBP experienced a 119

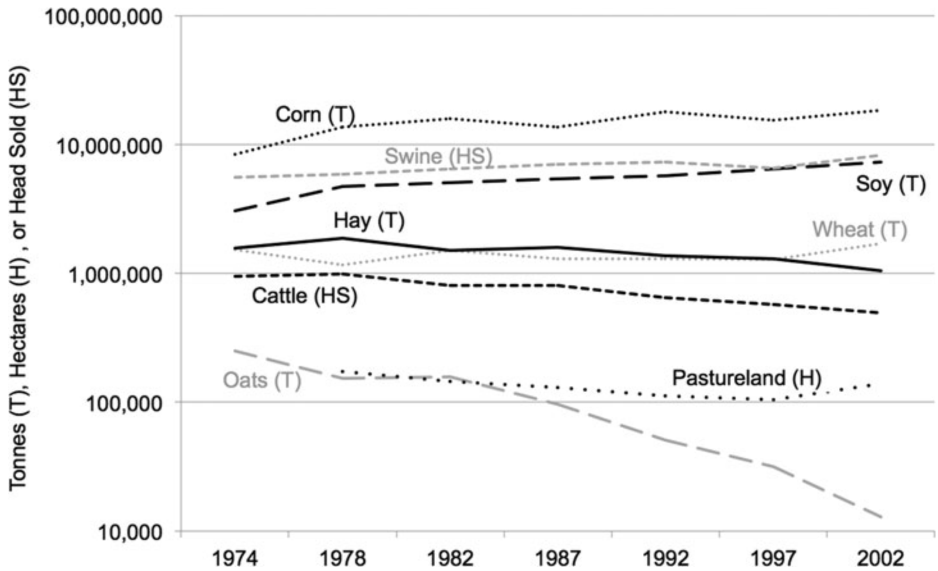


**Figure 4** *Overall trends in agricultural production in the Eastern Corn Belt Plains, 1974 to 2002. Note: Data for pastureland (hectares) were not available at the county scale for 1974.*

percent increase in corn production from 1974 to 2002. The twelve metropolitan counties that were the leading counties with respect to population growth had a 1.0 million tonne increase in corn production (a near doubling since 1974), showing that even counties that led the way in population gain (losing farmland to do so) substantially increased their agricultural output (Figure 5).

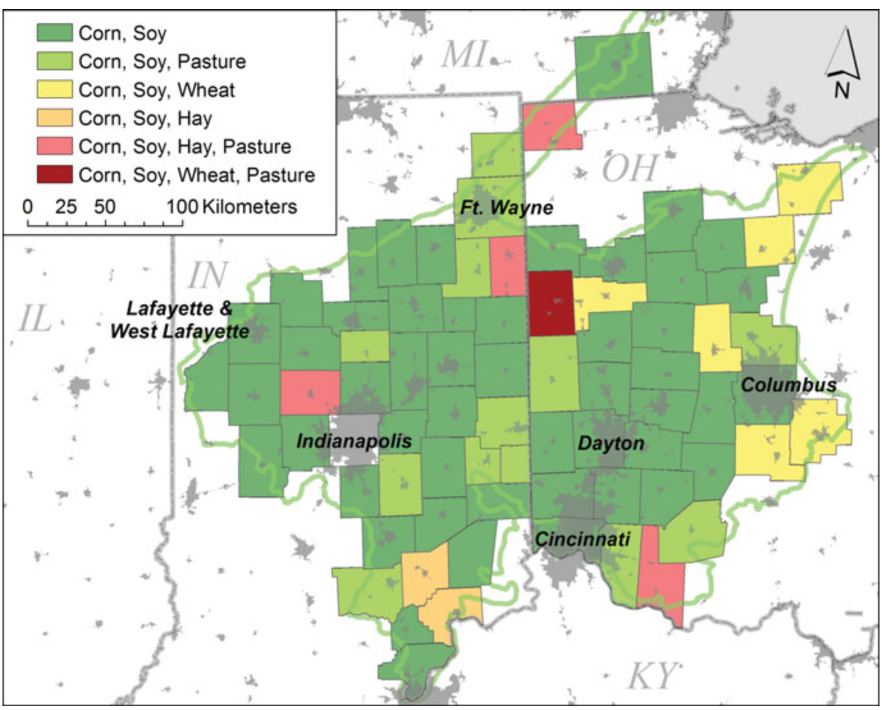


**Figure 5** *Counties that experienced an increase in corn (tonnes), soybeans (tonnes), wheat (tonnes), hay (tonnes), or pasture (hectares). Note: Oats (tonnes) decreased in all counties, and only one county (Indianapolis's core) experienced a decrease for all categories. (Color figure available online.)*

Soybeans, normally grown in rotation with corn, were the Corn Belt's second cash crop by the end of the 1940s. Soybeans fixed nitrogen, which helped increase the next year's corn yield; were used for additional livestock feed; and had high protein content and valuable oil. From the time soybean production reached 25,000 tonnes in Ohio, it took only four more years for that figure to increase tenfold (Hudson 1994). Such increases in soybean production in the Corn Belt have led some to suggest renaming this region the Corn-Soy Belt (Napton 2007). Within the ECBP, average soybean production increased from 3.0 million tonnes in 1974 to 7.3 million in 2002 (a 140 percent increase). And once more, the twelve counties that led the way in population growth (which also experienced a 91 percent increase in corn production) had a 111 percent increase in soybean production (up 427,000 tonnes from 1974 to 2002; Figure 5).

In the Corn Belt, corn and soybean production dominate the agricultural landscape. However, compared to the other two U.S. EPA Corn Belt ecoregions (the Western and Central Corn Belt Plains ecoregions; see Figure 1) the ECBP had other crops and agricultural land uses that have remained more prevalent: lands used to produce wheat, oats, hay and forage, and pastureland. These differences are the result of both the historical settlement of this region and physical limitations of the land itself.

Production of wheat, oats, and hay generally declined (Figure 5), mostly as a function of the increased abundance (and more lucrative markets) of corn and soybeans but also because of decreased numbers of livestock (mainly cattle) that would need both the feed and forage produced for sustenance as well as the pastureland provided by those crops once harvested. In 1974, wheat production was half that of soybeans and 15 percent of corn. By 2002, wheat production was only 12 percent of soybean and a mere 5 percent of corn production. Overall, wheat production decreased by 42 percent (1.5 million to 900,000 tonnes) and only seven counties produced more wheat in 2002 than in 1974. Oat production has also declined significantly. Nationally, from 1974 to 2002 hectares of oats harvested dropped from 4.5 million to 808,000 (82 percent loss), and production decreased from 7.6 million to 1.6 million tonnes (79 percent loss). The ECBP was highly representative of these national-scale trends. Each county in the ecoregion saw a marked decline in oat production, and across all counties there was a 95 percent decline in tonnes produced (from 251,356 in 1974 to 12,903 in 2002).

A less prevalent agricultural land-use type in the ECBP was land used to produce hay. The presence of large amounts of lands devoted to producing hay usually means that (a) they are not well suited for producing higher valued crops or (b) there are significant populations of livestock found locally who consume the hay being produced. Hay production in the ECBP declined by 34 percent from 1974 to 2002 (1.6 million tonnes down to 1.0 million). Most of the loss occurred in the core counties of the ecoregion, with the five counties that experienced increases found along the region's periphery. Neither point is surprising; higher quality lands (in the core) have been converted from hay to row crops, and the lands around the periphery, where soil quality is poorer and where slope variability is higher, are likely best suited for hay production (Figure 5). Hay land use is also correlated with cattle production, and the number of cattle in the ECBP ecoregion declined, a major trend that has been occurring throughout the Corn Belt over the past half-century (Hart 2003a). In the ECBP, forty-two counties (of seventy-seven) lost over half of their cattle, and seventeen counties lost over three fourths (Figure 6).

Another land use associated with cattle is pastureland. During the study period, the ECBP lost 35,342 hectares (353 km$^2$) of pastureland. This 20 percent loss (from 1978–2002) might at first glance seem impressive, leading some to ask whether cropland lost to urbanization was "replaced" by converting pastureland to cropland. This has occurred, but it is only a fraction of all agricultural land lost to urban development. Increase in pastureland, not surprisingly, was seen in the five counties that saw increased numbers of cattle. Further, in the eighteen counties where pastureland area increased, so did total production of both corn and soybeans, which limits the notion that pastureland to cropland conversions were commonplace. In stepping back to consider the scale of pastureland in the larger picture of all agricultural land use, the ECBP's proportion of pastureland declined from 2.6 percent in 1978 to 2.3 percent in 2002, numbers that would not point toward "hidden" land conversions that would downplay the role that urbanization has had on diminishing the amount of viable cropland in the region.

Hog production in the ECBP was also representative of what had happened across the rest of the Corn Belt, where the number of farms producing hogs had declined while the number of head produced on each remaining farm had increased (Furuseth 1997). In the ECBP's seventy-seven counties, the number of hogs sold increased from 5.5 million to just over 8.2 million from 1974 to 2002 (49 percent increase). During this time, this increase occurred on fewer farms in fewer counties. In 1974, 50 percent of the 5.5 million hogs sold were found in twenty-two of the seventy-seven counties (Figure 6). By 2002, 50 percent of the 8.2 million hogs sold were found in only eleven of the seventy-seven counties and nearly one fourth of all ECBP hogs sold were found in just four counties.

## Discussion

During the final three decades of the twentieth century, the ECBP expanded its agricultural production while continuing to add more urban and other built-up developed lands. Farmers continued to specialize and excel in contemporary Corn Belt agriculture as corn, soybean, and hog production increased and less valuable commodities per land unit witnessed declines. Developed land increased an estimated 92 percent during the same time period as the farmers' metropolitan

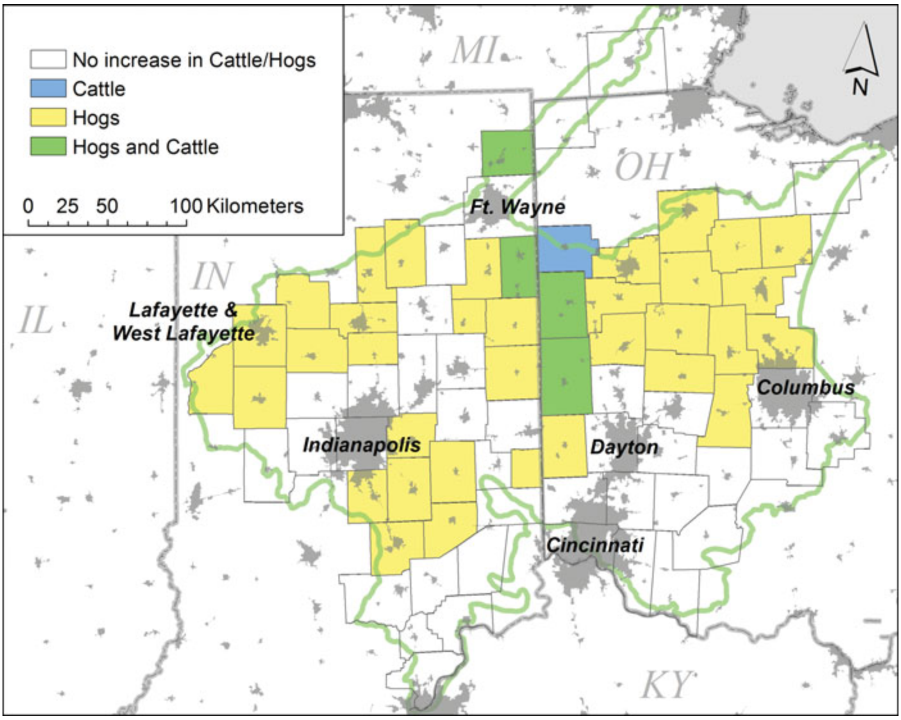


**Figure 6** *Counties that experienced an increase in number of hogs or cattle sold. (Color figure available online.)*



and micropolitan neighbors hurried to deconcentrate and spread out their developed land uses.

Analysis of how nonagricultural land uses, especially urbanization and other built-up land, affect U.S. farmland must include an examination of changes in agricultural production. Whereas urbanization does appear to be concentrating disproportionally on the "best" farmland (Greene and Stager 2001; Nizeyimana et al. 2001; Imhoff, Bounoua, DeFries, et al. 2004), increased crop production was occurring there as well (Hart 2001; Napton et al. 2010). At least in the last half to quarter of the twentieth century, this competition between agriculture and urbanization at the national scale, as well as in regions such as the ECBP, was accommodated.

In other regions with different sets of conditions (more overall developed land, or where agriculture is more confined because of biophysical factors), urbanization might displace farming or transition it from traditional to specialized products. California was the leading milk-producing state in 2000, with 19.2 percent of the U.S. total, a change from its number two position in 1975 with 9.4 percent of the national output (Blayney 2002). Hart (2003b) described how increased urbanization of greater Los Angeles had substantially decreased the number of dairy farms around Chino, California. Many of these farmers, however, used the capital acquired by selling out to development to relocate to California's Central Valley, which allowed them to modernize and expand their operations. A somewhat different situation occurred in New Jersey. In 1974, 17.6 percent of the state's total agricultural production value was from horticultural and nursery products, but in 2002 nearly half (47.6 percent) came from these types of items (see note 1). Although farming continued in New Jersey, it had become much more focused on catering to higher value products bound for metropolitan markets, thus following Hart's (1991) "perimetropolitan bow wave."

The dynamics of regional agricultural production and the interaction with increased urbanization might be more complex than generally given in national-scale comparisons (e.g., Imhoff, Bounoua, DeFries, et al. 2004) or in media representations (e.g., Erbé 2010). In the preceding example of intrastate relocation of regional dairy production, farmers from biophysically confined and highly urbanized Southern California moved to the Central Valley to join an already well-established agricultural system. The core Central Valley counties, between 1974 and 2002, experienced a 144 percent increase in the number of dairy cows, as well as a 291 percent increase in almond production, 68 percent increase in rice, and 3 percent decline in cotton production (NASS 2002), as the Central Valley ecoregion gained an estimated 1,129 km$^2$ of new developed land cover, 60 percent of it coming from agricultural land (Sleeter 2012).

The Piedmont ecoregion of the southeastern United States, in contrast, had been on a different agricultural land use trajectory well before recent times. It had been an important national farming region during the nineteenth century, but environmental degradation, along with its biophysical properties, had reduced the estimated agricultural proportion of its land cover to less than 25 percent of the ecoregion by 1973 (Napton et al. 2010). The Piedmont gained an estimated 7,436 km$^2$

of new developed land cover between 1973 and 2000 (with approximately 24 percent coming from agriculture) as amounts of leading agricultural products such as tobacco, cattle, hay, and broiler chickens decreased 51 percent and increased 6.5, 60, and 1,400 percent, respectively, between 1974 and 2002.

Back in the Midwest, the Central Corn Belt Plains ecoregion, with its developed land cover dominated by metropolitan Chicago, gained an estimated 2,347 km$^2$ of developed land cover (87 percent from agricultural land conversion) between 1973 and 2000 and production of its main agricultural commodities, corn and soybeans, increased by 73 and 132 percent, respectively.

During the study period, citizens of the ECBP appeared to "have it both ways"; an expansion of the built environment and increasing agricultural output. Is this "sustainable" into the future or will increased urbanization eventually curb the region's agricultural capability and potential? Some believe we have reached a point where increased yields per unit of land area will end (or at least greatly level off), or where we have reached an "acceptable" amount of land that "should" be cropped (Pimm 2001; Imhoff, Bounoua, Ricketts, et al. 2004). Others state that theoretical land potential or continued innovation and management changes will keep productivity ahead of demand (Wagner Weick 2001; Olmstead and Rhode 2008; Franck et al. 2011), whereas some view the situation as mixed, citing that wheat and rice yields have not kept pace with corn or that changes to climate will likely increase crop production in some regions while decreasing output in others (Lotze-Campen 2011; Pardey 2011).

One way that increased agricultural production was accomplished during the second half of the twentieth century was to increase the use of external inputs into the farming system, although the connection(s) between increased inputs and urbanization is tenuous. Between 1960 and the mid-1970s, the use of inorganic fertilizers in the United States increased nearly 170 percent, reaching approximately 20 million tonnes annually (USDA 2012b). We consider nitrogen used on corn as the keystone inorganic fertilizer for the ecoregion and thus looked at its changes over time. The amount of nitrogen applied to corn in the ECBP increased from 189,000 tonnes in 1974 to 374,000 tonnes in 1982. Since 1982, nitrogen fertilizer applied to corn has declined and remained steady, averaging just over 300,000 tonnes annually.[7]

Nationally, inorganic fertilizers used annually have followed similar patterns and have remained mostly constant between the late 1970s and 2010, at $\sim$20 million tonnes ($\pm$3 million) (USDA 2012b). The advent of precision application through enhanced geospatial data management is increasing (Batte and Arnholt 2003; Kock and Khosla 2003), which might decrease overall amounts applied in the future. Additionally, agricultural production has increased through advanced agronomic technologies, first through improved hybrid seeds that featured desired attributes, and subsequently through genetically modified (GMO) varieties of crops. Although trepidation of and resistance to GMO crops continues, the acknowledgment that only the frontier of such biotechnology has been reached must be made (Reganold et al. 2011).

Other major breakthroughs in agriculture, such as perennial grains (Glover et al. 2010) with comparable or even greater yielding capabilities, might alter the dynamics of producing components for the food industry once again, possibly requiring even less land to feed increasing populations than what is currently in use. The potential for even more farmland to become "surplus" is a possibility, and numerous other uses, including more urbanization, could result. Developed land uses might be disliked for many legitimate negative externalities, including some of the social–cultural vacuousness of their contemporary form (Knox 2008), but their threat to national or even global food security is yet to be determined. In 1981, *The New York Times* reported estimates made by USDA researchers that by 2000, the United States would need between 311,608 and 457,295 km$^2$ more farmland to meet the needs of the nation (Kneeland 1981). In reality, USGS Land Cover Trends results estimate that agricultural land decreased 99,158 km$^2$ in the conterminous United States between 1980 and 2000 (Sleeter et al. 2013). Although not fully comparable to the previously estimated amount, Census of Agriculture data reveal a loss of 45,312 km$^2$ of total cropland between 1982 and 2002.

The probability that large amounts of crops will be grown and livestock found on farmland in the ECBP between expansive urban systems several centuries hence should not be discounted. From 2000 to 2010, total U.S. population increased 9.7 percent (an increase of 27.3 million people). Over that same period of time, U.S. corn and soybean production increased by 25 percent and 21 percent, respectively (USDA 2013b). This trend of producing large quantities of Corn Belt–centric crops continued in 2013, with U.S. farmers expected to plant a record 70.6 million hectares of corn and soybeans (USDA 2013a), further reinforcing the notion that increased urbanization does not appear to be slowing the production of major agricultural commodities and that indeed we might actually "have it both ways," although impacts of recent perturbations, such as the Energy Security Independence Act (authorizing biofuel mandates) to the Great Recession's effects on new housing markets, to the multitudes of other LULC change driving forces that are constantly ebbing and flowing, are yet to be determined. Thus, the need for continued land change research remains constant. ■

## Notes

[1] Data years are as follows:
U.S. Census Bureau: Population, housing, and employment data: 1970, 1980, 1990, 2000.

U.S. Department of Agriculture: All data were either downloaded or keyed in from http://www.agcensus.usda.gov/. Census dates obtained: 1974, 1978, 1982, 1987, 1992, 1997, 2002.

U.S. Geological Survey Land Cover Trends Project: Land use/land cover change data: Nominally 1973, 1980, 1986, 1992, 2000.

[2] USGS Land Cover Trends project change estimates are given with an uncertainty range using an 85 percent confidence interval.

[3] USGS Land Cover Trends project definition of "agricultural" LULC is "Land in either a vegetated or an unvegetated state used for the production of food and fiber. This includes cultivated and uncultivated croplands, hay lands, pasture, orchards, vineyards, and confined livestock operations. Note that forest plantations are considered forests regardless of the use of the wood products" (Auch, Drummond et al. 2012, 357).

[4] USGS Land Cover Trends project definition of "developed" LULC is "Areas of intensive use with much of the land covered with structures or anthropogenic impervious surfaces (e.g., high-density residential, commercial, industrial, roads, etc.) or less intensive uses where the land cover matrix includes both vegetation and structures (e.g., low-density residential, recreational facilities, cemeteries, parking lots, utility corridors, etc.), including any land functionally related to urban or built-up environments (e.g., parks, golf courses, etc.)" (Auch, Drummond et al. 2012, 357).

[5] A comparison between sample-based Land Cover Trends ecoregion land cover and "wall-to-wall" land cover for the entire ecoregion was not done because of the following: (1) there are no 1973, 1980, or 1986 "wall-to-wall" land covers available for the ecoregion, and (2) the land cover classifications and methodologies used to produce the land cover data between Land Cover Trends and USGS 1992 and 2001 National Land Cover data sets do not make these directly comparable.

[6] Bushels and tons to tonne conversions are available at http://www.spectrumcommodities.com/pdf/convfactY2K.pdf.
Corn = bushels × 0.025400
Wheat and soybeans = bushels × 0.027216
Oats = bushels × 0.014515
1 tonne = 1 ton × 0.90718474
1 tonne = 2,204.62 lbs.

[7] There is no known comprehensive county-scale data set of inorganic fertilizer used in the United States, although the USDA (2012b) has multiple data sets devoted to national and state-level analysis (where county-level estimates can be derived). In general, application of nitrogen fertilizer is focused on corn. To calculate an estimated amount of nitrogen applied to corn in the ECBP, we used Census of Agriculture data (from 1974 to 2002) of county-level amounts of corn planted, multiplied those values by state-level values of the percentage of land area treated, and then multiplied that value by state-level values of application rates. These results represent the best estimates possible using available and appropriate USDA data.

## Literature Cited

Alig, R. J., J. D. Kline, and M. Lichtenstein. 2004. Urbanization on the U.S. landscape: Looking ahead in the 21st century. *Landscape and Urban Planning* 69:219–34.

Amundson, R., Y. Guo, and P. Gong. 2003. Soil diversity and land use in the United States. *Ecosystems* 6:470–82.

Anderson, J. R., E. E. Hardy, J. T. Roach, and R. E. Witmer. 1976. A land use and land cover classification system for use with remote sensor data. Professional Paper 964, U.S. Geological Survey. Washington, DC: U.S. Government Printing Office.

Auch, R. F., M. A. Drummond, K. L. Sayler, A. L. Gallant, and W. Acevedo. 2012. An approach to assess land cover trends in the conterminous United States (1973–2000). In *Remote sensing and land cover: Principles and applications*, ed. C. Giri, 351–67. Boca Raton, FL: Taylor & Francis/CRC Press.

Auch, R. F., D. E. Napton, S. Kambly, T. R. Moreland, Jr., and K. L. Sayler. 2012. The driving forces of land change in the northern piedmont of the United States. *Geographical Review* 102 (1): 53–75.

Batte, M. T., and M. W. Arnholt. 2003. Precision farming adoption and use in Ohio: Case studies of six leading-edge adopters. *Computers and Electronics in Agriculture* 38:125–39.

Berry, B. J. L. 1990. Urbanization. In *The earth as transformed by human action*, ed. B. L. Turner, II, W. C. Clark, R. W. Kates, J. F. Richards, J. T. Mathews, and W. B. Meyer, 103–19. Cambridge, UK: Cambridge University Press.

Blake, M. K., J. Mellor, and L. Crane. 2010. Buying local food: Shopping practices, place, and consumption networks in defining food as "local." *Annals of the Association of American Geographers* 100 (2): 409–26.

Blayney, D. P. 2002. The changing landscape of U.S. milk production. USDA, Economic Research Service, Statistical Bulletin Number 978. http://www.ers.usda.gov/publications/sb978/sb978.pdf (last accessed 3 April 2012).

Burian, S. J., and C. A. Pomeroy. 2010. Urban impacts on the water cycle and potential green infrastructure implications. In *Urban ecosystem ecology*, ed. J. Aitkenhead-Peterson and A. Volder, 277–96. Madison, WI: American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America.

Burros, M. 2007. Preserving fossil fuels and nearby farmland by eating locally. *New York Times* 25 April:F10.

Campbell, D. 2006. California's Central Valley losing best farmland fastest. http://findarticles.com/p/articles/mi_m0KFU/is_3_73/ai_n16485822/ (last accessed 22 May 2012).

Clark, J., J. S. Sharp, E. Irwin, and L. Libby. 2003. *Growth and change at the rural–urban interface: An overview of Ohio's changing population and land use*. Columbus: The Ohio State University, The Exurban Change Project. http://exurban.osu.edu/growthandchange/growth%20change%20-%20no%20graphics.pdf (last accessed 10 May 2011).

Czech, B., P. R. Krausman, and P. K. Devers. 2000. Economic associations among causes of species endangerment in the United States. *BioScience* 50 (7): 593–601.

Daniels, T. L. 2000. Integrated working landscape protection: The case of Lancaster County, Pennsylvania. *Society and Natural Resource* 13 (3): 261–71.

Erbé, B. 2010. Vanishing farmland: How it's destabilizing America's food supply. http://www.politicsdaily.com/2010/05/28/vanishing-farmland-how-its-destablizing-americas-food-supply/ (last accessed 22 May 2012).

Franck, S., W. von Bloh, C. Muller, A. Bondeau, and B. Sakschewski. 2011. Harvesting the sun: New estimations of the maximum population of planet Earth. *Ecological Modelling* 222 (12): 2019–26.

Furuseth, O. J. 1997. Restructuring of hog farming in North Carolina: Explosion and implosion. *The Professional Geographer* 49 (4): 391–403.

Giombolini, K. J., K. J. Chambers, S. A. Schlegel, and J. B. Dunne. 2011. Testing the local reality: Does the Willamette Valley growing region produce enough to meet the needs of the local population? A comparison of agricultural production and recommended dietary requirements. *Agriculture and Human Values* 28 (2): 247–62.

Glover, J. D., J. P. Reganold, L. W. Bell, J. Borevitz, E. C. Brummer, E. S. Buckler, C. M. Cox, et al. 2010. Increased food and ecosystem security via perennial grains. *Science* 328 (5986): 1638–39.

Gober, P. 1981. Falling household size and its effect on metropolitan growth and density. *Annals of Regional Science* 15 (3): 1–10.

Grady, W., and T. Tsouderos. 2004. New counties on the fringe. *Chicago Tribune* 13 May:2C1.

Greene, R. P., and J. Stager. 2001. Rangeland to cropland conversions as replacement land for prime farmland lost to urban development. *The Social Science Journal* 38:543–55.

Guzy, M. R., C. L. Smith, J. P. Bolte, D. W. Hulse, and S. V. Gregory. 2008. Policy research using agent-based modeling to assess future impacts of urban expansion into farmlands and forests. *Ecology and Society* 13 (1): 37.

Hall, P., Ed. 1966. *Von Thünen's isolated state*. Oxford, UK: Pergamon.

Hanlon, B., J. R. Short, and T. J. Vicino. 2010. *Cities and suburbs new metropolitan realities in the U.S.* London and New York: Routledge.

Hart, J. F. 1991. The perimetropolitan bow wave. *Geographical Review* 81 (1): 35–51.

———. 2001. Half a century of cropland change. *Geographical Review* 91 (3): 525–43.

———. 2003a. *The changing scale of American agriculture*. Charlottesville: University of Virginia Press.

———. 2003b. Specialty cropland in California. *Geographical Review* 93 (2): 153–70.

Hasse, J. E., and R. G. Lathrop. 2003. Land resource impact indicators of urban sprawl. *Applied Geography* 23: 159–75.

Heinricht, M. 2004. The importance of farmland. *Washington Post* 22 June:A16.

Heisler, G. M., and A. J. Brazel. 2010. The urban physical environment: Temperature and urban heat islands. In *Urban ecosystem ecology*, ed. J. Aitkenhead-Peterson and A. Volder, 29–56. Madison, WI: American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America.

Hudson, J. C. 1994. *Making the Corn Belt: A geographical history of middle-western agriculture*. Bloomington: University of Indiana Press.

Imhoff, M. L., L. Bounoua, R. DeFries, W. T. Lawrence, D. Stutzer, C. J. Tucker, and T. Ricketts. 2004. The consequences of urban land transformation on net primary productivity in the United States. *Remote Sensing of Environment* 89:434–43.

Imhoff, M. L., L. Bounoua, T. Ricketts, C. Loucks, R. Harriss, and W. T. Lawrence. 2004. Global patterns in human consumption of net primary production. *Nature* 429 (6994): 870–73.

Irwin, E. G., and N. E. Bockstael. 2007. The evolution of urban sprawl: Evidence of spatial heterogeneity and increasing land fragmentation. *Proceedings of the National Academy of Sciences* 104 (52): 20672–77.

Jackson, K. T. 1985. *Crabgrass frontier: The suburbanization of the United States*. New York: Oxford University Press.

James, L. A. 2011. Contrasting geomorphic impacts of pre- and post-Columbian land-use changes in Anglo America. *Physical Geography* 32 (5): 399–422.

Jenerette, G. D., and K. P. Alstad. 2010. Water use in urban ecosystems: Complexity, costs, and services of urban ecohydrology. In *Urban ecosystem ecology*, ed. J. Aitkenhead-Peterson and A. Volder, 353–71. Madison, WI: American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America.

Kavanaugh, M. C. 1996. An overview of the management of contaminated sites in the U.S.: The conflict between technology and public policy. *Water Science and Technology* 34 (7–8): 275–83.

Kelsey, T. W., and L. Singletary. 1996. Conflict at the rural/urban interface: Mushroom farms and composting in a suburbanizing environment. *Compost Science & Utilization* 4 (3): 89–96.

Kloppenburg, J., Jr., J. Hendrickson, and G. W. Stevenson. 1996. Coming to the foodshed. *Agriculture and Human Values* 13 (3): 33–42.

Kneeland, D. E. 1981. Urbanization of rural U.S. called peril to farmland. *New York Times* 16 June:B8.

Knox, P. L. 2008. *Metroburbia USA*. Piscataway, NJ: Rutgers University Press.

Kock, B., and R. Kholsa. 2003. The role of precision agriculture in cropping systems. *Journal of Crop Production* 9 (102): 361–81.

Laingen, C. R., and C. D. Craig. 2011. Adding another notch to America's Corn Belt. *FOCUS on Geography* 54 (2): 60–69.

Lewis, P. 1995. The urban invasion of rural America: The emergence of the galactic city. In *The changing American countryside: Rural people and places*, ed. E. N. Castle, 39–62. Lawrence: University of Kansas Press.

Lopez, R. A., A. O. Adelaja, and M. J. Andrews. 1988. The effects of suburbanization on agriculture. *American Journal of Agricultural Economics* 70 (2): 346–58.

Lotze-Campen, H. 2011. Climate change, population growth, and crop production: An overview. In *Crop adaptation of climate change*, ed. S. S. Yadev, R. J. Redden, J. L. Hatfield, H. Lotze-Campen, and A. E. Hall, 1–11. Chichester, UK: Wiley.

Loveland, T. R., T. L. Sohl, S. V. Stehman, A. L. Gallant, K. L. Sayler, and D. E. Napton. 2002. A strategy for estimating the rates of recent United States land-cover changes. *Photogrammetric Engineering and Remote Sensing* 68 (10): 1091–99.

McDonald, J. F. 2008. *Urban America: Growth, crisis, and rebirth*. Armonk, NY: Sharpe.

Miller, C., and D. R. Johnson. 1990. The rise of urban Texas. In *Urban Texas politics and development*, ed. C. Miller and H. T. Sanders, 3–29. College Station: Texas A&M University Press.

Mitchell, J. G. 2001. Urban sprawl. *National Geographic* 2000 (1): 48–73.

Mountford, K. 2000. Chesapeake Bay: The United States' largest estuarine system. In *Seas at the millennium: An environmental evaluation*. Vol. 1, ed. C. R. C. Sheppard, 335–49. New York: Pergamon.

Muller, P. O. 1986. Transportation and urban growth: The shaping of the American metropolis. *FOCUS on Geography* 36 (2): 8–17.

Napton, D. E. 2007. Agriculture. In *The American Midwest: An interpretive encyclopedia*, ed. R. Sisson, C. Zacher, and A. Cayton, 142–5. Bloomington: Indiana University Press.

Napton, D. E., R. F. Auch, R. Headley, and J. L. Taylor. 2010. Land changes and their driving forces in the southeastern United States. *Regional Environmental Change* 10 (1): 37–53.

National Agricultural Statistics Service (NASS). 2002. California 2002 County Agricultural Commissioners' data. http://www.nass.usda.gov/Statistics_by_State/California/Publications/AgComm/200208cactb00.pdf (last accessed 19 April 2013).

Nizeyimana, E. L., G. W. Petersen, M. L. Imhoff, H. R. Sinclair, Jr., S. W. Waltman, D. S. Reed-Margetan, E. R. Levine, and J. M. Russo. 2001. Assessing the impact of land conversion to urban uses on soils with different productivity levels in the USA. *Soil Science Society of America Journal* 65:391–402.

O'Kelly, M., and D. Bryan. 1996. Agricultural location theory: Von Thünen's contribution to economic geography. *Progress in Human Geography* 20 (4): 457–75.

Olmstead, A. L., and P. W. Rhode. 2008. *Creating abundance biological innovation and American agricultural development*. New York: Cambridge University Press.

Omernik, J. M. 1987. Ecoregions of the conterminous United States. *Annals of the Association of American Geographers* 77:118–25.

Pardey, P. G. 2011. A strategic look at global wheat production, productivity and R&D developments. *Czech Journal of Genetics and Plant Breeding* 47:S6–S19.

Petrov, A. N., and R. Sugumaran. 2009. Quantifying spatiotemporal dynamics of agricultural landscapes using remotely sensed data and landscape metrics. *Geocarta International* 24 (3): 223–40.

Pierce, J. T. 1994. Towards the reconstruction of agriculture: Paths of change and adjustment. *The Professional Geographer* 46 (2): 178–90.

Pimm, S. L. 2001. *A scientist audits the earth*. New Brunswick, NJ: Rutgers University Press.

Pollan, M. 2008. Farmer in chief. *New York Times* 12 October:MM62.

Power, A. G. 2010. Ecosystem services and agriculture: Tradeoffs and synergies. *Philosophical Transactions of the Royal Society B: Biological Sciences* 365 (1554): 2959–71.

Reganold, J. P., D. Jackson-Smith, S. S. Batie, R. R. Harwood, J. L. Kornegay, D. Bucks, C. B. Flora, et al. 2011. Transforming U.S. agriculture. *Science* 332 (6030): 670–71.

Rindfuss, R. R., S. J. Walsh, B. L. Turner II, J. Fox, and V. Mishra. 2004. Developing a science of land change: Challenges and methodological issues. *Proceedings of the National Academy of Sciences* 101 (39): 13976–81.

Santosa, S. J. 2010. Urban air quality. In *Urban ecosystem ecology*, ed. J. Aitkenhead-Peterson and A. Volder, 57–74. Madison, WI: American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America.

Shepherd, J. M., J. A. Stallins, M. L. Jin, and T. L. Mote. 2010. Urbanization: Impacts on clouds, precipitation, and lightning. In *Urban ecosystem ecology*, ed. J. Aitkenhead-Peterson and A. Volder, 1–27. Madison, WI: American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America.

Sleeter, B. M. 2012. Central California Valley ecoregion. In *Status and trends of land change in the Western United States—1973 to 2000*, ed. B. M. Sleeter, T. S. Wilson, and W. Acevedo. U.S. Geological Survey Professional Paper 1794-A. http://pubs.usgs.gov/pp/1794/a/pp1794a.pdf (last accessed 5 April 2013).

Sleeter, B. M., T. L. Sohl, T. R. Loveland, R. F. Auch, W. Acevedo, M. A. Drummond, K. L. Sayler, and S. V. Stehman. 2013. Land-cover change in the conterminous United States from 1973–2000. *Global Environmental Change* 23 (4): 733–48.

Slemp, C., M. A. Davenport, E. Seekamp, J. M. Brehm, J. E. Schoonover, and K. W. J. Willard. 2012. "Growing too fast": Local stakeholders speak out about growth and its consequences for community well-being in the urban–rural interface. *Landscape and Urban Planning* 106:139–48.

Smoyer-Tomic, K. E., J. C. Spence, and C. Amrhein. 2006. Food deserts on the prairies? Supermarket accessibility and neighborhood need in Edmonton, Canada. *The Professional Geographer* 58 (3): 307–26.

Sorensen, A. A., R. P. Greene, and K. Russ. 1997. *Farming on the edge*. Dekalb, IL: American Farmland Trust Center for Agriculture in the Environment.

Stehman, S. V., T. L. Sohl, and T. R. Loveland. 2003. Statistical sampling to characterize recent United States land-cover change. *Remote Sensing of Environment* 86:517–29.

Theobald, D. M. 2001. Land-use dynamics beyond the American urban fringe. *Geographical Review* 91 (3): 544–64.

Thomas, J. K., and F. M. Howell. 2003. Metropolitan proximity and U.S. agricultural productivity, 1978–1997. *Rural Sociology* 68 (3): 366–86.

Thompson, A. W., and L. S. Prokopy. 2007. Tracking urban sprawl: Using spatial data to inform farmland preservation policy. *Land Use Policy* 26:194–202.

U.S. Census Bureau. 1972. 1970 Census of Housing Detailed Housing Characteristics. http://www.census.gov/prod/www/abs/decennial/1970cenhousev1.html (last accessed 29 June 2012).

———. 1973. 1970 Census of Population: Vol. 1. Characteristics of the population, Tables 10, 123. http://www.census.gov/prod/www/abs/decennial/1970.html (last accessed 29 June 2012).

———. 1983a. 1980 Census of Housing: Vol. 1. Characteristics of housing units, Chapter B, Detailed housing characteristics, Table 94. http://www.census.gov/prod/www/abs/decennial/1980cenhouse.html (last accessed 29 June 2012).

———. 1983b. 1980 Census of Population: Vol. 1. Characteristics of the population, Tables 56, 178. http://www.census.gov/prod/www/abs/decennial/1980.html (last accessed 29 June 2012).

———. 1992. 1990 Census of Housing, CH-1, General housing characteristics, Table 1. http://www.census.gov/prod/cen1990/ch1/ch-1.html (last accessed 29 June 2012).

———. 1993. 1990 Census of Population, CP-2, Social and economic characteristics, Tables 1, 146. http://www.census.gov/prod/www/abs/decennial/1990.html (last accessed 29 June 2012).

———. 2002. 2000 Census of Population and Housing. http://www.census.gov/prod/www/decennial.html (last accessed 21 May 2014).

———. 2012. Urban/rural and metropolitan/nonmetropolitan population: 2000. http://factfinder.census.gov/servlet/GCTTable?_bm=y&-geo_id=01000US&-_box_head_nbr=GCT-P1&-ds_name=DEC_2000_SF1_U&-format=US-1 (last accessed 9 January 2012).

U.S. Department of Agriculture (USDA). 2009. 2009 Soil Survey Geographic (SSURGO) database for the United States. U.S. Department of Agriculture, Natural Resources Conservation Service database. http://soildatamart.nrcs.usda.gov/Default.aspx (last accessed 29 May 2013).

———. 2012a. *Data and statistics, Quick Stats 1.0*. Washington, DC: National Agricultural Statistics Service. http://www.nass.usda.gov/Data_and_Statistics/Quick_Stats_1.0/index.asp (last accessed 15 June 2012).

———. 2012b. Fertilizer use and price. http://www.ers.usda.gov/data/FertilizerUse/ (last accessed 3 April 2012).

———. 2013a. USDA expects record-high combined corn and soybean acreage. http://www.nass.usda.gov/Newsroom/2013/03_28_2013.asp (last accessed 19 April 2013).

———. 2013b. USDA National Agricultural Statistical Service quick stats. http://quickstats.nass.usda.gov (last accessed 19 April 2013).

U.S. Environmental Protection Agency. 1999. *Level III ecoregions of the continental United States (1:7,500,000-scale map)*. Corvallis, OR: National Health and Environmental Effects Research Laboratory.

———. 2010. Primary distinguishing characteristics of level III ecoregions of the continental United States. http://www.epa.gov/wed/pages/ecoregions/level_iii_iv.htm (last accessed 29 May 2012).

Vileisis, A. 1997. *Discovering the unknown landscape: A history of America's wetlands*. Washington, DC: Island.

Wagner Weick, C. 2001. Agribusiness technology in 2010: Directions and challenges. *Technology in Society* 23:59–72.

Watts, D. C. H., B. Ilbery, and D. Maye. 2005. Making reconnections in agro-food geography: Alternative systems of food provision. *Progress in Human Geography* 29 (1): 22–40.

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