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Land Use Change in NJ 1986 through 2015

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Dynamic mapping of New Jersey's land use change is available at
https://www.njmap2.com/landchange

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Executive Summary

This report is part of an ongoing series of collaborative studies between Rutgers and Rowan Universities examining New Jersey's urban growth and land use change since 1986. The analysis reported on herein represents an analysis of the change in the state's land use/land cover occurring between the spring of 2012 and spring of 2015 based on the DEP New Jersey Land Use/Land Cover Change (NJLULCC) data set. Conversion of green space to new urban development in New Jersey has continued to slow from its historic high pace of new urban development in the 1990's and 2000's. Between the year 2012 and 2015, New Jersey expanded the amount of urban land by 10,392 acres, equivalent to a rate of 3,464 acres of new urban development per year. This rate represents a continuation of the trend of decreasing urban development initiated during the Great Recession of 2008. In comparison, urban development grew at a pace of 16,852 acres per year in the late 1990's. Over the 2012 to 2015 time period, New Jersey had a population growth rate of 0.3% (from 8.85 million in 2012 to 8.87 million in 2015) and an urban growth rate of 0.7% (from 1.56 to 1.57 million acres). The three year period from 2012 to 2015 saw population growth occurring at less than the rate of urbanization, although the magnitude of both rates of change has declined significantly over the 29 year study period.

The T5(2012-2015) time period also saw a dramatic downward shift of the residential proportion to 40.0% of the urban development footprint. Not only was there a dramatic slowdown statewide in overall acres developed, the residential footprint shrank in relative proportion when compared to other land uses including *industrial, transportation, major roadway* and *other urban or built-up land* all which saw relative increases in their proportion of the T5(2012-2015) urban footprint. All counties experienced a significant slowdown in the rate of urbanization post the 2008 recession. However, as the economy began to recover post 2011 as evident in the increasing certificate of occupancy data, the pattern of residential development exhibited a continued drop in the rate of acres consumed for residential land uses. While large-lot development was not completely defunct, consuming more than half of the residential land developed, it became a smaller piece of the residential development pie during T5. Higher-density residential types significantly increased their proportion of land development acres as well as their proportion of population housed. More units were built on less land, signaling a significant shift toward denser residential development. While 18 counties had fewer CO's in the decade following the great recession than the decade preceding, Hudson, Union and Bergen counties had more CO's issued after 2008 than before, a clear indication of a post-recession trend toward urban redevelopment.

New Jersey's experiment with regional planning has set in motion three different approaches for coordinating regional-scale goals: the *State Development and Redevelopment Plan* (i.e. State Plan), the *Pinelands Comprehensive Management Plan* (CMP) and the *Highlands Regional Master Plan* (RMP). Together New Jersey's three main regional planning systems provide, in essence, a natural experiment for comparing various approaches to regional planning in a state that lies in one of the most significant growth corridors in the nation. The NJLULCC data indicates that the patterns of development that have occurred throughout the Garden State have been significantly influenced by New Jersey's regional planning systems.

The State Plan Planning Areas PA1 Urban and PA2 Suburban as well as Designated Centers are the intended smart growth areas of the plan. A substantial amount of development has occurred outside the smart growth zones in the rural and sensitive planning areas intended to receive minimal growth. The preponderance of the growth in these planning areas was attributable to a single land use category, type *LU-1140 Residential Rural Single-Unit* low-density housing. For three decades, large-lot single-unit housing was responsible for consuming the majority of state's most sensitive lands. However, the most recent land use data reveals a major departure from the sprawling trends of the previous decades in favor of the delineated smart growth zones.

Land use change and development growth in the Pinelands over the three decades since the Pinelands CMP implementation occurred at half the rate of the rest of the state relative to the proportion of the land area that the Pinelands occupies within the state. The development that did occur was more compact and less land consumptive than the state as a whole and generally occurred in areas designated as growth zones, which generally have the infrastructure to accommodate growth. The slower development rate in the conservation zones has maintained the majority of rural lands over the decades and thus given more time for conservation actions to occur.

Development patterns in the Highlands have shifted significantly since the implementation of the Highlands RMP. The amount of area developed has been substantially reduced from the pre-2007 era of rapid growth. A greater proportion of subsequent development was in the planning zones with an increasing portion of residential land occurring in a compact form while large-lot sprawling residential housing experienced an observable downturn. While it is difficult to tease out the degree to which many of these changes reflect economic drivers of development that slowed due to the 2008 recession versus the direct effect of the Highlands Regional Management Plan, the data suggests that the RMP is at least playing a role in shaping the way development occurs compared to pre-RMP growth.

The gross amount of forest land converted was slightly lower in T5(2012-2015) than in T4(2007-2012) with 3,894 acres per converted year in T5 vs. 4,209 acres per year in T4. The continued conversion of upland and wetland forests to urban land uses is concerning as these ecosystems play a critical role in removing and storing additional carbon from the atmosphere. Over the 2012-2015 time period, approximately 162,834 Mg (metric tons) of carbon storage from above- and below-ground biomass was potentially affected (i.e., trees cut down, stumps and roots dug up and removed. Based on the US Environmental Protection Agency Greenhouse Gas Equivalencies Calculator (https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator), that loss of carbon is equivalent to the greenhouse gas emissions from 67,183,301 gallons of gasoline consumed. The loss of carbon storage over the entire 1986-2015 time period is equivalent to the greenhouse gas emissions from 1,416,614,831 gallons of gasoline consumed or from 2,672,921 passenger vehicles driven for one year.

The net rate of agricultural land conversion has consistently declined from an annualized rate of 10,277 acres per year in T1 (1986- 1995) to the most recent 696 acres per year in T5 (2012-2015). This trend is closely related to the declining amount of farmland consumed by urbanization with 6,114 acres per year in T1, 5,149 in T2, 5,124 acres per year in T3 vs. 1,444 acres per year in T4 to 875 acres per year in T5 (2012-2015). In addition to conversion of agricultural land to urban land uses, agricultural land continues to be abandoned and allowed to regenerate to forest, a process that has been going on in New Jersey since the peak of agricultural expansion in the mid to late 1800's. However, this rate continues to decline, with only 341 acres per year in T5 as compared to 1,986 acres per year in T4 vs. 2,435 acres per year in T3.

A companion study suggests that nearly 4,400 acres of salt marsh were converted to tidal mud flat or open water during the past three decades. In some locations, the shoreline has retreated over 1,000'. Modeling the future distribution of salt marshes under sea level rise suggests that approximately 20% (or 44,000 acres) of New Jersey's salt marshes are highly vulnerable to conversion to tidal mud flat or open water or heightened "drowning" stress by 2050. If sea level rise accelerates as some studies suggest then additional areas of salt marsh may be vulnerable. A proportion of the expected loss due to erosion and drowning may be balanced by new marsh created as upland/wetland forests or abandoned cropland are converted (through natural succession) to salt marsh We refer to those areas where new marsh may develop in the future as marsh retreat or migration zones. Our modeling mapped over 66,000 acres of potential marsh retreat zones statewide. We suggest that these marsh retreat zones should be high priority for conservation protection to allow New Jersey's salt marshes to "migrate" to partially compensate for expected losses from sea level rise in the coming decades.

While our results support the notion that New Jersey may be entering a new "post-suburban" phase that reflects a stronger push towards smart growth and a focus on urban redevelopment (Hughes and Seneca 2014, 2019), the degree to which this shift in residential development is a meaningful divergence from previous trends or a short-term anomaly remains to be seen. We write this report at the same time that New Jersey and more broadly, the United States, is in the throes of the COVID19 pandemic and widespread demonstrations against systemic racism. It is unclear how these intertwined events will affect the state's future development/redevelopment patterns but we expect that the shock wave will reverberate for years to come. If anything positive has come out of this pandemic, it is the widespread appreciation for New Jersey's public open space lands as vital to our quality of life, as a place for solace, exercise and fresh air. The challenge in the years ahead will be to ensure that New Jersey is able to provide an expanding array of housing opportunities as well as public open space lands that are easily and equitably accessible to all of its inhabitants. On-going efforts to conserve the most critical remaining ecological, agricultural and recreational lands while creatively redeveloping our existing urban areas will be key to enhancing the state's ability to adapt to both climate and social change.

1 Introduction

Using high-precision aerial photography, the state has created one of the most comprehensive inventories of land composition of any state. The land use mapping initially developed by the NJ DEP in 1986 has just been updated to give a picture of land use patterns and changes in the Garden State up through 2015.

This report is part of an ongoing series of collaborative studies between Rutgers and Rowan Universities examining New Jersey's urban growth and land use change. The DEP New Jersey Land Use/Land Cover Change (NJLULCC) data set utilized for the analysis represents a detailed mapping of the land use and land cover as depicted in high resolution aerial photography that was acquired in the spring of 2015. The imagery was then classified and mapped (Figure 1.1) providing a window into how the Garden State has developed over the past several decades (from 1986 through 2015) and the subsequent consequences to its land base. It views land development patterns from several different angles providing a "report card" on urban growth and open space loss.

New Jersey has a long history as having the highest population density, as well as having the highest percentage of its land area in urban land uses of any state in the United States. New Jersey's population pressure stems from its geographic location, wedged between the nation's largest and 6th largest cities, New York and Philadelphia. These factors have resulted in New Jersey maintaining its status as one of the most rapidly urbanizing states in the nation throughout the past several decades. By the year 2015, nearly 33% of the state's nearly 5 million acre territory (excluding marine waters) had become urbanized, more than any other land use type in total number of acres.

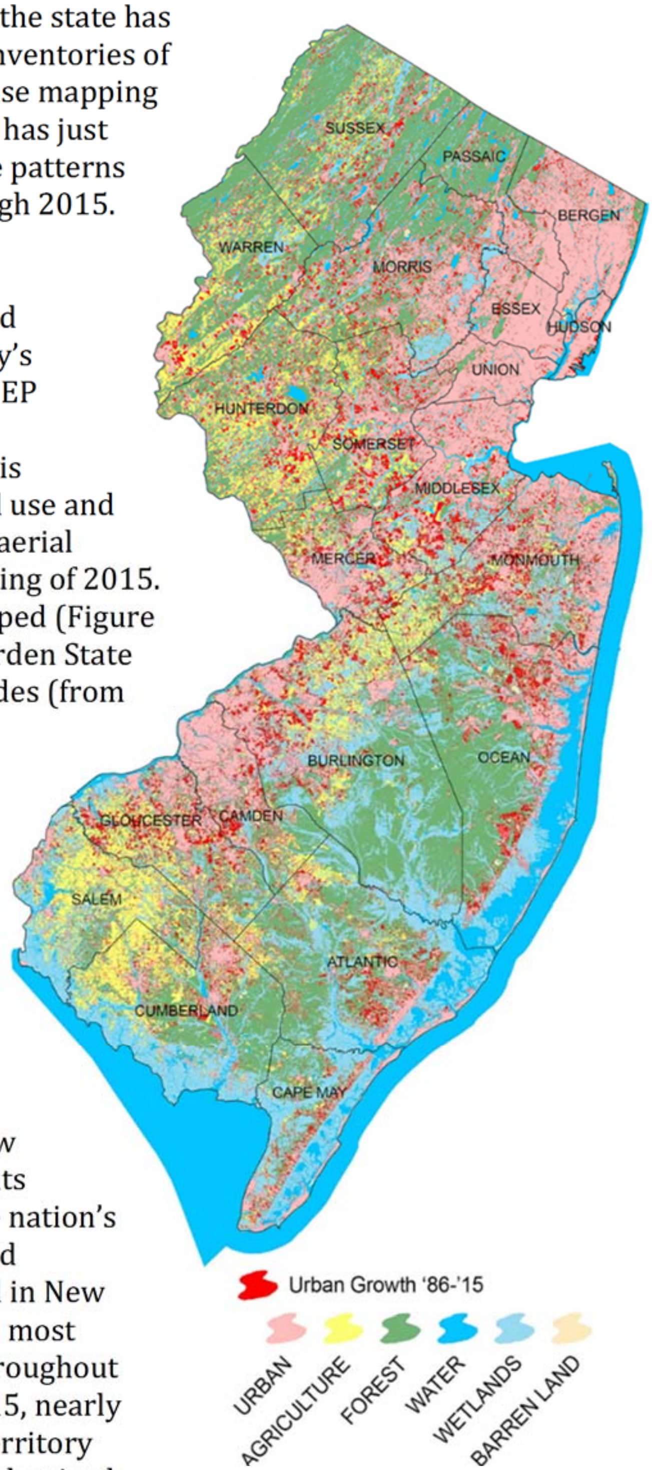


Figure 1.1 Land use and urbanization in New Jersey 1986 through 2015.

2 Level I Land Use Changes

This report relies on the 2015 New Jersey Land Use/Land Cover (LU/LC) dataset released by the New Jersey Department of Environmental Protection (NJDEP) in 2019 (NJDEP, 2019a). Employing the 2015 LU/LC dataset, a Level 1 analysis looks at the broadest categories of landscape change that have occurred statewide over time. A Level 1 analysis groups all land into six broad categories of land use/land cover: *urban*, *agriculture*, *forest*, *water*, *wetlands*, and *barren*. Since the LU/LC datasets utilized in this study were produced for the years 1986, 1995, 2002, 2007, 2012 and 2015 an accounting of the number of acres within each of the Level 1 category reveals the changes over this 29 year time period (Table 2.1; Figure 2.1). It should be noted that this most recent mapping of land use in 2015 also included a remapping of land use in 2012. Thus comparing earlier versions of 2012 land use mapping data set vs. the updated 2012 version in the 2015 release, one will find substantive differences in some categories of land use/land cover (please see Appendix A for greater detail).

Looking first at *urban (i.e., developed)* land, the analysis reveals that New Jersey has continued to slow from its historic high pace of new urban development in the 1990's and 2000's. Given the timing of the Great Recession with a start in 2008 and continuing economic slowdown through the end of the 2012 time period, this slowdown in the rate of urban development during T4 was not unexpected. These newest data suggest that the rate of newly urbanized land during T5 (2012-2015) has declined even further. Between the year 2012 and 2015 (T5) New Jersey expanded the amount of urban land by 10,392 acres to a statewide total of 1,569,541 acres total urban land (Table 2.1). Since the time spans between dates in the datasets are different, annualizing the rates of change allows for more direct comparison. Given that the total territory of the state hasn't changed over the time period of interest, when development increases there must also be a corresponding decrease in other categories of land. Normalizing the number of new acres of development by the 3 year time span provides a rate of 3,464 acres of new urban development per year (Figure 1.2; Table 2.2). This represents a nearly 30% decrease in the rate of development from the previous land use mapping period of T4 (2007-2012) when urban development grew at a pace of 4,907 acres per year (Figure 2.2), both of which are well below the peak of 16,852 acres per year observed in T2 (1995-2002).

Table 2.1 Level 1 land use/land cover for 1986, 1995, 2002, 2007, 2012 and 2015 time periods. Note 2012 numbers represent the revised 2012 numbers released as part of the 2015 mapping.

	1986 (acres)	1995 (acres)	2002 (acres)	2007 (acres)	2012* (acres)	2015 (acres)	29 yr Change	29 yr % Change
Urban	1,208,553	1,334,542	1,452,503	1,534,612	1,559,149	1,569,541	+360,988	+29.9%
Agriculture	744,382	652,335	594,696	559,615	545,591	543,504	-200,878	-27.0%
Forest	1,641,279	1,616,522	1,568,809	1,531,128	1,528,232	1,518,738	-122,541	-7.5%
Water	783,260	800,610	803,185	811,468	807,563	806,415	+23,155	+3.0%
Wetlands	1,049,269	1,022,253	1,005,636	994,836	994,385	992,095	-57,174	-5.4%
Barren	57,223	56,698	59,138	52,216	49,027	53,653	-3,570	-6.2%

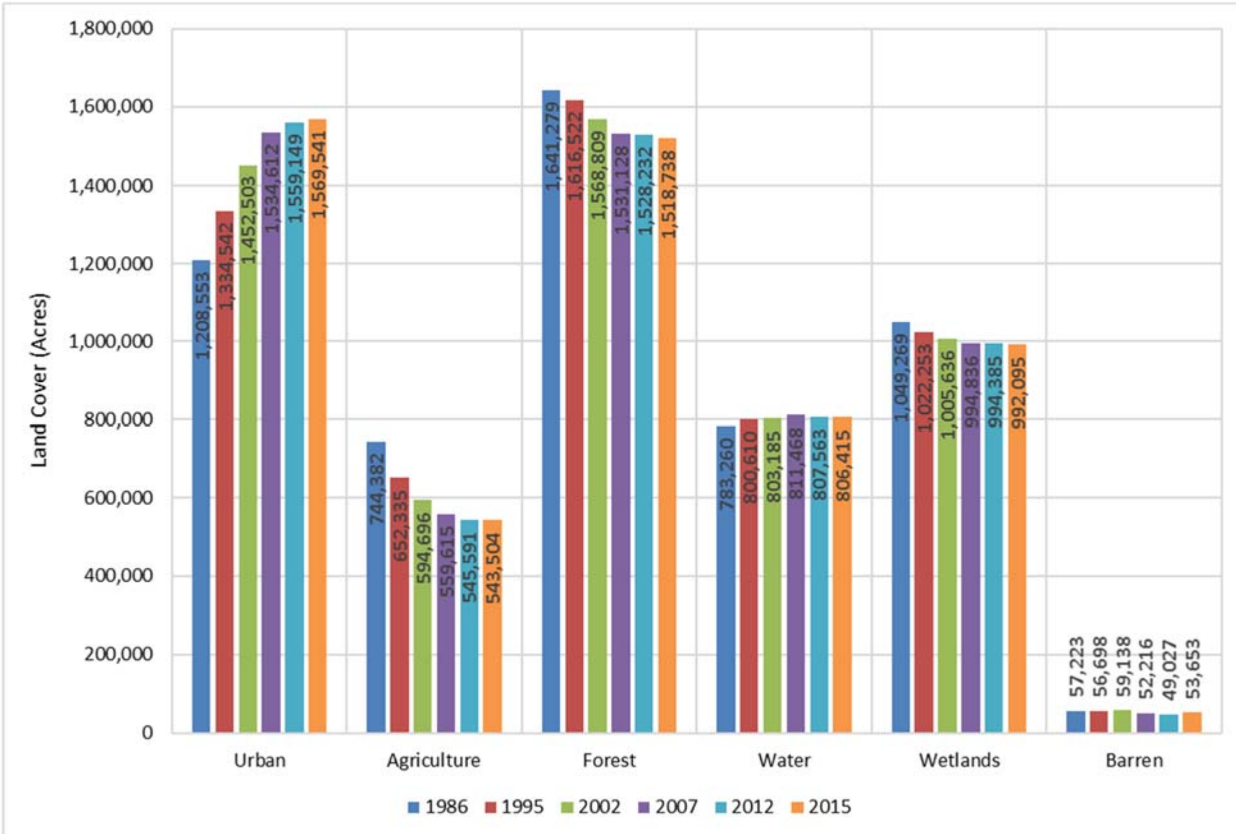


Figure 2.1 Change in each Level 1 category over the 1986, 1995, 2002, 2007, 2012 and 2015 time periods.

During the 29 year period since the datasets were first compiled, New Jersey urbanized a massive 360,988 acres (564 sq. mi) of land adding nearly 30% to the state's pre 1986 urban footprint. At the same time, New Jersey added 1.25 million residents to reach a population of over 8.8 million, an increase of only 16.4% during the same 1986 to 2015 time period. Examining the 1986 to 2007 time period, population growth increased by 14% while urban growth increased by 27%. In other words, NJ's urban growth rate was nearly twice as fast as its population growth rate during the first three decades under consideration. Looking at only the last 3 years of available data (2012 to 2015), this pattern has resumed (after ceasing in T4), albeit on a much smaller scale, with a population growth rate of 0.3% (from 8.85 million in 2012 to 8.87 million in 2015) and an urban growth rate of 0.7% (from 1.56 to 1.57 million acres). That is to say that the three year period from 2012 to 2015 saw population growth occurring at less than the rate of urbanization, although the magnitude of both rates of change has declined significantly over the 29 year study period.

Table 2.2 Annualized rates of land use change.

	Annualized rates of change				
	T1('86-'95)	T2('95-'02)	T3('02-'07)	T4('07-'12 revised)	T5('12revised-'15)
Urban	13,999	16,852	16,422	4,907	3,464
Agriculture	-10,227	-8,234	-7,016	-2,805	-696
Forest	-2,751	-6,816	-7,536	-579	-3,165
Water	1,928	368	1,657	-781	-383
Wetlands	-3,002	-2,374	-2,160	-90	-763
Barren	-58	349	-1,384	-638	1,542

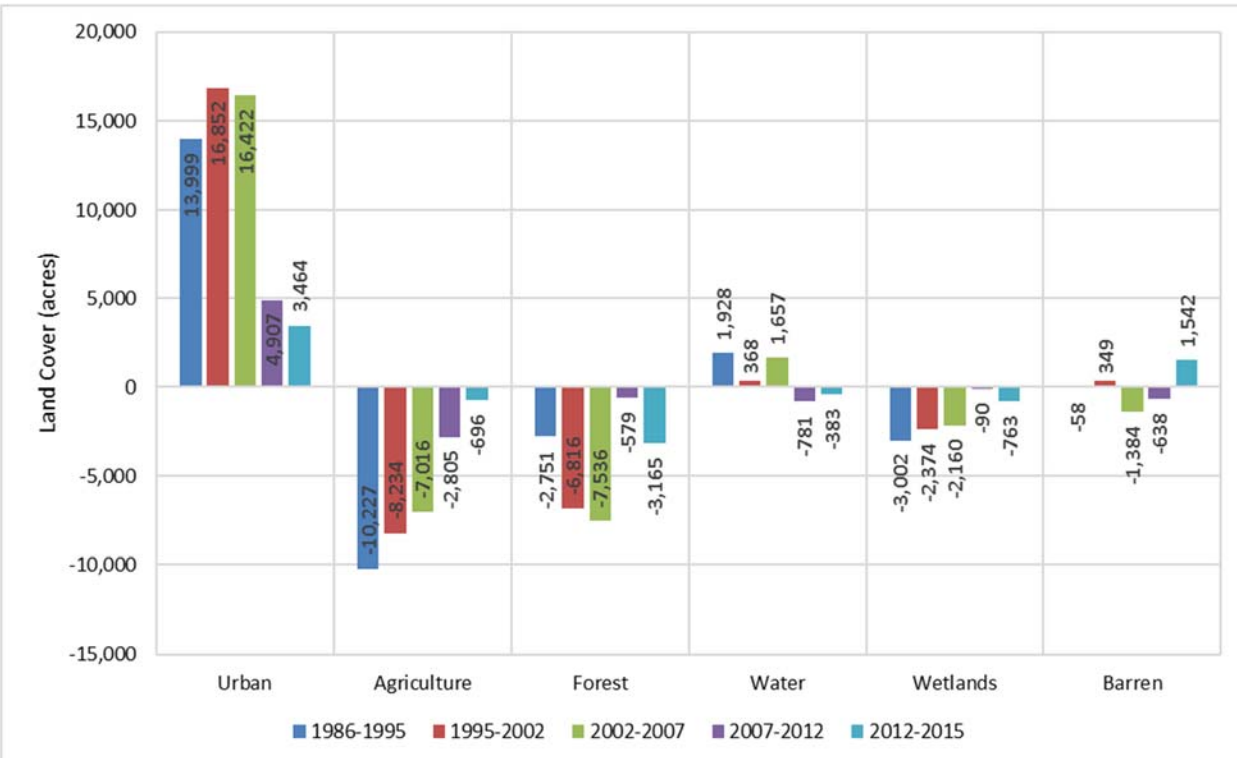


Figure 2.2 Annualized rates of land use change (acres per year).

3 Level III Land Use Changes

In the analysis provided above, we have looked at land use change through a level I framework of six classes: *urban*, *agriculture*, *forest*, *water*, *wetlands* and *barren* lands. We also provide a second, slightly more complex classification framework (Hasse Lathrop) that distinguishes *wetlands* (a legally defined land use category in New Jersey) from other land uses with which there is an overlap (i.e. *agricultural wetlands, forested wetlands, etc.*). However, the modified level I analysis can only provide broad brushstrokes of the location where development has occurred, the rate at which it developed and the lands lost to the development. Level I analysis does not distinguish the specific type of development that has occurred nor how the trends of development type change over time. To do this we turn to the level III classification available in the New Jersey land use/land cover dataset which employs an Anderson (1976) schema modified for New Jersey's unique land use (https://www.nj.gov/dep/gis/digidownload/metadata/lulc15/anderson2015.html). The Anderson land use classification system builds a hierarchy of land use types where level I represents the broadest category, level II distinguishes a more general sub-type and level III provides a still more detailed sub-sub-type. For example, a housing tract delineated in the data may have a level I type label of 'URBAN', a level II label of 'RESIDENTIAL' and a level III label of 'SINGLE UNIT, MEDIUM DENSITY'. We summarize the 29 level II/III urban subclasses for three time periods across all of the datasets issued since the 1986 benchmark data layer including: (1) all development previous to 1986, (2) all development growth between 1986 and 2015, and (3) all development growth in the most recent 2012-2015 time period.

Residential-Level III

For decades, the majority of urban land in New Jersey has consists of residential. Prior to 1986 all residential lands combined occupied 780,487 acres representing 64.6% of the total urban lands in the state (Figure 3.1). During the following three decades T0-T5(1986-2015) residential land development consumed an additional 247,318 acres or 68.6% of all the 360,000 acres of land development that occurred during that time, indicating that residential was increasing its piece of the total development acreage pie. However, the T5(2012-2015) time period saw not only a significant reduction in the annual acres of land consumed overall by urbanization, but also a dramatic downward shift of the residential proportion to 40.0% of the urban development footprint. Not only was there a dramatic slowdown statewide in overall acres developed, the residential footprint shrank in relative proportion when

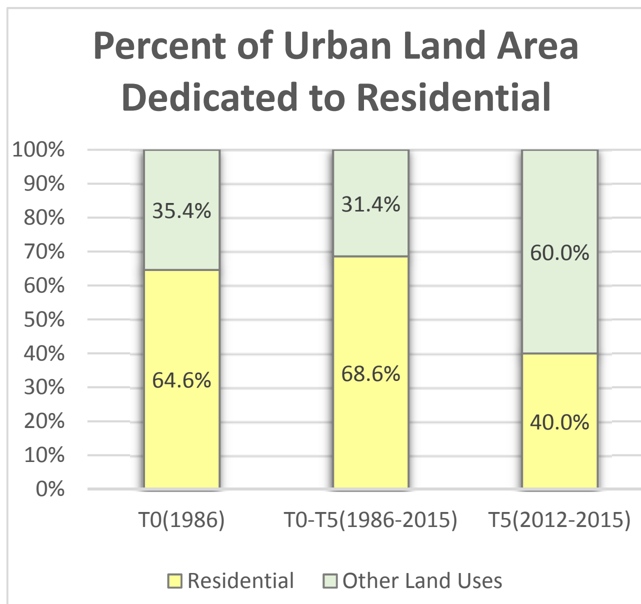
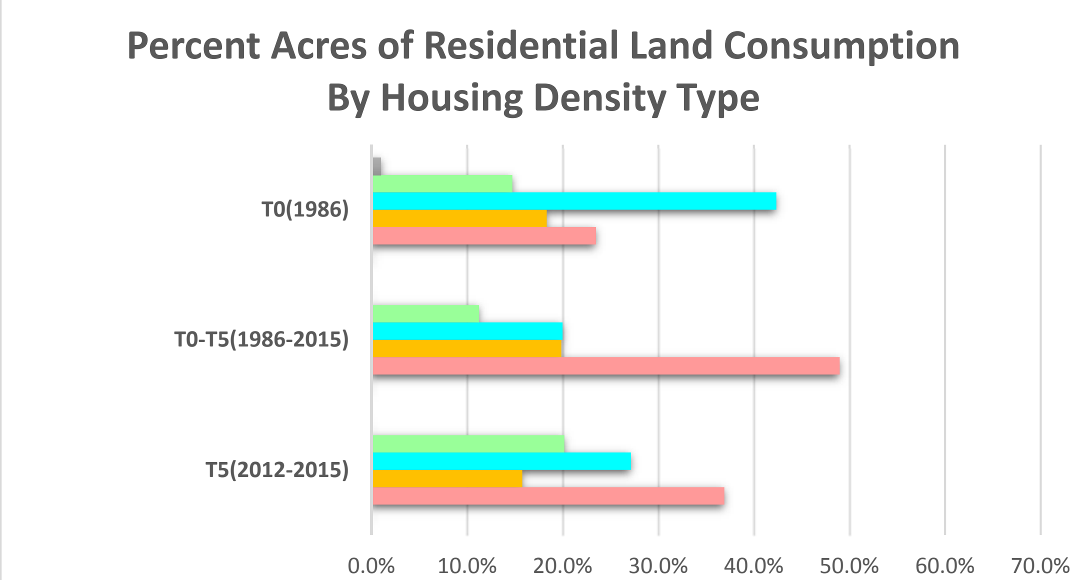


Figure 3.1 Residential land use consumed on average 2/3 of the urban lands developed from 1986 to 2015 but dropped to 2/5 of the 2012-2015 urban growth footprint.

compared to other land uses including *industrial, transportation, major roadway* and *other urban or built-up land* all which saw relative increases in their proportion of the T5(2012-2015) urban footprint.

The type of residential development also saw a major shift throughout the study period. Broken out by housing density type (Figure 3.2), the T0(pre-1986) residential lands allocated a combined 57% of residential acres to the two highest density residential types (LU1110 and LU1120). These are multi-unit and smaller lot sizes up through ½ acre. Using building footprint data we estimate these higher and medium density residential categories accommodated 81% of T0(pre1986) housing units. Subsequently the lower density and rural density residential categories (*LU1130* and *LU1140*) representing lots greater than ½ acre consumed 41.8% of residential lands accommodating an estimated 18.6% of the T0(pre1986) housing units.



	T5(2012-2015)	T0-T5(1986-2015)	T0(1986)
1100 RESIDENTIAL	0.0%	0.0%	1.0%
1110 RESIDENTIAL, HIGH DENSITY, MULTIPLE DWELLING	20.2%	11.3%	14.7%
1120 RESIDENTIAL, SINGLE UNIT, MEDIUM DENSITY	27.1%	20.0%	42.3%
1130 RESIDENTIAL, SINGLE UNIT, LOW DENSITY	15.8%	19.9%	18.3%
1140 RESIDENTIAL, RURAL, SINGLE UNIT	36.9%	49.0%	23.5%
1150 MIXED RESIDENTIAL	0.0%	0.1%	0.1%

Figure 3.2 Residential type by development period. New Jersey residential development experienced major shifts in development density throughout the study period. Pre-recession residential development became less dense and more land consumptive. However, that trend shifted toward higher density, less land consumptive in the T5(2012-2015) time period.

In the three decades that followed 1986, there was a dramatic shift toward larger lot development in terms of the acres dedicated to residential land use. The T0-T5(1986-2015) period of growth saw the two higher-density category of residential (*LU1110* and *LU1120*) consuming a combined 31.3% of total land develop into residential providing an estimated 60% of housing (Table 3.1). Whereas the two least dense residential categories (*LU1130* and *LU1140*) consisting of lots larger than ½ acre consumed a combined 68.9% of the land developed for residential while accommodating an estimated 39% of the housing units built (Figure 3.3). The level III data provides a clear indication that the post 1986 decades T0-T5(1986-2015) saw New Jersey development trend toward more and larger-lot residential development in a highly land-consumptive pattern (i.e. suburban and rural sprawl).

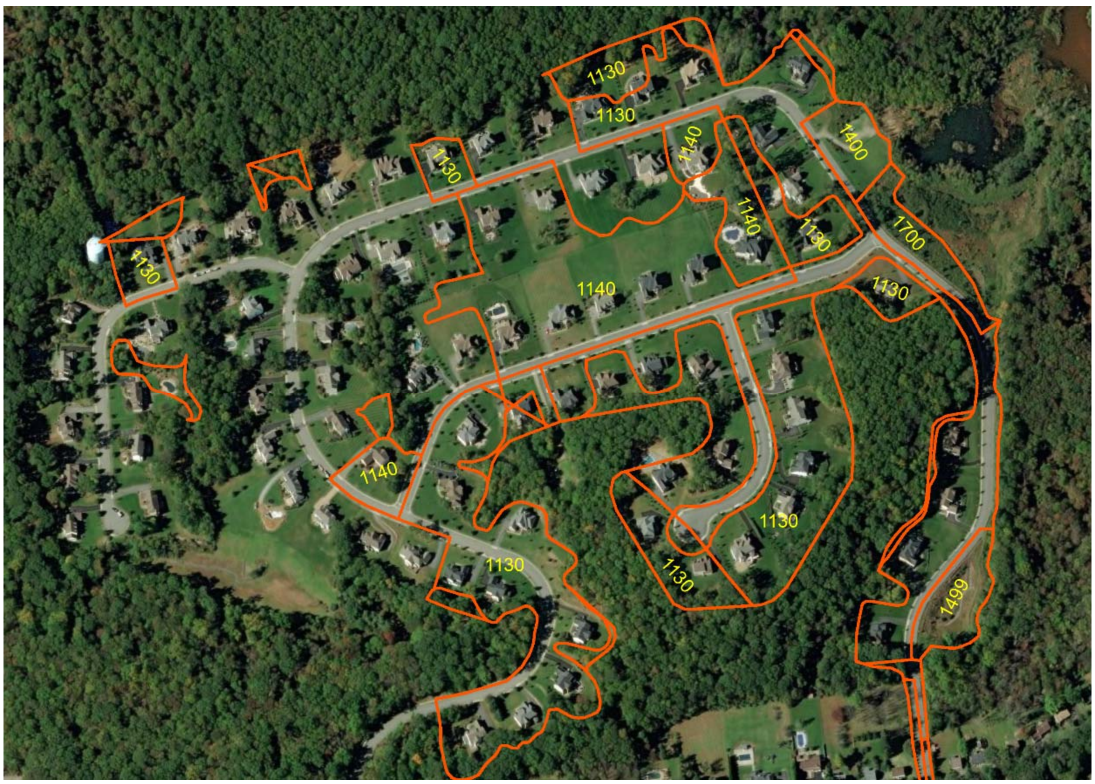


Figure 3.3 Low-Density Residential Ubanization in Mount Olive Township, Morris County. Large-lot residential development such as the LU1130 and LU1140 pictured above, continued to occur in T5(2012-2015) but a proportionately slower rate than more compact residential units than during previous periods.

As dramatically as the patterns became highly sprawling in the late 1980's through to the early 2000's, the great recession of 2008 marked a threshold into a markedly different residential form. The recession T4(2007-2012) period saw acres of residential development drop precipitously in overall magnitude. This slowdown in residential expansion was not surprising in light of the major economic downturn. However, as the economy began to recover post 2011 as evident in the increasing certificate of occupancy data (detailed in section 4, p. 20), the pattern of residential development exhibited a continued drop in the rate of acres consumed for residential land uses. More units were being built on less land signaling a significant shift toward denser residential development.

The proportion of residential land in T5(2012-2015) dedicated to the two higher density residential types (*LU1110* and *LU1120*) increased to 47.3% of total residential land developed and accommodated an estimated 86% of housing units built (Figure 3.4). The two lower density categories (*1130* and *1140*) consumed 52.7% of the land developed into residential and accommodated an estimated 14% of the total residential units built. So the large-lot development, while becoming more sprawling in terms of housing unit per acre and still consuming more than half of the residential land developed, became a smaller piece of the residential development pie during T5 while the higher-density residential types significantly increased their proportion of land development acres as well as their proportion of population housed.

Figure 3.4 Higher Density Residential Development Monroe Township, Middlesex County- Areas of residential growth that occurred during T5 (2012-2015) are outlined in red. High Density or Multiple Dwelling (*LU 1110*) consisting of town houses can be seen on the left side of the photo. Single Unit, Medium Density (*LU 1120*) small lot single family units can be seen in the center of the photo. This higher density form of residential urbanization became more prominent during T5 than during previous time periods.

The degree to which this shift in residential development toward a more compact and less sprawling pattern is a meaningful divergence from previous trends or a short-term anomaly remains to be seen. An important caveat in the data is that T5(2012-2015) only represents a three year period, whereas all previous datasets represent five to nine years of change. Annual variability in development rates are dampened when averaged over longer time periods while potentially amplified with shorter time sets. Future data points will be necessary to determine if the compact residential development patterns of T5 are the new normal or whether low density sprawling residential development will return to prominence in the future.

Non-residential Level III Urbanization

The non-residential component of urban growth substantially increased in relative proportion of its share of new urbanization relative to residential during T5(2012-2015) when compared to previous decades. However, with the exception of TRANSPORTATION/COMMUNICATIONS/ UTILITIES and MAJOR ROADWAY classes which we will examine below, most categories of non-residential did increase their proportion of total urban growth but nevertheless grew at a slower rate during T5 than in previous decades. In comparing T0-T5(1986-2015) to T5(2012-2015), COMMERCIAL/SERVICES (*LU1200*) dropped slightly in its proportion of development from 9.5% to 8.7% whereas INDUSTRIAL (*LU1300*) saw an increase from 4.4% to 6.6% respectively (Figure 3.5). The pattern of industrial growth suggests that large-box warehousing was a significant component of the 1,049 acres of industrial expansion. In contrast, RECREATIONAL LAND (*LU 1800*) dropped in proportion from 7.7% to 4.5% of the development footprint during T5(2012-2015) compared to the previous three decade average.

Figure 3.5 New non-residential urban growth adjacent to the New Jersey Turnpike. Industrial (LU1300), other urban or built-up land (LU1700) and stormwater basins (LU1499) all experienced an increase in their proportion of acres developed during T5(2012-2015) in comparison to previous decades.

A number of other urban land uses significantly increased in their proportion of the T5(2012-2015) urban growth footprint compared with previous growth patterns. UPLAND RIGHTS-OF-WAY UNDEVELOPED (*LU 1463*) grew from 1.4% to 2.3%. This was largely attributable to new utilities Rights-of-Ways (ROWs) such as the Tennessee Pipeline line in northern New Jersey. STORMWATER BASIN (*LU 1499*) grew from 3.7% to 5.6% of the overall urban growth footprint suggesting that stormwater infrastructure has become

Table 3.1 Summary of acres within urban Level III land use category for T0(pre '86) through T5(2012-2015). It should be noted that there have been category changes/additions resulting in lack of data in the 1986 column. Categories such as Industrial and Transportation expanded into multiple categories by 2015.

Land Use Code	Land Use Label	Acres in 1986	% of Total 1986	Acres in 2015	Acres Change 1987-2015	% of Total Change 1986-2015	Acres Change 2012-2015	% of Total Change 2012-2015
1100	RESIDENTIAL	7,688	0.6%	NA	NA		NA	
1110	RESIDENTIAL, HIGH DENSITY, MULTIPLE DWELLING	115,032	9.5%	142,843	27,811	7.7%	1,290	8.1%
1120	RESIDENTIAL, SINGLE UNIT, MEDIUM DENSITY	330,490	27.3%	379,888	49,397	13.7%	1,734	10.8%
1130	RESIDENTIAL, SINGLE UNIT, LOW DENSITY	143,096	11.8%	192,177	49,081	13.6%	1,008	6.3%
1140	RESIDENTIAL, RURAL, SINGLE UNIT	183,298	15.2%	304,327	121,029	33.6%	2,359	14.8%
1150	MIXED RESIDENTIAL	884	0.1%	708	(175)	0.0%		0.0%
1200	COMMERCIAL/SERVICES	110,289	9.1%	144,558	34,270	9.5%	1,385	8.7%
1211	MILITARY RESERVATIONS	8,125	0.7%	8,598	473	0.1%	90	0.6%
1214	NO LONGER MILITARY, USE TO BE DETERMINED	33	0.0%	333	300	0.1%		0.0%
1300	INDUSTRIAL	63,525	5.3%	65,011	15,708	4.4%	1,049	6.6%
1400	TRANSPORTATION/COMMUNICATIONS/UTILITIES	65,606	5.4%	31,493	11,221	3.1%	1,253	7.8%
1410	MAJOR ROADWAY			31,542	4,522	1.3%	630	3.9%
1411	MIXED TRANSPORTATION CORRIDOR OVERLAP AREA			81	10	0.0%	1	0.0%
1420	RAILROADS			10,447	3,512	1.0%	21	0.1%
1440	AIRPORT FACILITIES			4,858	537	0.1%	35	0.2%
1462	UPLAND RIGHTS-OF-WAY DEVELOPED			2,421	525	0.1%	12	0.1%
1463	UPLAND RIGHTS-OF-WAY UNDEVELOPED			17,027	4,903	1.4%	366	2.3%
1499	STORMWATER BASIN			16,391	13,292	3.7%	899	5.6%
1500	INDUSTRIAL/COMMERCIAL COMPLEXES	378		1,279	419	0.1%	2	0.0%
1600	MIXED URBAN OR BUILT-UP LAND	1,444	0.1%	2,683	35	0.0%	2	0.0%
1700	OTHER URBAN OR BUILT-UP LAND	103,542	8.6%	95,878	39,974	11.1%	2,934	18.4%
1710	CEMETERY		0.0%	11,216	954	0.3%	67	0.4%
1800	RECREATIONAL LAND	60,877	5.0%	85,690	27,582	7.7%	726	4.5%
1804	ATHLETIC FIELDS (SCHOOLS)	14,252	1.2%	16,547	3,086	0.9%	42	0.3%
1810	STADIUM, THEATERS, CULTURAL CENTERS AND ZOOS			2,933	745	0.2%	79	0.5%
	TOTAL ACRES	1,208,558		1,568,929	360,372		15,984	

an increasingly important factor in the development. The urban land use category that saw the greatest proportional shift in its footprint from T0-T5(1986-2015) to T5(2012-2015) was OTHER URBAN OR BUILT-UP LAND (*LU1700*) which went from 11.1% of the development footprint to 18.4% respectively. This is a generalized land use category for areas of undeveloped, open lands within urban areas such as highway medians, landscape buffers and lawns between buildings. Also included are large, managed, maintained lawns common to some residential areas, and those open areas of commercial/service complexes, educational installations, etc. Undeveloped, but maintained lawns in urban parks are also part of this category, if a specific recreational use is not evident. The degree to which the change represents a meaningful shift in land use versus a classification nuance attributable to the finer resolution imagery used for delineation of the more recent dataset remains to be determined for this catch-all category.

The most significant shift in urban growth during T5(2012-22015) compared with T0-T5(1986-2015) was a major uptick in TRANSPORTATION/COMMUNICATIONS/ UTILITIES (*LU 1400*) and MAJOR ROADWAY (*LU 1410*) which not only consumed a larger portion of the urban growth footprint but grew in the number of gross acres developed per year during T5 compared the previous three decade average. One of the largest components of growth for the LU 1400 land use type were solar panel installations, which emerged in solar fields throughout the state (Figure 3.6). The increased rate of urbanization for LU 1410 can be traced to several major infrastructure projects, the most significant being the New Jersey Turnpike lane expansion between exit 6 and exit 8A (Figure 3.7).

Figure 3.6 Solar Panel installations constituted a major component of the Transportation/Communication/Utilities (LU1400) land use type which grew by 1,253 acres during T5(2012-2015).

Figure 3.7 The New Jersey Turnpike lane expansion between exit 6 and Exit 8A was one of the factors that significantly increased the Major Roadway(LU1410) land use footprint. The red color indicates new urban growth during the T5(2012-2015) time period near exit 7A.

Non-Urban to Urban Level III Land Use Change

The spread of urbanization into previously non-urban lands is perhaps the most important landscape change to gain an understanding of given the implication for environmental impacts, requirements for associated infrastructure and services, implications for transportation and energy usage, social consequences and loss of critical land resources such as prime farmlands. The acreage gained for urban growth must come at the expense of the loss of another land use. Table B.1 (Appendix B) gives the broad level I overview of change showing that urban growth during T5 came at the expense of 4,556 acres of forest and 2,626 acres of farmland, land resources that are important for maintaining a landscape function in terms of habitat and water quality as well as food production. However, more urban growth (8,015 acres) occurred on barren land than both forest and agriculture combined. Looking at the level III sub-category of barren responsible for the majority of urban growth (Table 3.2) the predominant land use type was Transitional Areas (*LU 7500*). According to the land use data metadata, this category encompasses lands on which site preparation for a variety of development types has begun, but the future land use has not been realized. Included are residential, commercial and industrial areas under construction. Also, areas that are under construction for unknown use and abandoned structures are included. Active construction as well as stalled construction with a high level of ground disturbance, scraped land associated with construction and destruction, and areas where buildings have been removed that have a high level of ground disturbance are included in this category. These areas are usually sparsely vegetated.

The urbanization of Transitional Areas accounted for 11 out of the 15 largest land use transitions (Table 3.2) representing a total of 7,556 acres land use change. The largest transition was to Other Urban or Built-Up Land followed by higher-density residential, then commercial, then lower density residential and industrial. The overriding pattern in the data reveals that much of urban growth is preceded by *transitional* land use conditions. This is a logical finding considering that land clearing and road construction often precedes newly developed buildings. This knowledge could be used to identify current Transitional Areas in the data as sites that will have a high likelihood of transitioning to urban growth in the future. This could be important for identifying where future development is likely to occur and thus be used for establishing policy and planning to mitigate potential impacts of future growth.

Other significant non-urban to urban transitions included croplands changing to low-density residential as well as to Transportation/Communication/Utility. Deciduous Forest (>50% Crown Closure) transitioned to low density residential, upland rights of way and commercial/services. The evaluation of level III change of previously non-urban land uses such as barren, forest or farmlands into urban land can be revealed in the data with a high level of accuracy. This makes non-urban to urban land change analysis of significance to evaluate considering the environmental impacts of green fields lost to urban lands such as the loss of wildlife habitat, prime farmlands and water quality impacts due to increasing impervious surface among others.

Table 3.2 Level III Land Use Change from Non-Urban to Urban land uses greater than 100 acres, ranked by acres of change.

Land Use Codes	Land Use 2012 Label	Land Use 2015 Label	Total Acres
7500 to 1700	TRANSITIONAL AREAS	OTHER URBAN OR BUILT-UP LAND	1,628.8
7500 to 1120	TRANSITIONAL AREAS	RESIDENTIAL, SINGLE UNIT, MEDIUM DENSITY	1,151.9
7500 to 1110	TRANSITIONAL AREAS	RESIDENTIAL, HIGH DENSITY OR MULTIPLE DWELLING	985.1
7500 to 1200	TRANSITIONAL AREAS	COMMERCIAL/SERVICES	728.6
7500 to 1140	TRANSITIONAL AREAS	RESIDENTIAL, RURAL, SINGLE UNIT	587.0
2100 to 1140	CROPLAND AND PASTURELAND	RESIDENTIAL, RURAL, SINGLE UNIT	560.7
7500 to 1300	TRANSITIONAL AREAS	INDUSTRIAL	559.6
2100 to 1400	CROPLAND AND PASTURELAND	TRANSPORTATION/COMMUNICATION /UTILITIES	503.9
7500 to 1410	TRANSITIONAL AREAS	MAJOR ROADWAY	497.1
2100 to 1700	CROPLAND AND PASTURELAND	OTHER URBAN OR BUILT-UP LAND	461.5
4120 to 1140	DECIDUOUS FOREST (>50% CROWN CLOSURE)	RESIDENTIAL, RURAL, SINGLE UNIT	454.0
7500 to 1130	TRANSITIONAL AREAS	RESIDENTIAL, SINGLE UNIT, LOW DENSITY	401.0
7500 to 1800	TRANSITIONAL AREAS	RECREATIONAL LAND	353.3
7500 to 1499	TRANSITIONAL AREAS	STORMWATER BASIN	349.1
7500 to 1400	TRANSITIONAL AREAS	TRANSPORTATION/COMMUNICATION /UTILITIES	314.2
4120 to 1130	DECIDUOUS FOREST (>50% CROWN CLOSURE)	RESIDENTIAL, SINGLE UNIT, LOW DENSITY	216.2
4120 to 1463	DECIDUOUS FOREST (>50% CROWN CLOSURE)	UPLAND RIGHTS-OF-WAY UNDEVELOPED	162.0
4410 to 1700	OLD FIELD (< 25% BRUSH COVERED)	OTHER URBAN OR BUILT-UP LAND	150.5
2100 to 1499	CROPLAND AND PASTURELAND	STORMWATER BASIN	134.3
4120 to 1200	DECIDUOUS FOREST (>50% CROWN CLOSURE)	COMMERCIAL/SERVICES	130.4
2100 to 1800	CROPLAND AND PASTURELAND	RECREATIONAL LAND	126.1
2100 to 1300	CROPLAND AND PASTURELAND	INDUSTRIAL	125.1
2100 to 1130	CROPLAND AND PASTURELAND	RESIDENTIAL, SINGLE UNIT, LOW DENSITY	122.8
4410 to 1140	OLD FIELD (< 25% BRUSH COVERED)	RESIDENTIAL, RURAL, SINGLE UNIT	119.3
4120 to 1120	DECIDUOUS FOREST (>50% CROWN CLOSURE)	RESIDENTIAL, SINGLE UNIT, MEDIUM DENSITY	117.7
2100 to 1120	CROPLAND AND PASTURELAND	RESIDENTIAL, SINGLE UNIT, MEDIUM DENSITY	114.8
2100 to 1200	CROPLAND AND PASTURELAND	COMMERCIAL/SERVICES	101.0

Urban to Urban Level III Land Use Change

Delineating non-urban to urban land use change as done above can be done to a high level of confidence utilizing the land use/land cover data due to the distinct differences in patterns, texture and spectral signatures of the general level I land use classes. However, redevelopment of previously developed land is more challenging to accurately identify in the land use/land cover data. This is particularly true in more urbanized locations where it is difficult to discern if land has meaningfully changed when existing buildings are redeveloped into a different land use such as the conversion of former factory building to residential condominiums. But as suggested by the skyrocketing certificates of occupancy in urban counties (as discussed in Section 4) that are essentially already built-out, there is a significant amount of urban to urban change that occurs within already developed areas that may or may not be reflected in the land use/land cover change data.

During the T5(2012-2015) time period, 4,028 acres of land changed from one type of urban to another. This amount of urban to urban change equates to about 25.2% of the 15,980 acres of land that became newly urbanized. The predominant level III urban land use to change into a different urban land use was Other Urban or Built-Up Land (*LU 1700*) representing the largest nine urban to urban land use type transitions that total 56% of the acres of change (Table 3.3). The development of Other Urban or Built-Up Land represents essentially infill development that went to commercial, residential and industrial land uses. This reflects some of the redevelopment that has been occurring in many older urban locations such as Jersey City, New Brunswick and Glassboro. While some of this change is captured in the land use data, it is limited in its ability to provide a more nuanced reflection of the type of change and other data ancillary data would be useful. For example, the downtown redevelopment of Glassboro, Gloucester County (Figure 3.8) indicated a change from residential and other urban land to commercial but it did not capture the fact that the commercial buildings were mixed use 6 story building with commercial on the ground floor with residential apartment on the upper 5 floors.

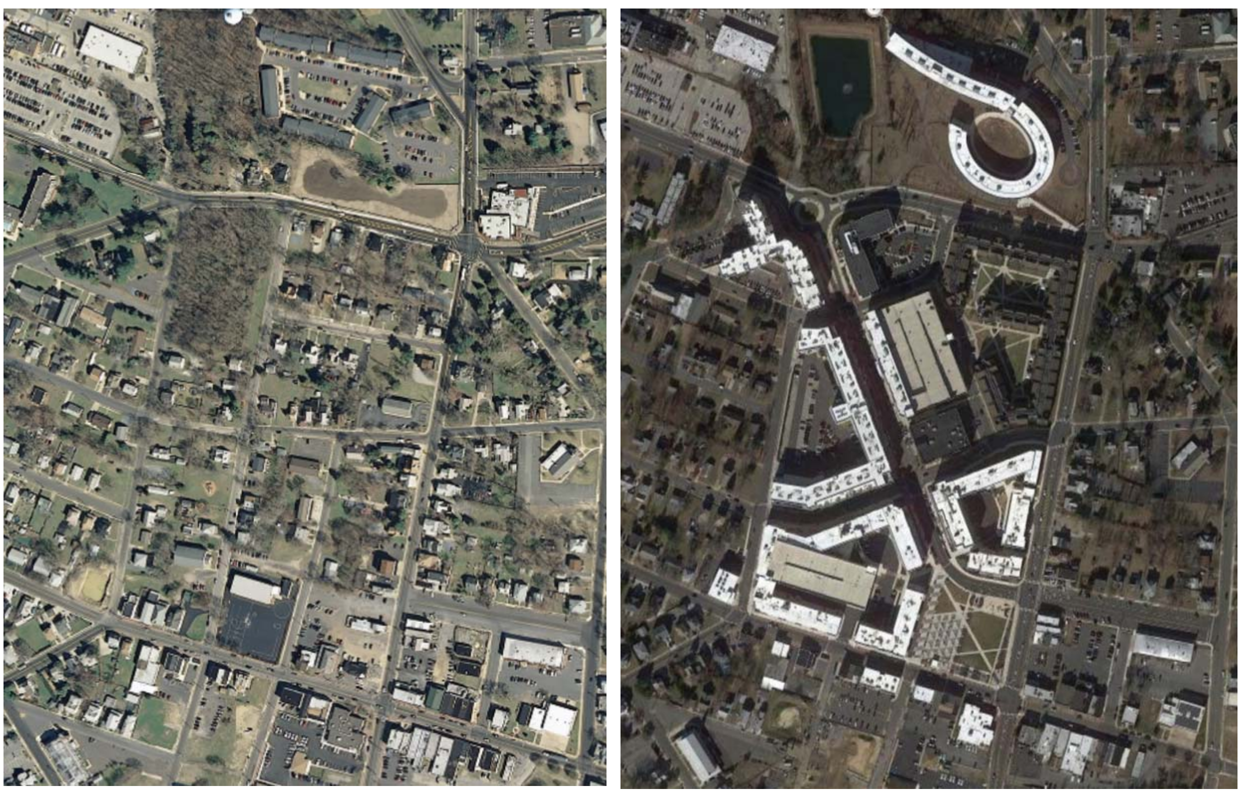


Figure 3.8 Downtown Glassboro Rowan Boulevard redevelopment project illustrates a formerly medium densisty residential neighborhood that was redeveloped into 5-6 story mixed use apartments and commericial land uses.

Table 3.3 Level III Land Use Change from Urban to Other Urban land uses greater than 30 acres, ranked by acres of change.

Land Use Codes	Land Use 2012 Label (From)	Land Use 2015 Label (To)	Total Acres
1700 to 1200	OTHER URBAN OR BUILT-UP LAND	COMMERCIAL/SERVICES	544.2
1700 to 1140	OTHER URBAN OR BUILT-UP LAND	RESIDENTIAL, RURAL, SINGLE UNIT	411.6
1700 to 1300	OTHER URBAN OR BUILT-UP LAND	INDUSTRIAL	311.1
1700 to 1400	OTHER URBAN OR BUILT-UP LAND	TRANSPORTATION/COMMUNICATION/UTILITIES	277.4
1700 to 1110	OTHER URBAN OR BUILT-UP LAND	RESIDENTIAL, HIGH DENSITY OR MULTIPLE DWELLING	190.5
1700 to 1499	OTHER URBAN OR BUILT-UP LAND	STORMWATER BASIN	159.2
1700 to 1800	OTHER URBAN OR BUILT-UP LAND	RECREATIONAL LAND	135.4
1700 to 1130	OTHER URBAN OR BUILT-UP LAND	RESIDENTIAL, SINGLE UNIT, LOW DENSITY	121.6
1700 to 1410	OTHER URBAN OR BUILT-UP LAND	MAJOR ROADWAY	116.6
1800 to 1700	RECREATIONAL LAND	OTHER URBAN OR BUILT-UP LAND	103.9
1140 to 1700	RESIDENTIAL, RURAL, SINGLE UNIT	OTHER URBAN OR BUILT-UP LAND	95.8
1200 to 1700	COMMERCIAL/SERVICES	OTHER URBAN OR BUILT-UP LAND	85.3
1200 to 1110	COMMERCIAL/SERVICES	RESIDENTIAL, HIGH DENSITY OR MULTIPLE DWELLING	84.5
1700 to 1120	OTHER URBAN OR BUILT-UP LAND	RESIDENTIAL, SINGLE UNIT, MEDIUM DENSITY	81.9
1130 to 1140	RESIDENTIAL, SINGLE UNIT, LOW DENSITY	RESIDENTIAL, RURAL, SINGLE UNIT	77.7
1300 to 1700	INDUSTRIAL	OTHER URBAN OR BUILT-UP LAND	71.8
1300 to 1200	INDUSTRIAL	COMMERCIAL/SERVICES	63.7
1700 to 1440	OTHER URBAN OR BUILT-UP LAND	AIRPORT FACILITIES	50.0
1140 to 1200	RESIDENTIAL, RURAL, SINGLE UNIT	COMMERCIAL/SERVICES	45.9
1804 to 1200	ATHLETIC FIELDS (SCHOOLS)	COMMERCIAL/SERVICES	35.5
1120 to 1110	RESIDENTIAL, SINGLE UNIT, MEDIUM DENSITY	RESIDENTIAL, HIGH DENSITY OR MULTIPLE DWELLING	35.5
1700 to 1804	OTHER URBAN OR BUILT-UP LAND	ATHLETIC FIELDS (SCHOOLS)	32.7
1300 to 1110	INDUSTRIAL	RESIDENTIAL, HIGH DENSITY OR MULTIPLE DWELLING	31.6
1140 to 1130	RESIDENTIAL, RURAL, SINGLE UNIT	RESIDENTIAL, SINGLE UNIT, LOW DENSITY	30.2

Urban to Non-Urban Level III Land Use change

Once land becomes urbanized, it generally stays urbanized even if redevelopment results in a change from one land use label to another. What is less intuitive is that a substantial portion urban lands do change into an non-urban land use types. During the T5 (2012-2015) time period a total of 5,576 acres transition from an urban to a non-urban land use (Table 3.4). The most common change out of urban is to a Barren land use category. This is logical because a demolished building that became a vacant lot or construction site for a new building would likely be classified as the barren type Transitional Areas (*LU 7500*) (sites under construction). As Transitional Areas they have a high likelihood of becoming redeveloped into another urban land use.

Table 3.4 Level III Land Use Change from Urban to Non-Urban land uses greater than 50 acres, ranked by acres of change.

Land Use Codes	Land Use 2012 Label	Land Use 2015 Label	Total Acres
1700 to 7500	OTHER URBAN OR BUILT-UP LAND	TRANSITIONAL AREAS	1,640.8
1300 to 7500	INDUSTRIAL	TRANSITIONAL AREAS	975.9
1200 to 7500	COMMERCIAL/SERVICES	TRANSITIONAL AREAS	692.9
1800 to 7500	RECREATIONAL LAND	TRANSITIONAL AREAS	272.6
1140 to 7500	RESIDENTIAL, RURAL, SINGLE UNIT	TRANSITIONAL AREAS	256.3
1700 to 2100	OTHER URBAN OR BUILT-UP LAND	CROPLAND AND PASTURELAND	253.5
1214 to 4430	NO LONGER MILITARY	CONIFEROUS BRUSH/SHRUBLAND	169.9
1400 to 7500	TRANSPORTATION/COMMUNICATION/UTILITIES	TRANSITIONAL AREAS	148.5
1214 to 7500	NO LONGER MILITARY	TRANSITIONAL AREAS	130.2
1120 to 7500	RESIDENTIAL, SINGLE UNIT, MEDIUM DENSITY	TRANSITIONAL AREAS	91.0
1130 to 7500	RESIDENTIAL, SINGLE UNIT, LOW DENSITY	TRANSITIONAL AREAS	88.2
1110 to 7500	RESIDENTIAL, HIGH DENSITY OR MULTIPLE DWELLING	TRANSITIONAL AREAS	78.4
1700 to 7400	OTHER URBAN OR BUILT-UP LAND	ALTERED LANDS	55.2
1140 to 2100	RESIDENTIAL, RURAL, SINGLE UNIT	CROPLAND AND PASTURELAND	50.7

4. County Analysis

New Jersey's 21 counties contain a spectrum of urban, suburban, and rural landscapes and each experienced a different pattern of growth over the three decades covered in this study (Figure 4.1). While all counties experienced substantial land development, each has its own unique juxtaposition largely determined by geography and socioeconomic circumstances. Counties along the state's central corridor between metro Philadelphia and metro New York as well as along the Atlantic coast experienced rapid population growth and suburbanization. Counties on the southern and norther rural fringe experienced more dispersed ex-urban growth. As land is consumed for development or set aside as preserved farmland or public open space, the amount of available land remaining for future development shrinks. A county's remaining available lands is an indication of how close the county is to approaching *buildout* where land is locked into a pattern of development or preserved open space.

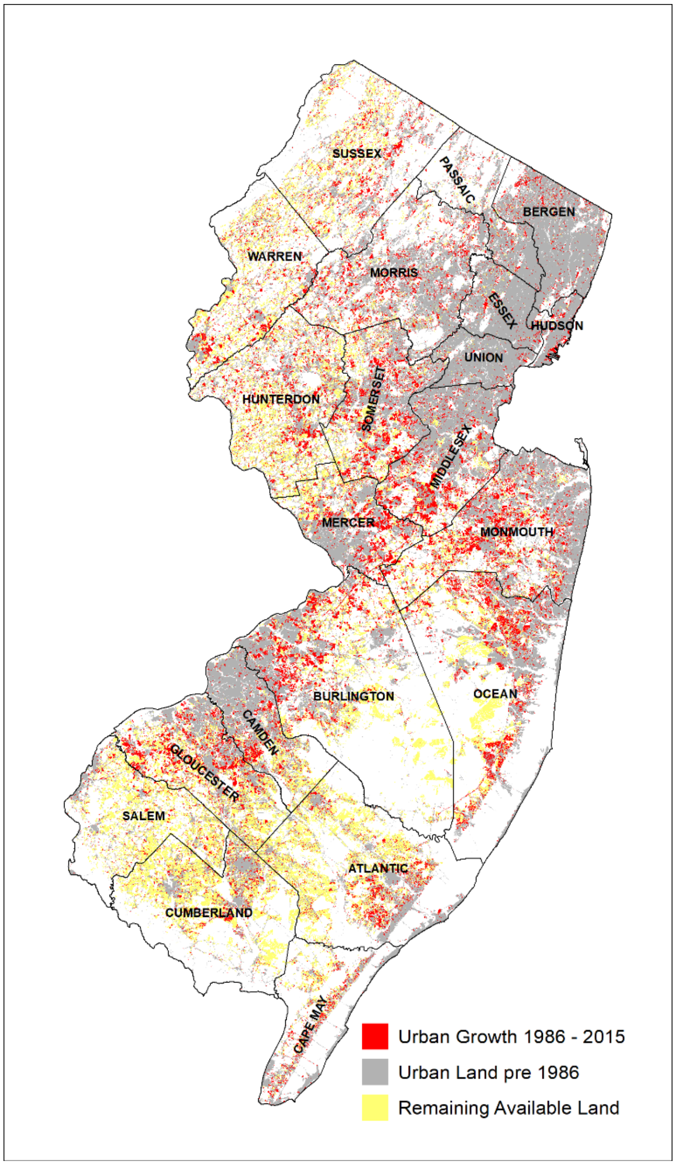


Figure 4.1 Urbanization and Available Land in NJ – Growth patterns vary significantly throughout the state among urban, suburban, and rural counties.

Land development patterns by county during the 1986-2015 period of analysis demonstrate that although development was ubiquitous throughout all counties, some counties grew a lot more than others. Figure 4.2 graphs the annual rate of urban expansion by county during the three-decade study period and demonstrates that all counties experienced a significant slowdown in the rate of urbanization post the 2008 recession. However, the data reveals that as the economy recovered, the expansion of urban growth did not pick back up but counter intuitively continued to drop below the recession rate during T5 (20012-2015) for most of New Jersey's 21 counties.

Only Mercer and Middlesex counties saw an increase in development rate from the recession T4(2007-2012) period and although the rate bumped up in these two suburban core counties, the

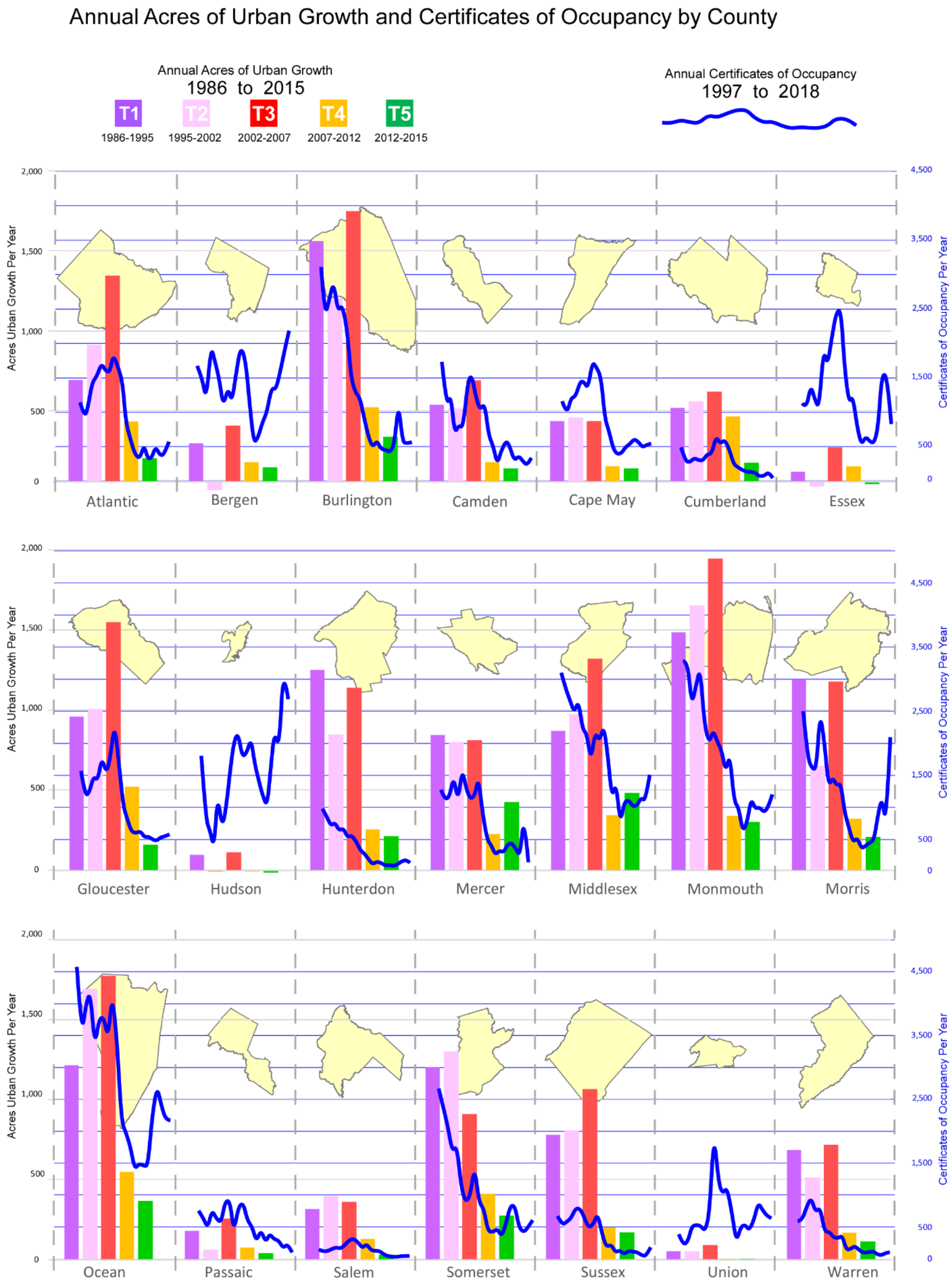


Figure 4.2 Annual Acres of Urban Growth and Certificates of Occupancy by County

The states most urbanized counties provide indications that they are nearing or at functional buildout with little remaining undeveloped available land for further urban expansion. Growth in these counties occurs in the form of redevelopment and infill. Passaic and Cape May counties are also approaching buildout although they have a significant portion of their territory in preservation for watershed and open space protection. Camden and Morris are also significantly populated counties that are nearing buildout because much of their remaining developable vacant lands are under the jurisdiction of the Pinelands and Highlands management systems. Many other suburban counties that still have significant amounts of undeveloped lands nonetheless exhibited a post-recession slowdown, although certainly not a halt, in urbanization. This included Atlantic, Burlington, Gloucester, Hunterdon, Monmouth, Ocean and Somerset counties.

The final group are the rural Salem, Cumberland, Warren and Sussex counties. These Counties were experiencing relatively lower levels of pre-recession development pressure than the suburban counties and have slowed down even further post-recession and into the T5(2012-2015) period. The rural counties have had active farmland preservation and conservation activities which also lessens the development pressures.

The slowdown in urban growth revealed in the land use/land cover data despite the recovering economy provides an indication that a significant change occurred in development practices over the post-recession decade. While the land use mapping does an excellent job of capturing the change of non-urban lands into urban lands, the data is less suited to capture the redevelopment that occurs on already existing urban and suburban lands. To better capture the redevelopment process we analyze building permit certificate of occupancy data.

Statewide certificate of occupancy (CO) data tracked annually over the study period (Figure 4.3) reveals an alternate perspective of development from the land use land cover data alone. The post-recession slowdown in state-wide development rates after a 2005 peak of over 31,039 per year are clearly evident in the drop of certificates of occupancy through a 2011 low of about 10,352 per year. Interestingly, while the rate of acres of urban growth dropped further state-wide during T5(2012-2015) even as the economy recovered, the number of certificates of occupancy steadily increased from its 2011 low point rising to 17,318 per year by 2018, the most recent year of data availability. This statewide simultaneous slowdown in land consumption attributable to urban development and uptick in CO's is an indication that the recent growth has been on a more compact development pattern as well as an indication of redevelopment.

The certificate of occupancy data by county demonstrates more clearly both of these trends in play. Figure 4.2 provides the county annual summary of CO's super imposed as a trend line with the county urban growth data. The data highlights that there was an unprecedented shift toward redevelopment in NJ's most urban counties whose growth in CO's outstripped their pre-recession highs. While 18 counties had fewer CO's in the decade following the great recession than the decade preceding, Hudson, Union and Bergen counties had more CO's issued after 2008 than before, a clear indication of a post-recession trend toward urban redevelopment. The dramatic increase in CO's for Hudson, Bergen and Essex counties in the last decade reflects the trends for re-inhabiting urban locations. In addition, growth hotspots in a number of suburban counties also absorbed a substantial proportion of new housing units as indicated by CO's most notably Ocean, Middlesex, Monmouth and Morris. The magnitude of new CO's in these counties outstrips magnitude of acres of urban growth indicating that the growth that is occurring during the most recent decade is more compact, consuming less land per capita and thus lower indicators of land resource impacts (Hasse and Lathrop 2003).

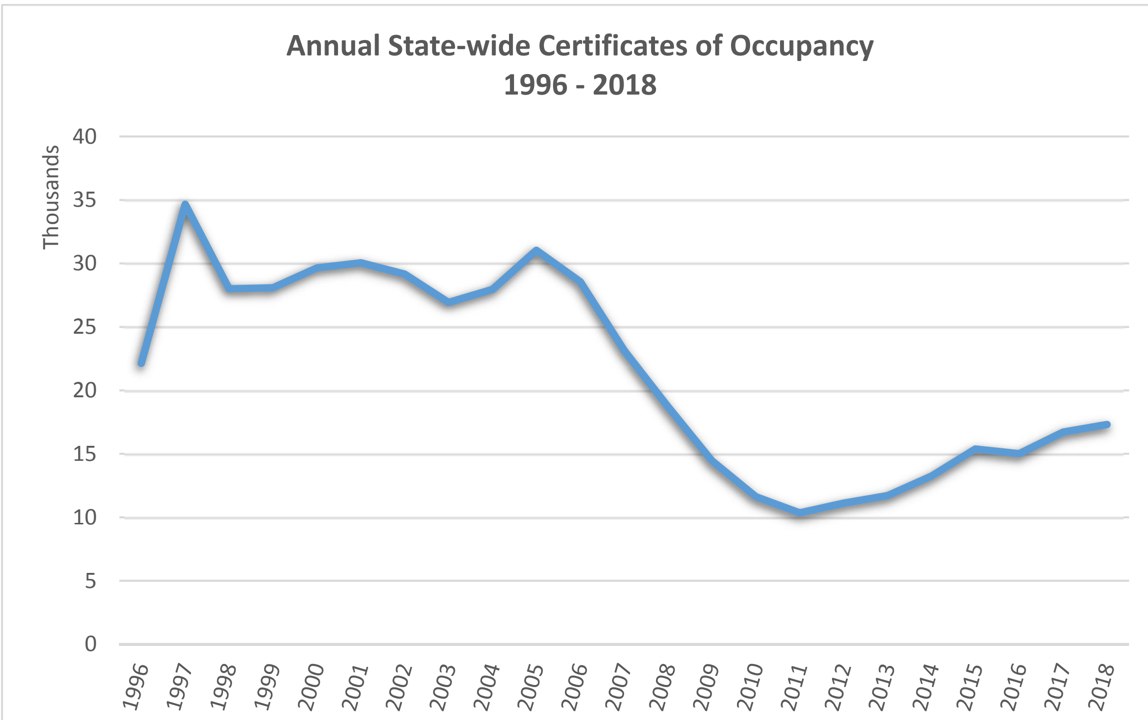


Figure 4.3 Annual Statewide Certificates of Occupancy data for New Jersey reveal a 2005 pre-recession peak of 31,039 followed by a six year decline to a 2011 post-recession low of 10,352 and a subsequent recovery rising to 17,318 units per year by 2018.

The states most rural counties including Salem, Cumberland, Warren and Sussex all exhibited a downward trend in CO's continuing throughout the post-recession decade with less of an indication of a shift toward compact development. In other words, urban growth in rural counties slowed down but the growth that did occur was more sprawling compared to the shift toward compact development demonstrated by other counties. This may in part be attributable to the lack of sewer service in large swaths of these rural counties, which is often a prerequisite for compact development.

5 Urban Growth in NJ's Regional Planning Areas

New Jersey is a state with one of the strongest *home rule* governing systems of land use management in the nation. The 1975 New Jersey Municipal Land Use Law (MLUL) codified the power to manage land use to be under jurisdiction of the state's 565 independent municipalities. In contrast to the majority of states which vest significant land use control at the county level and thus have more regional objectives, New Jersey's home rule approach had the tendency for land management decisions to be driven by competitive interests of local municipalities on time scales that reflect the short-term transitory nature of the municipal political cycle. From a land use perspective, home rule has been one of the drivers of poorly coordinated and land-consumptive development patterns that have led to inherent problematic environmental and socioeconomic consequences over the decades. While New Jersey's home rule political structure has been fiercely defended for over a century, in recent decades several regional planning initiatives have emerged in an effort to achieve broader environmental, land resource and infrastructure goals by coordinating land planning among municipalities through a regional planning system. Comparative analysis of land use change among the different regional planning programs can provide insight into the efficacy of regional planning in the home-rule state. The three most significant regional planning initiatives (Figure 5.1) include the *State Development and Redevelopment Plan* (i.e. State Plan), the *Pinelands Comprehensive Management Plan* (CMP) and the *Highlands Regional Master Plan* (RMP). Each of these planning regions has a different backstory, different inception date and different implementation mechanism. Most significantly, each regional planning initiative has a different degree of legal enforceability. Together New Jersey's three main regional planning systems provide, in essence, a natural experiment for comparing various approaches to regional planning in a state that lies in one of the most significant growth corridors in the nation.

Evaluation of the land use change that occurred over the three decades of the study illustrate the differences between the regional planning systems and their relationship to managing land use change. The State Plan region experienced the largest portion of land use change. Occupying 64% of the state's territory, it saw 264,108 acres (73%) of urban acres developed. This came at the loss of 156,804 acres of farmland (78% of all farmland loss), 72,567 acres of upland forest (60% of forest lost), and 49,402 acres of wetlands (89% of total wetlands loss). The Highlands occupying 17% of the state's land territory was the next most active area of land use change with 63,372 acres (18%) of urban growth, 35,108 acres (17%) of the state's farmland loss, 26,809 acres (22%) of forest loss and 5,565 acres (10%) of wetlands loss. The Pinelands Comprehensive Management Planning area occupies 19% of the state's land base and saw the least amount of land use change overall with urban growing by 32,421 acres (9%), agriculture shrinking by 8,963 acres (4%), forest declining by 22,216 acres (18%) and wetlands losing 442 acres (1%). Looking deeper into the data provides insights into how the regional planning systems have been functioning over the decades and how they may influence future land change patterns in the decades to come.

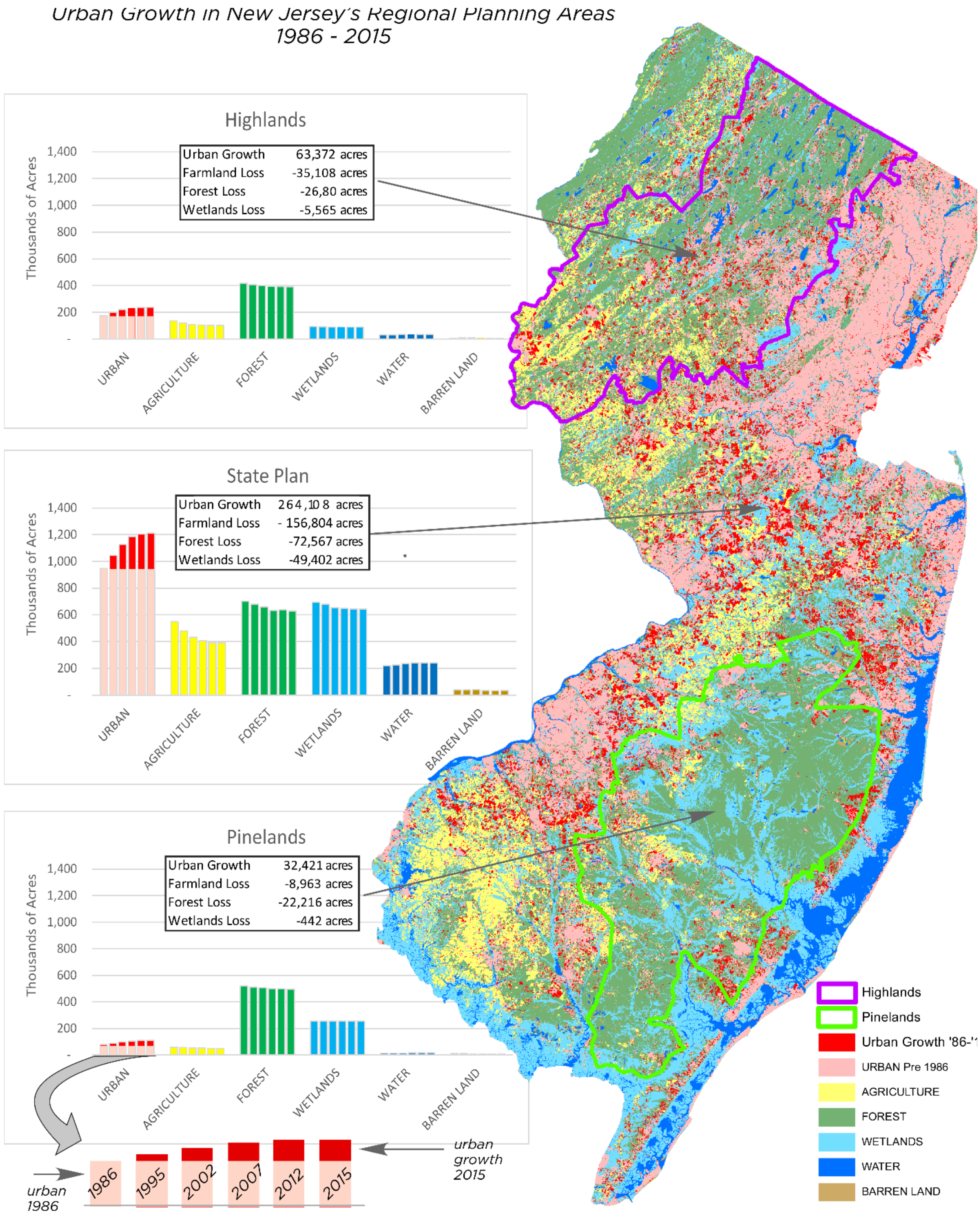


Figure 5.1 Comparison of Urban Growth in New Jersey's Regional Planning Areas – including the State Plan, the Pineland Comprehensive Management Plan and the Highlands Regional Master Plan. The graphs depict acreage of major land uses as they change from dataset to dataset from 1986 through 2015.

The State Development and Redevelopment Plan

The New Jersey State Development and Redevelopment Plan (State Plan) had its origins in the New Jersey State Planning Act (N.J.S.A. 52:18A-196 et seq) which was signed into law on January 5, 1986. There have been several iterations with the most recent official version adopted March 1, 2001. In an effort to mitigate the rapidly increasing pressures for development in New Jersey, the plan was envisioned to "...conserve [New Jersey's] natural resources, revitalize its urban centers, protect the quality of its environment, and provide needed housing and adequate public services at a reasonable cost while promoting beneficial economic growth, development and renewal."

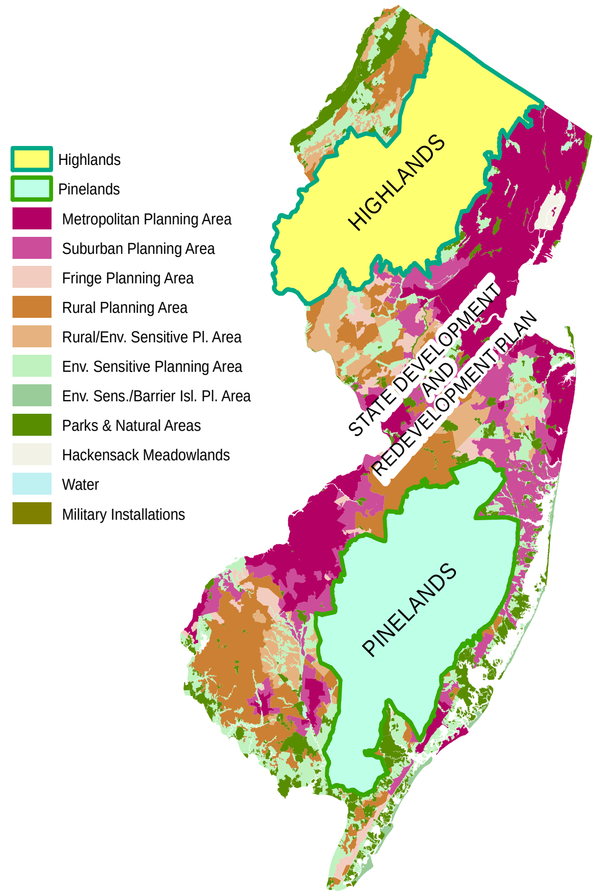


Figure 5.2 New Jersey's State Development and Redevelopment Plan delineates 7 planning zones and centers throughout the state. The Pinelands Comprehensive Management Plan (CMP) and the Highlands Regional Master Plan (RMP) have independent jurisdiction from the State Plan although there are areas of overlap including the Pinelands National Reserve portion of the CMP and the Highlands Planning Area portion of the RMP.

In order to engage municipal buy-in within the framework of NJ's home rule structure, the plan was non-regulatory and designed to be inclusive to local interest through an interactive negotiation process called *cross-acceptance*. The plan delineates seven zones of land use (Figure 5.2)) 1) *PA1 Metropolitan Planning Area*, 2) *PA2 Suburban Planning Area*, 3) *PA3 Fringe Planning Area*, 4) *PA4 Rural Planning Area*, 5) *PA4B Rural/Environmentally Sensitive Planning Areas*, 6) *PA5 Environmentally Sensitive Planning Area*, and 7) *PA5B Environmentally Sensitive Barrier* Island. The planning areas prescribe the type of urban development and land preservation that is most appropriate for each zone. PA1 (*Metro*) & PA2 (*Suburban*) are areas where development growth and redevelopment is encouraged. PA3 is a fringe area intended to receive some growth balanced with land conservation measures. Planning areas PA4, PA4B and PA5 are "rural" and/or "environmentally sensitive" zones where large scale development is to be minimized and land conservation fostered. The plan also designates *centers* which are focused areas of development and redevelopment that can occur in any of the planning areas.

The State Plan does not have regulatory enforceability but is instead a "statement of state policy" intended to guide local agencies in the exercise of their statutory authority. The non-regulatory nature of the system relies on voluntary participation of each municipality to coordinate their own land use planning with the goals of the State Plan through the cross-acceptance process. Once a municipality's plan is considered in alignment with the State Plan the municipal plan is sanctioned as "endorsed." Endorsement provides some potential benefits such as financial and technical assistance from the state. Endorsement is also intended to accelerate the coordination between state agencies regarding planning and development review.

Evaluating the patterns of land use change that occurred since the State Plan was initiated provides a window into the efficacy of plan. Figure 5.3 depicts the urban growth in the central part of the state over the three-decade study period. Planning Areas PA1 Urban and PA2 Suburban as well as Designated Centers are the intended smart growth areas of the plan and rendered in light green in the map. What stands out is the substantial amount of

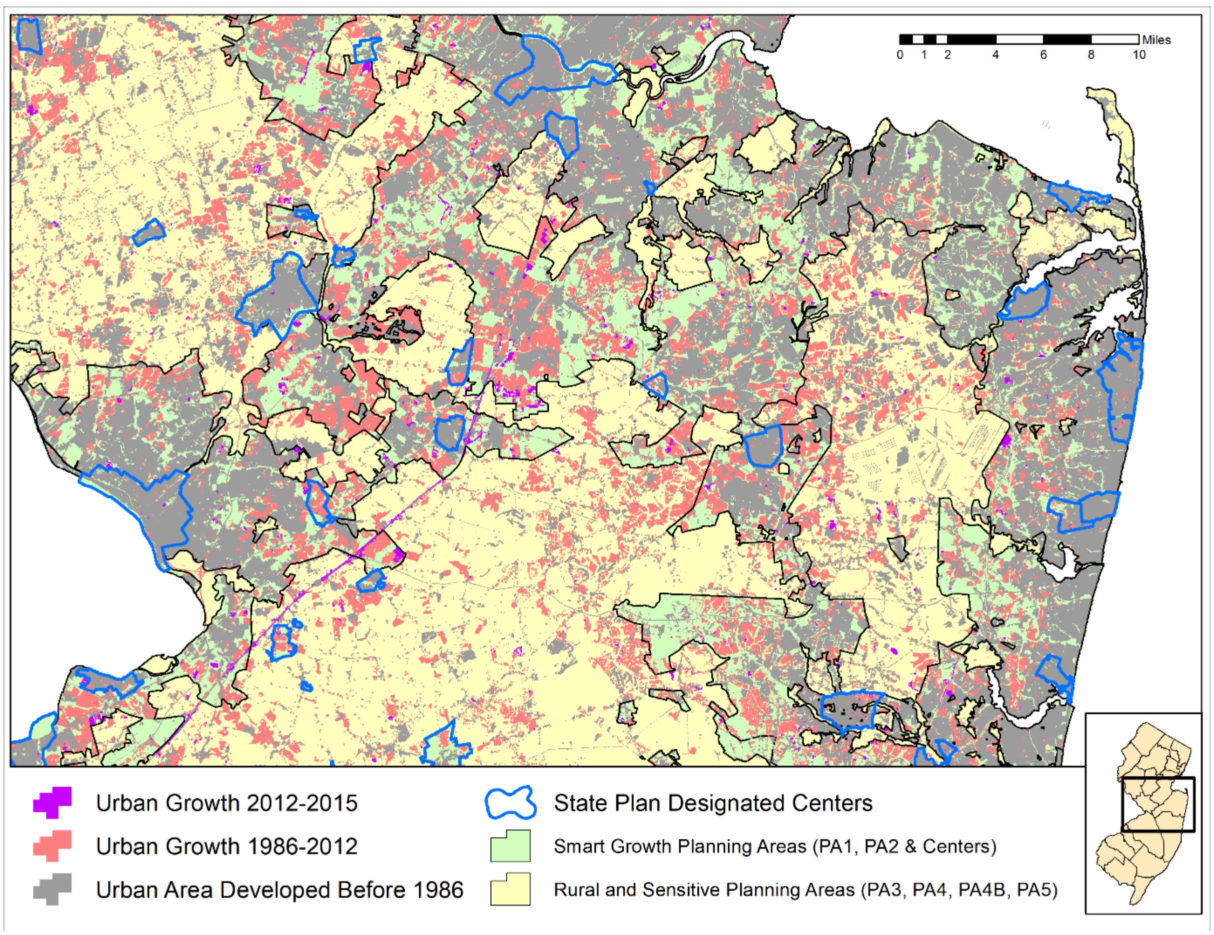


Figure 5.3 Development in relationship to the NJ State Planning Areas for central New Jersey. Urban growth that occurred during T0-T4(1986-2012) is red and growth during T5(2012-2015) is purple. Light green zones represent the smart growth zones consisting of PA1, PA2 and Centers. Yellow areas represent the sensitive planning areas of PA3, PA4, PA4b and PA5. The map reveals the scattered pattern of development throughout the state during the entire 1986-2015 period when over half of the acres developed occurred outside of a smart growth zone. A significant shift occurred during T5(2012-2015) when over 60% of developed acres where in smart growth zones.

development that occurred outside the smart growth zones in the rural and sensitive planning areas intended to receive minimal growth depicted light yellow on the map. During T0-T5('86-'15), about 32% of all the development (133,732 acres) that occurred in areas of the state under the jurisdiction of the state plan took place in the PA4 Rural, PA4B Rural/Environmentally Sensitive or PA5 Environmentally Sensitive planning areas (Table 5.1). The preponderance of the growth in these planning areas was attributable to a single land use category, type *LU-1140 Residential Rural Single-Unit* low-density housing which contributed 132,279 acres (33% of the state's total land development) in the three rural/environmental State Plan planning zones. For three decades, large-lot single-unit housing was responsible for consuming the majority of state's most sensitive lands.

However, the most recent land use data reveals a major departure from the sprawling trends of the previous decades in favor of the delineated smart growth zones. The T5(2012-2015) data (Table 5.2) demonstrates a significant drop from 32% to 17% in the proportion of total development that went into the State Plan's three most sensitive planning areas. And the proportion of the total development in these planning areas that went to the lowest density rural single-unit residential dropped from 32% to 14% of the total state-wide development footprint. Considering that rate of acres developed per year during T5(2012-2015) was about 1/3 of the average rate of acres developed per year T0-T5(1986-2015) and that of the acres that were newly developed land, a lower percentage went to low-density rural residential housing in the state's most sensitive rural planning areas, the land resource-consumptive pattern of rural sprawl of the 1990's and early 2000's seems to have significantly slowed, at least for the three year period of 2012-2015.

Looking at three decades of growth (T0-T5) in the PA1 Metro and PA2 Suburban planning regions revealed that about 34% of the total development in each region went to the two highest-density categories of residential land use *LU-1110 Residential High Density* and *LU-1120 Residential, Single Unit, Medium Density* whereas the remaining two low-density residential categories *LU-1130 Residential, Single Unit, Low Density* and *LU-1140 Residential Rural Single-Unit* consumed 18% and 27% of the land in each planning area respectively. The majority of the remaining development footprint in PA1 and PA2 went to *LU-1200 Commercial/Services* (22%), *LU-1300 Industrial* and LU-1700 *Other Urban or Built Up Land* (22%). The most recent T5(2012-2015) land use data for Planning Areas PA1 Metro and PA 2 Suburban (Table 5.2) also reveals a significant shift away from lower-density residential (*LU-1130* and *LU-1140)* which each dropped significantly in their proportion of the development in these smart growth zones compared with T0-T5. In addition, the percentage of development in each smart growth zone that went into higher density residential (*LU-1110* and *LU-1120*) substantially increased from T0-T5 to T5. This increase in the proportion of land developed as higher-density residential is and an indication of a more compact development pattern. The data also reveals a substantial uptick for the proportion of development in Planning Areas PA1 Urban and PA2 Suburban dedicated to non-residential. While commercial *LU-1200* hovered around the same 8% proportion of growth over the 30 year study period, Industrial *LU-1300* increase its proportion of the development in the smart growth zones doubling in PA1 from 8% to 16% of the development footprint. This is likely mirroring the increase in warehousing evident throughout the statewide analysis.

PA3 Fringe experienced the smallest total amount of growth during T0-T5 (1986-2015) among all the major planning areas receiving only 25,036 acres (6%) of the total growth. This relatively small urban footprint is in part attributable to PA3 covering the smallest amount of territory of the plan's major planning areas. The majority of T0-T5 growth in PA3 was attributable to low-density and rural single-unit housing where the two lowest residential densities (*LU-1130* and *LU-1140*) were responsible for 67% of total acres developed in the zone. During the most recent T5 (2012-2015) period, the proportion of development within PA3 Fringe dropped slightly to 5% of the total acres of growth while the proportion of acres that went to more compact residential *LU-1110* and *LU-1120* more than doubled. Further, the two lowest residential densities growth in PA3 combined dropped from 67% to 46% of total land developed in the zone, another indication in a shift away from large lot toward more compact land development. The three rural and environmentally sensitive planning areas PA 4, PA 4B and PA5 saw a moderate shift in their proportion of the development footprint going from 38.3 % of the total urban footprint over the T0-T5 time period to 30% of the total urban growth footprint during T5 (2012-2015). They also demonstrated a shift to a lower percentage of land going to the lowest density residential land use type during T5 compared to the three decade T0-T5 time span.

Analysis of land use change data within the various State Plan planning areas demonstrates that there has been a substantial differentiation in the development patterns occurring in the various SDRP planning areas. Over three decades a significant amount of development did occur where it was intended in the PA2 Suburban (29% of total acres of growth) followed by PA1 Metro (17% or total acres of growth). However, the plan's non-regulatory status is evident by looking at the fact that 32% of development acres that occurred throughout the state over the last three decades was in rural and environmentally sensitive areas of the State Plan. The most recent data for T5 (2012-2015) indicates that a smaller portion (26%) of the developed footprint was located in the rural and sensitive regions. While the overall pace of development has slowed in the last decade and there is evidence that there has been a shift in the location of urban growth toward the smart growth planning regions (as well as a move toward higher-density residential development), it is difficult to tease out how much of the shift is the result of the State Plan versus other socioeconomic factors. Considering that the State Planning process began in 1986 (the same year as our base-line land use data), with few measures of enforceability, the data indicate that SDRP has been only moderately effective in encouraging center-based smart growth and mitigating sprawl in New Jersey's sensitive planning areas covered by the plan over the three decades since its establishment. This contrasts with the two special planning areas of the state that have stronger measures of enforceability, the Pinelands and the Highlands.

Table 5.1 Urban Growth 1986-2015 in the New Jersey State Development and Redevelopment Planning Areas by Anderson Level 3 use codes during T1-T5(1986-2015). The table excludes 67,414 acres of development in Pinelands Area, Highlands Preservation Area, parks and Federal Lands.

		PA1 Metro		PA2 Suburban		PA3 Fringe		PA4 Rural		PA4B Rur Env Sens		PA5 Env Sens		Total	
LU Code	LABEL	Acres Growth	% PA total	Acres Growth	% PA total	Acres Growth	% PA total	Acres Growth	% PA total	Acres Growth	% PA total	Acres Growth	% PA total	Acres Growth	% total
1110	RES, HIGH DENSITY	7,775.7	11.7%	12,519.3	10.7%	650.0	2.6%	925.3	1.7%	372.3	1.1%	891.9	2.3%	25,286.0	6.3%
1120	RES, SIN UNIT, MED DENS	15,944.4	24.0%	28,090.7	24.0%	1,381.2	5.5%	1,483.6	2.7%	832.0	2.4%	2,221.4	5.7%	57,467.6	14.2%
1130	RES, SIN UNIT, LOW DENS	7688.2	11.6%	20650.7	17.7%	5005.2	20.0%	5465.8	10.1%	2757.8	7.8%	4445.8	11.5%	54,244.3	13.4%
1140	RES, RUR, SIN UNIT	4,496.3	6.8%	12,452.4	10.6%	11,863.3	47.4%	33,113.0	61.0%	22,673.8	64.3%	20,442.5	52.9%	132,279.1	32.7%
1150	MIXED RESIDENTIAL	0.2	0.0%	82.3	0.1%	-		-		1.2	0.0%	0.3	0.0%	86.3	0.0%
1200	COMMERCIAL/SERVICES	9,244.3	13.9%	10,030.3	8.6%	1,216.8	4.9%	1,643.1	3.0%	1,127.4	3.2%	1,338.6	3.5%	27,531.1	6.8%
1211	MILITARY INSTALLATION	18.3	0.0%	10.8	0.0%	1.1	0.0%	0.2	0.0%	2.5	0.0%	316.5	0.8%	1,681.8	0.4%
1214	FORMER MILITARY	19.1	0.0%	-		0.4	0.0%	0.6	0.0%	-		2.0	0.0%	22.0	0.0%
1300	INDUSTRIAL	5,380.2	8.1%	6,200.6	5.3%	427.3	1.7%	842.7	1.6%	445.6	1.3%	808.8	2.1%	15,879.5	3.9%
1400	TRANS/COMM/UTIL	1,342.7	2.0%	2,070.8	1.8%	154.0	0.6%	1,242.3	2.3%	387.2	1.1%	684.1	1.8%	7,038.5	1.7%
1410	MAJOR ROADWAY	648.9	1.0%	825.5	0.7%	63.4	0.3%	239.5	0.4%	88.3	0.3%	181.7	0.5%	2,627.3	0.7%
1411	MIXED TRANSP CORR	3.4	0.0%	0.1	0.0%	-		-		0.4	0.0%	-		4.2	0.0%
1420	RAILROADS	608.2	0.9%	182.2	0.2%	32.7	0.1%	132.6	0.2%	87.3	0.2%	186.4	0.5%	1,595.4	0.4%
1440	AIRPORT FACILITY	73.2	0.1%	145.9	0.1%	10.2	0.0%	38.1	0.1%	36.2	0.1%	7.2	0.0%	422.7	0.1%
1462	UPLAND R-O-W DEVELOP	49.3	0.1%	124.7	0.1%	13.9	0.1%	23.7	0.0%	7.2	0.0%	14.0	0.0%	252.1	0.1%
1463	UPLAND R-O-W UNDEVEL	182.9	0.3%	344.7	0.3%	44.7	0.2%	360.1	0.7%	245.4	0.7%	260.0	0.7%	2,324.7	0.6%
1499	STORMWATER BASIN	1,738.0	2.6%	4,703.2	4.0%	721.2	2.9%	1,026.5	1.9%	687.1	1.9%	626.1	1.6%	10,932.3	2.7%
1500	INDUST/COMMERC CMPLX	223.6	0.3%	140.0	0.1%	10.7	0.0%	2.7	0.0%	8.5	0.0%	26.4	0.1%	419.5	0.1%
1600	MIXED URBAN OR BUILT UP	8.3	0.0%	10.3	0.0%	1.3	0.0%	4.3	0.0%	3.8	0.0%	4.6	0.0%	34.5	0.0%
1700	OTHER URBAN OR BUILT	7,733.7	11.7%	13,339.7	11.4%	1,932.3	7.7%	4,139.1	7.6%	3,043.3	8.6%	3,547.2	9.2%	40,040.5	9.9%
1710	CEMETERY	319.0	0.5%	99.9	0.1%	77.1	0.3%	225.1	0.4%	67.1	0.2%	76.9	0.2%	963.4	0.2%
1800	RECREATIONAL LAND	2,535.2	3.8%	3,912.5	3.3%	1,174.5	4.7%	2,912.7	5.4%	2,067.3	5.9%	2,511.0	6.5%	19,890.7	4.9%
1804	ATHLETIC FIELDS (SCHLS)	305.8	0.5%	681.7	0.6%	134.9	0.5%	435.9	0.8%	273.8	0.8%	52.4	0.1%	2,182.6	0.5%
1810	STADIUM / CULTURAL CENT	38.3	0.1%	369.1	0.3%	116.2	0.5%	12.9	0.0%	-		11.2	0.0%	619.9	0.2%
	Total Acres Developed	**66,378**		**116,989**		**25,036**		**54,274**		**35,257**		**38,662**			
	% of Total Acres Developed	**16.43%**		**28.96%**		**6.20%**		**13.43%**		**8.73%**		**9.57%**			

Table 5.2 Urban Growth 2012-2015 in the New Jersey State Development and Redevelopment Planning Areas by Anderson Level 3 use codes during T5(2012-2015). The table excludes 1,857 acres of development in Pinelands Area, Highlands Preservation Area, parks and Federal Lands.

		PA1 Metro		PA2 Suburban		PA3 Fringe		PA4 Rural		PA4B Rur Env Sens		PA5 Env Sens		Total	
LU Code	LABEL	acres devel	% PA total	acres devel	% PA total	acres devel	% PA total	acres devel	% PA total	acres devel	% PA total	acres devel	% PA total	acres devel	% total
1110	RES, HIGH DENSITY	586.3	16.4%	495.4	8.8%	44.0	5.8%	28.3	1.5%	32.0	3.0%	17.3	1.5%	1,203.4	8.5%
1120	RES, SIN UNIT, MED DENS	289.4	8.1%	957.3	17.1%	100.0	13.1%	26.1	1.3%	40.8	3.8%	62.9	5.4%	1,476.5	10.5%
1130	RES, SIN UNIT, LOW DENS	130.3	3.7%	343.1	6.1%	171.7	22.5%	26.8	1.4%	126.5	11.7%	65.9	5.7%	864.3	6.1%
1140	RES, RUR, SIN UNIT	132.6	3.7%	320.5	5.7%	176.5	23.1%	623.0	32.2%	322.6	29.8%	397.1	34.4%	1,972.2	14.0%
1200	COMMERCIAL/SERVICES	543.4	15.2%	442.5	7.9%	74.7	9.8%	86.3	4.5%	50.1	4.6%	72.4	6.3%	1,269.3	9.0%
1211	MILITARY INSTALLATION			7.7	0.1%									7.7	0.1%
1300	INDUSTRIAL	551.1	15.5%	380.4	6.8%	8.7	1.1%	23.4	1.2%	6.0	0.6%	25.3	2.2%	995.0	7.1%
1400	TRANS/COMM/UTIL	178.1	5.0%	413.8	7.4%	13.4	1.8%	365.6	18.9%	99.5	9.2%	134.6	11.7%	1,204.9	8.5%
1410	MAJOR ROADWAY	39.1	1.1%	246.2	4.4%	12.0	1.6%	226.1	11.7%	45.3	4.2%	15.8	1.4%	584.6	4.1%
1411	MIXED TRANSP CORRIDOR									0.6	0.1%			0.6	0.0%
1420	RAILROADS	11.5	0.3%	6.9	0.1%					0.4	0.0%			18.8	0.1%
1440	AIRPORT FACILITY	15.4	0.4%			7.1	0.9%	3.8	0.2%					26.2	0.2%
1462	UPLAND R-O-W DEVELOP	5.6	0.2%	2.6	0.0%	1.2	0.2%	1.1	0.1%	1.1	0.1%			11.6	0.1%
1463	UPLAND R-O-W UNDEVEL	15.3	0.4%	39.5	0.7%	0.6	0.1%	75.8	3.9%	44.0	4.1%	25.7	2.2%	200.8	1.4%
1499	STORMWATER BASIN	176.7	5.0%	392.8	7.0%	46.2	6.1%	80.9	4.2%	67.3	6.2%	59.6	5.2%	823.5	5.8%
1500	INDUST/COMMERC CMPLX	1.7	0.0%											1.7	0.0%
1600	MIXED URBAN OR BUILT UP			1.5	0.0%									1.5	0.0%
1700	OTHER URBAN OR BUILT	521.0	14.6%	1,339.7	23.9%	95.6	12.5%	270.7	14.0%	227.9	21.0%	237.3	20.6%	2,692.2	19.1%
1710	CEMETERY	41.5	1.2%	2.2	0.0%	0.2	0.0%	17.8	0.9%	2.7	0.2%			64.3	0.5%
1800	RECREATIONAL LAND	298.4	8.4%	141.6	2.5%	4.5	0.6%	77.7	4.0%	16.2	1.5%	38.3	3.3%	576.8	4.1%
1804	ATHLETIC FIELDS (SCHLS)	14.3	0.4%	15.7	0.3%	5.0	0.7%	4.1	0.2%			1.6	0.1%	40.7	0.3%
1810	STADIUM / CULTURAL CENT	12.7	0.4%	55.1	1.0%	1.5	0.2%					0.1	0.0%	69.5	0.5%
	Total Acres Developed	3,564.4		5,604.5		762.7		1,937.5		1,082.9		1,153.9		14,105.9	
	% of Total Acres Developed	22.33%		35.11%		4.78%		12.14%		6.78%		7.23%			

The Pinelands Comprehensive Management Plan

The New Jersey Pine Barrens is an important ecological region located in southern New Jersey's Outer Coastal Plain. Occupying approximately 1.1 million acres of relatively undeveloped forestland, the Pine Barrens is internationally recognized as an exceptional and unique ecosystem (Stokes and Grogan, 2011). The Pine Barrens is also located above the Kirkwood-Cohansey aquifer, one of the most significant and pristine ground water aquifers in the northeast. The Pinelands Comprehensive Management Plan (CMP) (Figure 5.4) is a regional plan that overlays and coordinates municipal zoning into nine different planning management areas. The plan came into effect in 1981 and is managed by the Pinelands Commission, a board of 15 members appointed by the state and member counties with one federal member. While local municipalities still maintain planning and

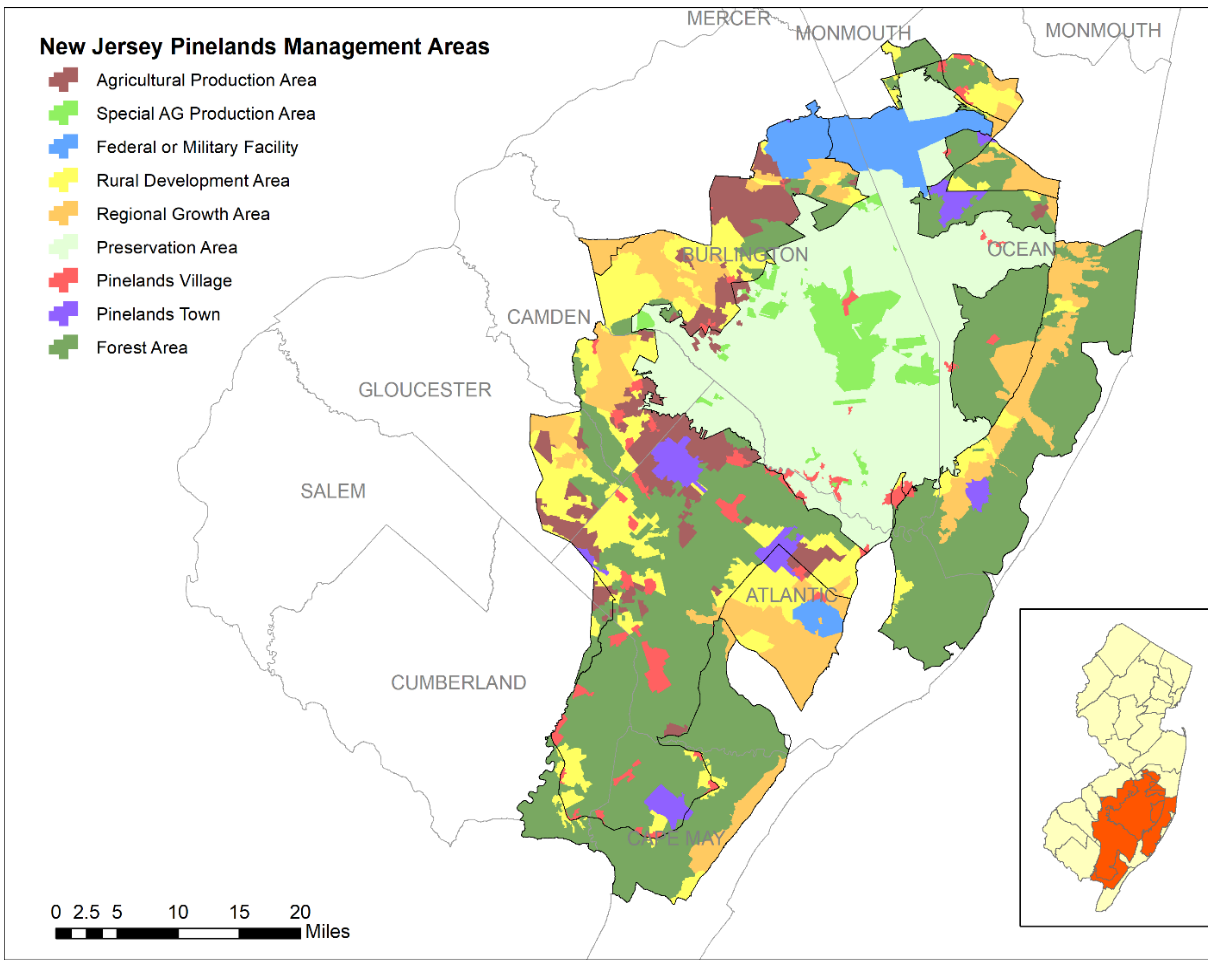


Figure 5.4 This map depicts the areas under the jurisdiction of the Pinelands Commission and includes both the Pinelands Planning Areas and the National Reserve Areas. Since the National Reserve portion falls under the State Plan, the analysis covers only the area exclusively occupied by the Pinelands Planning Area which is independent from the State Plan, delineated by the black boundary in the map.

zoning activities within their jurisdiction, land use ordinances are required by state statute to be consistent with the goals of the regional plan and the Pinelands Commission plays a significant role in the coordination of planning as well as development decision making. Management areas have specific goals ranging from preservation in the "core" area to higher density development consistent with the principles of smart growth in designated growth areas. Each management area allows a different level of development and housing density, ranging from deterring new development in the preservation core to regional growth areas where development is encouraged to be located. There is also a transfer of developments rights program to provide equitable options for land owners to sell their development rights in the conservation regions as part of the comprehensive planning system (NJAPA, 2018).

The mission of the Pinelands CMP is to "promote orderly development of the Pinelands so as to preserve and protect the significant and unique natural, ecological, agricultural, archaeological, historical, scenic, cultural and recreational resources of the Pinelands" (Pinelands Commission 2020). The Pinelands CMP (Figure 5.4) has some common aspects to the New Jersey State Plan in that there are various planning zones that are established to synchronize municipal planning in order to guide growth to the most appropriate locations in the region and conserve the regions more sensitive areas. However, the Pinelands CMP is markedly different from the State Plan in that it carries statutory jurisdiction in land use approvals.

The geography of the Pinelands Management Plan is complex because the jurisdictional boundaries of the federal delineation and state delineation differ somewhat. The boundaries of the federal oversight area was established through the Pinelands National Reserve, created by the *National Parks and Recreation Act of 1978* and state the state-designated Pinelands Area was created by the *1979 Pinelands Protection Act*. The main difference is that the 1.1 million acre federal National Reserve is larger, including land east of the Garden State Parkway and to the south bordering the Delaware Bay, which is omitted from the state Pinelands Area. The Comprehensive Management Plan covers both state and federal jurisdictions but handle federal areas somewhat differently. Areas of the Pinelands National Reserve (PNR) that are outside of the state's Pinelands Area are not subject to most of the obligations of the Comprehensive Management Plan (CMP) except for the land designations (e.g. forest, preservation area, growth area). Municipalities that are in the PNR exclusively must follow the general land designations for what types of activities are able to occur, but they are not required to have their plans approved by the Pinelands Commission or go through the Commission's permitting process. As such, we analyze solely the 927,000 acre Pinelands Area region designated by the state legislation since it is exclusive from the State Plan whereas the portions covered solely by the PNR fall under the jurisdiction of the State Plan evaluated above.

When comparing urban growth inside the Pinelands (Figure 5.5) to growth in the rest of the state covered by the State Plan, the greater efficacy of the Pinelands plan is evident. The Pinelands Area region occupies 927,000 acres (18.5%) of the total land area of the state but only experienced 35,549 acres (8.8%) of the 360,000 acres of growth that occurred from 1986-2016. During T5(2012-2015) the Pinelands experienced 1,016 acres of growth which represented 6.4% of the total 15,963 acres of growth that occurred statewide during this time. The overall pace of urbanization gauged against the proportion of available land demonstrates that the magnitude of acres developed was measurably less inside than outside of the Pinelands.

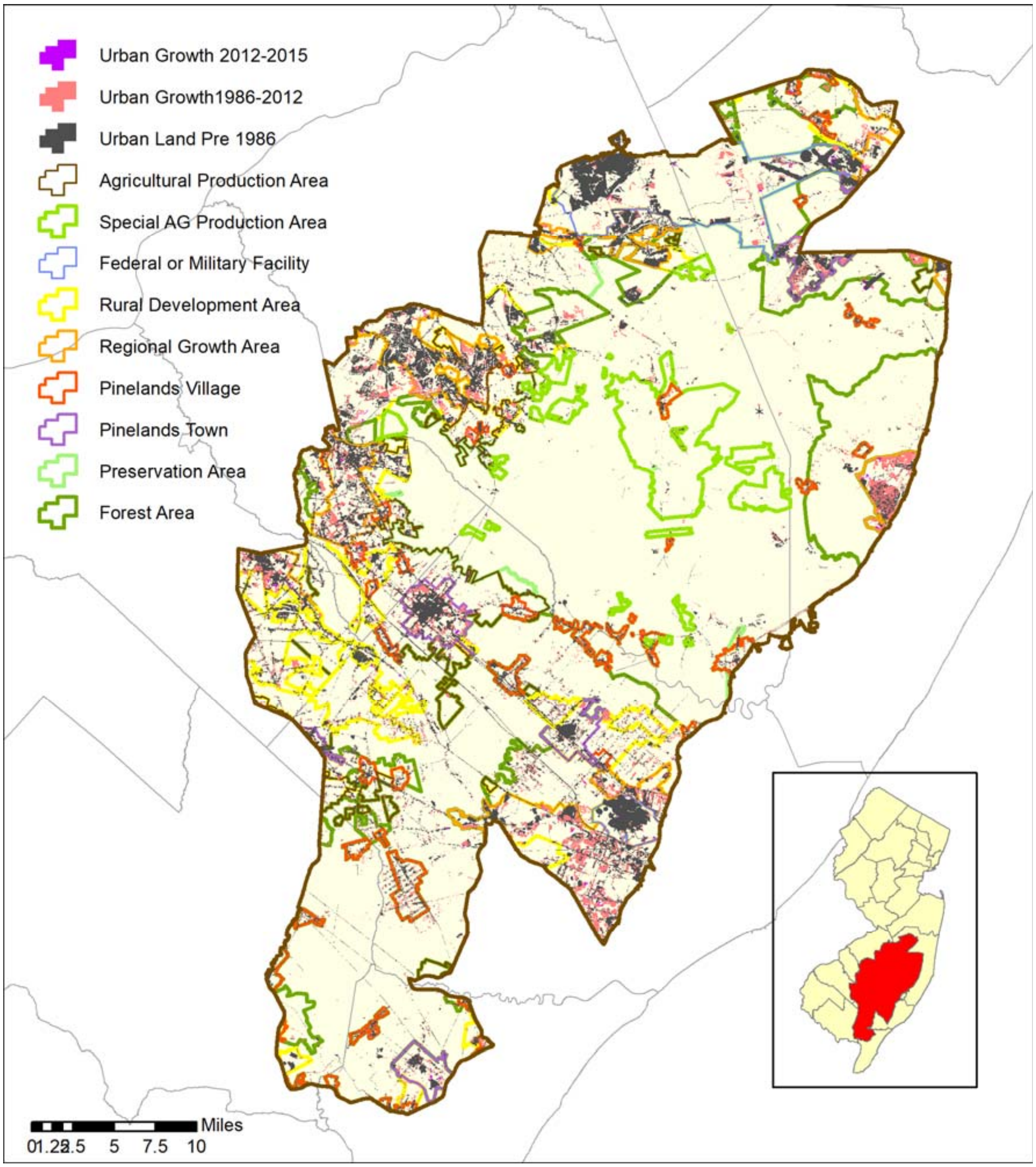


Figure 5.5 Urban Growth in the Pineland Planning Area – The Pinelands experienced 35,549 acres of urban growth over the 1986-2015 study period, less than 1/10 of the total acres developed statewide while occupying over 1/5th of the state's territory. The majority of growth that did occur (54%) was located in the Regional Growth, Pinelands Town and Pinelands Village Smart Growth Zones.

The Level III residential breakdown of that growth (Table 5.3) demonstrates that the residential growth trended toward a less land-consumptive pattern compared to the overall state-wide residential pattern. Within the Pinelands Area during T0-T5(1986-2015) the proportion of the total urban footprint dedicated to the two highest density residential categories (*LU1110* and *LU1120*) summed to 7,297 acres or 31.3% of the total residential acres developed and the balance of 68.7 % of residential acres went to the lower density housing types (*LU1130* and *LU1140*). In the rest of the state outside the Pinelands the two higher density residential categories develop 22.6 % of total residential acres developed while 77.4% went to the two more land-consumptive low-density residential category.

Table 5.3 – Residential densities in the Pinelands versus non-Pinelands regions.

		Pinelands		Non-Pinelands		Pinelands		Non-Pinelands	
		T0-T15(1986-2015)		**T0-T5(1986-2015)**		**T5(2012-2015)**		**T5(2012-2015)**	
LU Code	**LABEL**	**Acres Growth**	**% res total**	**Acres Growth**	**% res total**	**Acres Growth**	**% res total**	**Acres Growth**	**% res total**
1110	RES, HIGH DENSITY	1,378.6	5.9%	23,907.4	10.9%	36.6	6.9%	1,251.5	21.4%
1120	RES, SIN UNIT, MED DENS	5,918.4	25.4%	25,945.0	11.8%	217.8	41.3%	1,515.0	25.9%
1130	RES, SIN UNIT, LOW DENS	4,211.5	18.0%	50,032.8	22.7%	94.1	17.8%	913.1	15.6%
1140	RES, RUR, SIN UNIT	11,827.4	50.7%	120,451.8	54.7%	179	33.9%	2,178.1	37.2%
	Total Residential	**23,335.9**	100.0%	**220,337.0**	100.0%	**527.5**		**5,857.7**	

Factors other than regulatory control including geographical location and context also play a role in the diminished propensity for development within the CMP. The Pinelands lies off to the southeast flank of the I-95 growth corridor that runs diagonal through the state from the Philly metro through the Trenton metro to the NYC metro. Its relative remoteness and fact that farming largely skipped over its sandy soils leaving the Pinelands sparsely settled likely also contributed to lower development pressures. Nevertheless, New Jersey's small size and the fact that the Pinelands is within an hour's drive to the urban centers of New York, Philadelphia and Atlantic City puts the entire Pinelands region well within acceptable commuting distance for a significant population. Evidence of the pressure can be seen in the many tracts of development growth that can be identified encircling the entire perimeter of the Pinelands (Figure 5.5) with the exception of the extreme southern portion, whereas inside the Pinelands the three decades of development occurs largely clustered in the designated growth zones. The ring of development outside of the Pinelands boundary is a compelling indication that the Pinelands Comprehensive Management Plan has substantially slowed development growth relative to the rest of the state and has had a discernable effect on alternate sides of the regulatory line.

Further exploration of the land use data provides evidence that in addition to slowing growth, the CMP also had an effect on the type and location of development. Table 5.4 displays the development rates for each planning area and the proportion of development for both T0-T5(1986-2015) and T5(2012-2015). Looking at the acreage of new urban development within each of the nine management areas over the three decades since plan implementation, a substantially higher proportion of development occurred in the designated growth areas, which include the *Regional Growth (38%)*, *Rural Development (22%)*, *Towns(8%)*, and *Villages(8%)* as compared to the more protected *Preservation(3%)*, *Special Agricultural(5%)* and *Forest* (10%) areas, which receive far less development but are much larger in acreage than the growth zones. It's important to note that the amount of available land for each management area is significantly different between zones and that the amount of land available for development in each management area is substantially less than total area of land due to large tracts of open space preservation and the regulations of wetlands.

Equally important as to where the development is occurring is the type of development. Low-density residential housing consumes more land per capita than high-density growth. Higher density development requires infrastructure such as sewer and water which is typically available in the growth zones. The Level III land use codes in the data help distinguish the types of development in the various planning zones. In the *Forest* and *Agricultural Projection* area nearly 2/3's of all development went to *LU-1140 Residential, Rural, Single Unit* indicating that *t*he majority of residential development in the zones intended for conservation are consistent with the permitted housing densities for the area at one half to one acre lots or greater. For example, a low-density of one housing unit per ten up to forty acres is provided for in the Agricultural Production areas which is borne out by the observed land use pattern. The conservation zones also had a much lower propensity for *LU-1200 Commercial* as well as *LU-1300 Industrial* when compared to the growth zones.

Conversely, when looking at the zones intended to receive growth, the types of development that occurred were substantially higher density. This means that a higher population will be housed for each acre developed, a more efficient use of land in growth areas. The *Regional Growth* planning area received the most urban development overall of all the Pinelands planning areas (13,619 acres or 38% of all Pinelands development). This zone also had the highest proportion of high density residential growth with 44% of the acres developed in the zone going to *LU-1110 Residential, High Density* and *LU-1120 Residential, Single Unit, Medium Density* residential categories. The Regional Growth zone also had the majority of *LU 1200 Commercial* development (1,280 acres) as well as *LU-1300 Industrial* (274 acres) urbanized. The *Regional Growth* zone which occupies 8% of the territory of the pinelands absorbed 38% of the growth in development.

The *Rural Development* zone absorbed the second highest amount of growth (7,717 acres or 22%). This zone had a larger proportion of acres (77%) dedicated to residential and proportionately less land that went into other developed land uses such as *LU-1200 Commercial* and *LU-1300 Industrial* compared to the *Regional Growth* zone. Pinelands *Town* and Pinelands *Village* planning zones each saw about 8% of the total land development that occurred in the pinelands. These zones each occupy less than 3% of the Pinelands total territory and they have much of their territory already occupied by previously existing development leaving less land available for growth. Therefore the growth these zones did absorb indicates that a significant amount of development in the Pinelands went to infill growth within these existing settlements.

Like the state as a whole, the Pinelands saw a slowdown in the magnitude of growth per year during the most recent three year land use data T5(2012-2015) (Table 5.5). But the development type and location continued the thirty year trend of the Pinelands development type toward compact smart growth. The data demonstrate that development was more compact and largely occurring in the zones designated for growth as well as infill in the existing towns and villages located within its boundaries. Although some development has occurred in the more sensitive forest and core conservation zones, the development has been measured and mostly low-density residential in nature. The conservation zones have largely retained their rural character and maintained a significant portion of their agricultural and forested lands.

In summary, the land use change and development growth in the Pinelands over the three decades since its implementation leads to a number of findings.

- Development growth in the Pinelands occurred at half the rate of the rest of the state relative to the proportion of the land area that the Pinelands occupies within the state.
- The development that did occur was more compact and less land consumptive than the state as a whole.
- The majority of development occurred in areas designated as growth zones which generally have the infrastructure to accommodate growth.
- The slower development rate in the conservation zones has maintained the majority of rural lands over the decades and thus given more time for conservation actions to occur.

The land use change data provides compelling evidence that the Pinelands Comprehensive Management Plan has been generally efficacious in guiding development in a manner consistent with its mission to "promote orderly development of the Pinelands so as to preserve and protect the significant and unique natural, ecological, agricultural, archaeological, historical, scenic, cultural and recreational resources." The region has retained a significant measure of its unique pine forest landscape, and channeled much of its development into designated growth locations. Although the New Jersey Pinelands still is vulnerable to land use changes that may occur in the future, the Pinelands CMP regional land use coordination and Transfer of Development Rights (TDR) has been largely successful in maintaining the ecological integrity while also sustaining the regional economy (Montgomery, 2011). When the region of northern New Jersey known as the Highlands began considering regional coordination in an effort to protect the water supply of the state's more populous norther region, the Pinelands CMP offered much in which to inform the establishment of the Highlands Regional Master Plan.

Table 5.4 Urban growth T0-T5(1986-2015) Tabulated by the Pinelands Comprehensive Management Planning zones in the Pinelands Area.

		Preservation		Forest		Agricultural Production		Rural Development		Regional Growth		Town		Federal		Village		Special Agr Production	
	Size of Planning Zone	294,354		256,831		68,504		109,348		77,228		21,847		47,529		25,886		37,594	
	% of Pinelands Area	31.3%		27.3%		7.3%		11.6%		8.2%		2.3%		5.1%		2.8%		4.0%	
LU code	**LABEL**	**acres devel**	**% total**	**acres devel**	**% total**	**acres devel**	**% total**	**acres devel**	**% total**	**acres devel**	**% total**	**acres devel**	**% total**	**acres devel**	**% total**	**acres devel**	**% total**	**acres devel**	**% total**
1110	RES, HIGH DENSITY	2.3	0.2%	81.9	2.3%	0.6	0.0%	425.0	5.5%	682.0	5.0%	185.4	6.5%	-		1.4	0.1%	-	
1120	RES, SIN UNIT, MED DENSI	12.4	1.1%	53.0	1.5%	3.1	0.2%	186.2	2.4%	5,262.7	38.6%	311.7	11.0%	0.1	0.0%	90.1	3.3%	0.2	0.2%
1130	RES, SIN UNIT, LOW DENS	47.4	4.1%	210.8	5.8%	105.6	5.7%	1,089.6	14.1%	1,895.1	13.9%	478.0	16.8%	0.2	0.0%	397.0	14.7%	2.7	2.6%
1140	RES, RUR, SIN UNIT	309.7	26.5%	2337.4	64.8%	1202.2	65.3%	4,265.5	55.3%	1,509.7	11.1%	572.3	20.1%	11.1	0.6%	1,577.9	58.6%	61.9	59.5%
1200	COMMERCIAL/SERVICES	59.3	5.1%	68.4	1.9%	47.4	2.6%	174.0	2.3%	1,279.8	9.4%	300.8	10.6%	0.6	0.0%	100.2	3.7%	2.7	2.6%
1211	MILITARY INSTALLATION	39.4	3.4%	0.0	0.0%	-	-	-		-		-		1,191.2	60.9%	-		-	
1300	INDUSTRIAL	14.0	1.2%	65.9	1.8%	90.2	4.9%	210.1	2.7%	274.2	2.0%	112.4	4.0%	-		82.4	3.1%	-	
1400	TRANS/COMM/UTIL	45.5	3.9%	55.8	1.5%	38.0	2.1%	76.6	1.0%	203.1	1.5%	61.8	2.2%	90.8	4.6%	25.4	0.9%	9.8	9.4%
1410	MAJOR ROADWAY	146.3	12.5%	120.6	3.3%	0.1	0.0%	45.7	0.6%	128.0	0.9%	0.3	0.0%	0.2	0.0%	27.1	1.0%	-	
1420	RAILROADS	14.4	1.2%	17.4	0.5%	0.2	0.0%	2.1	0.0%	-		9.6	0.3%	-		0.3	0.0%	-	
1440	AIRPORT FACILITIES	22.1	1.9%	15.7	0.4%	1.7	0.1%	6.1	0.1%	12.4	0.1%	3.0	0.1%	18.9	1.0%	-		-	
1462	UPLAND RIGHTS-OF	1.5	0.1%	1.2	0.0%	0		0.1	0.0%	0.4	0.0%	2.9	0.1%	-		-		-	
1463	UPLAND RIGHTS-OF-W	96.4	8.2%	78.6	2.2%	6.9	0.4%	56.4	0.7%	91.7	0.7%	8.7	0.3%	32.4	1.7%	7.1	0.3%	0.6	0.6%
1499	STORMWATER BASIN	9.2	0.8%	39.3	1.1%	15.3	0.8%	116.0	1.5%	650.9	4.8%	96.0	3.4%	48.0	2.5%	36.9	1.4%	-	
1500	INDUST/COMMER COMPLX	0.2	0.0%	0.0	0.0%	0.0	0.0%	3.3	0.0%	-		-		-		-		-	
1700	OTHER URBAN OR BLT	265.6	22.7%	351.2	9.7%	239.1	13.0%	389.6	5.0%	861.1	6.3%	420.6	14.8%	556.9	28.5%	183.5	6.8%	25.5	24.5%
1710	CEMETERY	2.4	0.2%	6.1	0.2%	1.2	0.1%	27.9	0.4%	10.2	0.1%	8.1	0.3%	-		1.9	0.1%	-	
1800	RECREATIONAL LAND	80.2	6.9%	103.9	2.9%	81.2	4.4%	601.7	7.8%	675.6	5.0%	175.1	6.2%	6.2	0.3%	143.0	5.3%	0.7	0.7%
1804	ATHLETIC FIELDS	0.0		0.1	0.0%	7.1	0.4%	40.6	0.5%	73.7	0.5%	96.9	3.4%	0.4	0.0%	17.8	0.7%	-	
1810	STADIUM, THEATRS, CULT	0.5	0.0%							8.8	0.1%								
	Total Acres Develop:	**1,168.8**		**3,607.3**		**1,839.9**		**7,716.5**		**13,619.4**		**2,843.8**		**1,957.1**		**2,691.9**		**104.1**	
	% Overall Acres Developed	**3.3%**		**10.1%**		**5.2%**		**21.7%**		**38.3%**		**8.0%**		**5.5%**		**7.6%**		**0.3%**	

Table 5.5 Urban growth T5(2012-2015) tabulated by the Pinelands Comprehensive Management Planning zones in the Pinelands Area.

		Preservation		**Forest**		**Agricultural Production**		**Rural Development**		**Regional Growth**		**Town**		**Federal**		**Village**		**Special Agr Production**	
	Size of Planning Zone	294,354		256,831		68,504		109,348		77,228		21,847		47,529		25,886		37,594	
	% of Pinelands Area	31.3%		27.3%		7.3%		11.6%		8.2%		2.3%		5.1%		2.8%		4.0%	
LU code	**LABEL**	**acres devel**	**% total**	**acres devel**	**% total**	**acres devel**	**% total**	**acres devel**	**% total**	**acres devel**	**% total**	**acres devel**	**% total**	**acres devel**	**% total**	**acres devel**	**% total**	**acres devel**	**% total**
1110	RES, HIGH DENSITY			7.6	13.4%					19.4	65.7%	9.6	8.3%						
1120	RES, SIN UNIT, MED DENSI			0.9	1.6%			0.1	0.1%	206.6	699.9%	10.1	8.8%			0.2	0.2%		
1130	RES, SIN UNIT, LOW DENS			1.0	1.8%	0.2	0.7%	33.5	22.6%	25.3	85.8%	10.3	8.9%			23.7	30.3 %		
1140	RES, RUR, SIN UNIT	7.9	14.6%	31.8	55.8%	20.7	69.1%	52.6	35.5%	23.5	79.6%	11.3	9.8%			30.9	39.6 %	0.7	100 %
1200	COMMERCIAL/SERVICES			5.9	10.4%	0.5	1.7%	0.1	0.1%	17.3	58.7%	14.6	12.7%			2.7	3.5%		
1211	MILITARY INSTALLATION													80.4	56.5%				
1300	INDUSTRIAL			0.6	1.1%			7.3	4.9%	5.6	19.0%	0.1	0.1%			0.2	0.3%		
1400	TRANS/COMM/UTIL			0.5	0.9%			2.0	1.3%	2.7	9.1%	0.3	0.2%	7.3	5.1%				
1410	MAJOR ROADWAY	6.1	11.2%	2.4	4.2%			11.6	7.8%	1.0	3.5%					10.9	13.9 %		
1420	RAILROADS																		
1440	AIRPORT FACILITIES	2.7	5.0%											5.5	3.9%				
1462	UPLAND RIGHTS-OF																		
1463	UPLAND RIGHTS-OF-W	2.9	5.4%	1.3	2.3%			11.5	7.8%	8.9	30.3%								
1499	STORMWATER BASIN			1.1	2.0%			11.7	7.9%	25.7	87.0%	10.5	9.1%	10.2	7.2%	1.3	1.6%		
1500	INDUST/COMMER COMPLX																		
1700	OTHER URBAN OR BLT	31.5	58.0%	2.5	4.3%	5.4	18.0%	3.3	2.2%	29.5	100.0%	25.4	22.0%	39.1	27.4%	7.8	10.0 %		
1710	CEMETERY									0.7	2.5%								
1800	RECREATIONAL LAND	3.2	5.9%	1.3	2.2%	3.1	10.5%	14.5	9.8%	18.3	62.1%	21.7	18.8%			0.5	0.6%		
1804	ATHLETIC FIELDS											1.4	1.2%						
1810	STADIUM, THEATRS, CULT																		
	Total Acres Develop:	**54.4**		**57.0**		**30.0**		**148.2**		**384.7**		**115.2**		**142.5**		**78.2**		**0.7**	
	% of total Acres Developed	**5.4%**		**5.6%**		**3.0%**		**14.7 %**		**38.1 %**		**11.4 %**		**14.1 %**		**7.7%**		**0.1%**	

New Jersey Highlands Water Protection and Planning Act

The New Jersey Highlands Water Protection and Planning Act implemented in 2004 is the most recent of NJ's regional planning systems. The Plan's main objective is to protect water quality and ecological integrity within the Highlands physiographic region of the state because it is the source for the drinking water for over 5 million people (Highlands 2020). The plan (Figure 5.6) delineates two main activity areas, a *preservation area* intended to conserve the most critical land resource where the regulatory structure is mandatory to municipal and county governments and a *planning area* where municipalities largely maintain planning authority to implement the goals of the Act. There are also seven *Land Use Capability Zones* overlays that provide all levels of government guidance on the capacity of lands for development as well as where special consideration is required to protect regionally significant resources in both the planning and preservation areas.

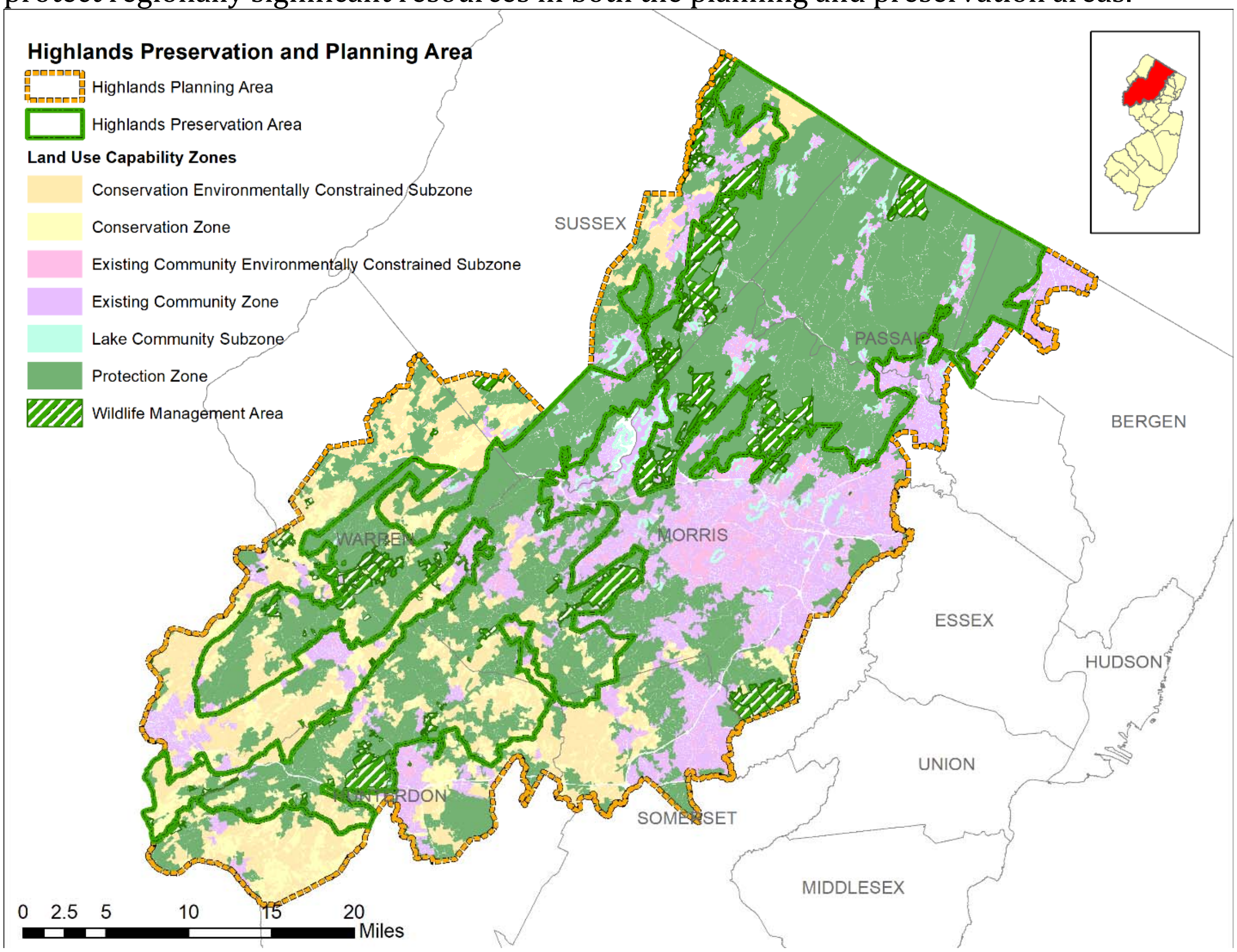


Figure 5.6 The Highlands Water Protection and Planning Act delineates a protection area "core" and a planning area "periphery" to coordinate land development and conservation. There are seven Land Use Compatibility Zone overlays each with specific objectives for the particular resource of the zone.

The Highlands Regional Master Plan (RMP) guides implementation of the Highlands Water Protection and Planning Act of 2004 and was officially adopted by the Highlands Council in

2008 (Swan, 2011). While the plan has only been in place for just over a decade, an examination of the development patterns that have occurred in the region pre and post plan implementation can provide insight into the efficacy that the Highlands RMP is having for managing development growth.

Previous to the RMP implantation there were three iterations of the NJ land use/land cover dataset T1(1986-1995), T2(1995-2002) and T3(2002-2007). This 21 year period provides a baseline growth rate that had occurred in the region when it was experiencing rapid growth in the absence of the Highlands RMP. From 1986 to 2007 the area saw 58,957 acres of development growth for an average of 2,8078 acres of growth per year. The rate dropped significantly in the time periods after plan implantation falling to 883 acres per year during T4 (2007-2012) and further dropping to 592 acres of growth per year during T5(2012-2015), the most recent data time period available (Figure 5.7). It is difficult to determine to what degree the drop in development rate can be attributed directly to the effect of the RMP or is a reflection in the statewide economic slowdown. The initial drop most likely mirrors similar dropping rates of development that occurred throughout the state that were essentially tied to the economic downturn of the great recession of 2008. However, the further drop in the annual rate of development in T5(2012-2015) runs counterintuitive to the recovering economy that began in 2011 and during a time of increasing numbers of building certificates of occupancy (CO's) discussed earlier in this report. In particular, Morris County, the urban core of the Highlands region, saw a spike in post-2011 CO's during a time when acres of new land development was slowing. The explanation for the increasing number of housing units at a time of decreasing acres of land development must logically be tied to a combination of a more compact, less land-consumptive development pattern as well as redevelopment of lands that had been previously developed, two goals of the Highlands Regional Master Plan.

Examining the level III details of the land use change data in the Highlands (Table 5.6) provides more insight to the shifting development trends as they relate to the Highlands Regional planning map. During the 1986-2002 period (pre-Highlands RMP) the two lowest-density residential categories (*LU1130* and *LU 1140*) combined to consume nearly 60% of the total land developed throughout the Highlands. This represents large-lot housing that is the most land consumptive of the residential development categories. Approximately 25% of the total development consisted of low-density housing in what would become the Preservation Area of the Highlands Plan. Post 2007, not only did the overall number of new acres developed drop precipitously, the proportion of those acres that went to the two lowest density types of residential housing (*LU-1130* and *LU-1140)* dropped to approximately 40% of the development footprint whereas the higher density categories of residential development (*LU-1110* and *LU-1120*) increased their proportion of the total development footprint during T5 (2012-2015) to 7.8% of the total development. Considering that substantially more housing units can be accommodated in the high-density category than in the low density categories, this trend signifies a substantial shift away from larger-lot, land consumptive sprawl toward more compact, lower-impact development growth. Commercial (*LU 1200*) and Industrial (*LU 1300*) land categories of development stayed relatively consistent in their proportion of the development footprint although the magnitude of Commercial/Industrial slowed in step with the overall slowdown in development post 2007.

Other level III land use categories that had significant change in their proportion of the urban growth footprint from pre-2007 to post 2007 included a marked increase the land use category of Transportation/Communication/Utilities (*LU 1400*) which had consistently been below 2% but grew to 10% of the T5 (2012-2015) footprint. A significant majority of this increase was attributable to the growth in large solar arrays. Upland Rights of Way – Undeveloped (*LU 1463*) also saw a significant portion of the T5 (2012-2015) development footprint. The majority of this category was due to the expansion of pipeline easements including the Tennessee Pipeline that transects the northern portion of the Preservation Area.

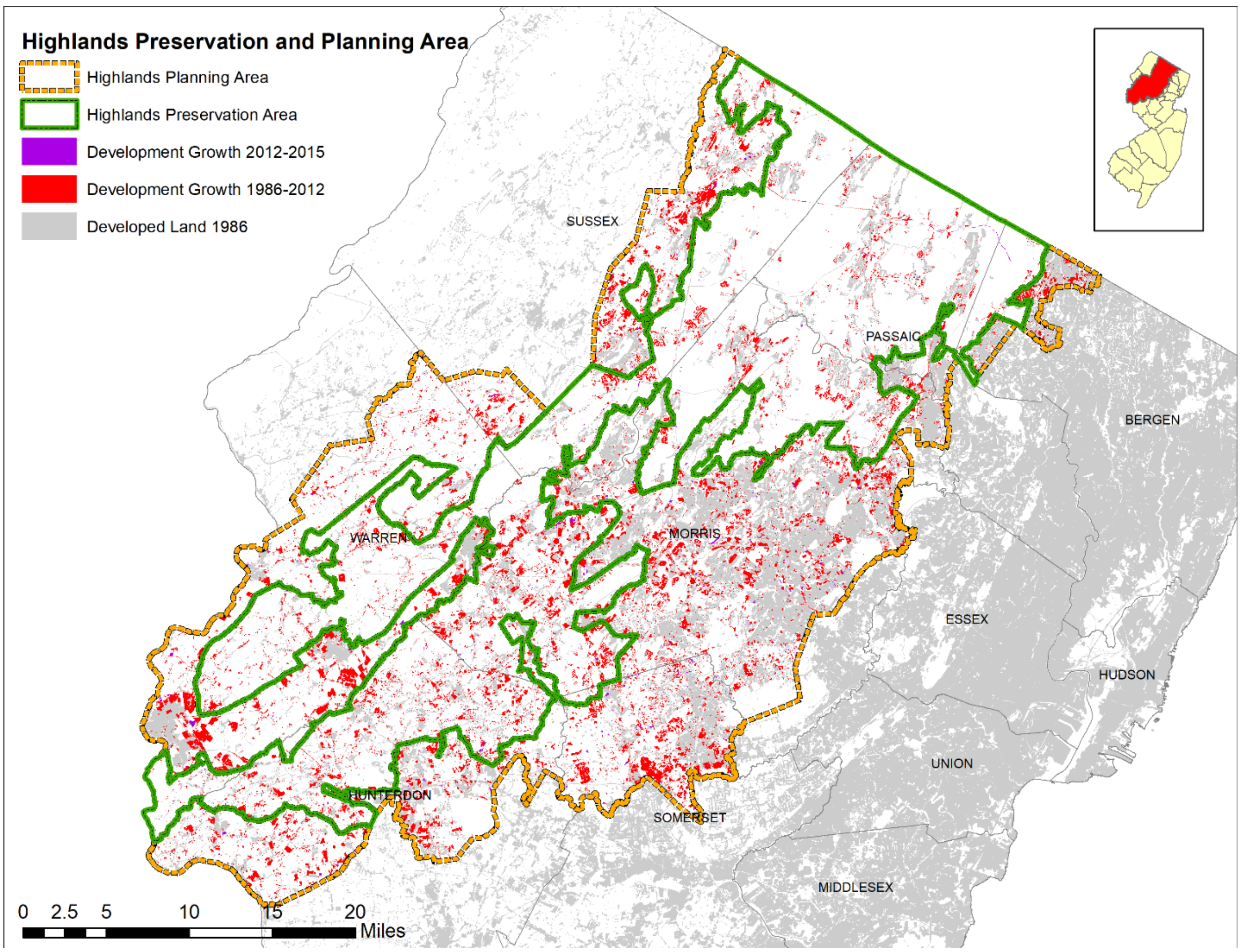


Figure 5.7 Urban development in the Highland consumed 65,148 acres from 1986 to 2015. The rate of development significantly dropped after 2007 although the degree to which the change can be attributed to the Highlands Regional Master Plan versus the economic downturn of the great recession of 2008 is difficult to distinguish.

Another indication of the efficacy of the Highlands RMP is the shift in proportion of development that occurred in the Planning versus Preservation zones. Figure 5.8 depicts the acres of development growth per year across the five time periods of the study. The data make evident the dramatic drop in total acres developed annually from 2,754 acres per year during T1(1986-1995) to 592 acres per year in T5(2012-2015). The data also demonstrates a shift in the ratio of land development from the *Preservation Area* to the *Planning Area*. During T1 for every acre developed in the planning area there was 0.5 acres developed in the preservation areas. By T5 not only did the magnitude of acres developed drop but the ratio between zones of annual acres developed dropped to 0.37 acres of land developed in the *Preservation Area* for every acre developed in the *Planning Area* suggesting that the RMP may have begun to influence the regional growth patterns in a manner consistent with the plan's mission.

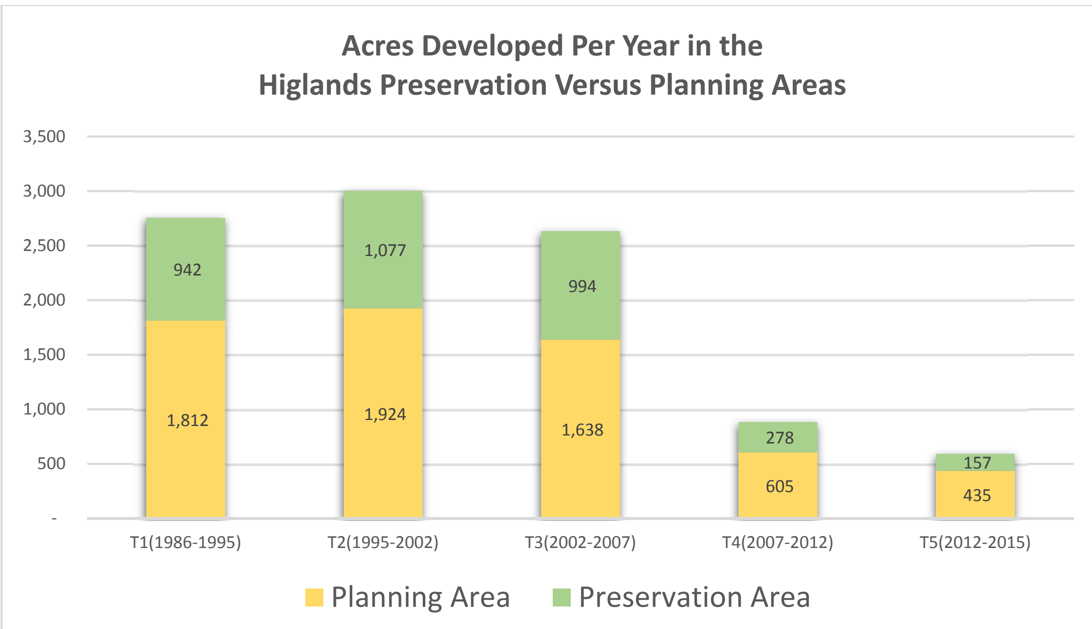


Figure 5.8 Acres Developed Per Year in the New Jersey Highlands Planning and Preservation Areas. The Highlands Regional Master Plan was enacted in 2008. Not only was there a drop in the magnitude of acres developed but a shift in proportion of acres develop from the Preservation Area to the Planning Area.

In sum, the land use data of the three-decade study period indicates that development patterns in the Highlands have shifted significantly since the implementation of the Highlands Regional Management Plan. The amount of acres developed (and thus land resources lost) has been substantially reduced from the pre-2007 era of rapid growth. A greater proportion of development that did occur was in the planning zones with an increasing portion of residential land occurring in a compact form while large-lot sprawling residential housing experiencing an observable downturn. While it is difficult to tease out the degree to which many of these changes reflect economic drivers of development that slowed due to the great recession versus the direct effect of the Highlands Regional Management Plan, the data suggests that the RMP is at least playing a role in shaping the way development occurs compared to pre-RMP growth.

Table 5.6 – Urban growth in the Highlands Regional Master Planning Area 1986-2015.

LU Code	LU Label	Zone	T1(1986-1995) Acres Growth	% Total	T2(1995-2002) Acres Growth	% Total	T3(2002-2007) Acres Growth	% Total	T4(2007-2012) Acres Growth	% Total	T5(2012-2015) Acres Growth	% Total
1110	RESIDENTIAL, HIGH DENSITY OR MULTIPLE DWELLING	Planning Area	1,428.8	5.8%	860.8	4.1%	432.5	3.3%	128.9	2.9%	120.0	6.8%
1110	RESIDENTIAL, HIGH DENSITY OR MULTIPLE DWELLING	Preservation Area	119.6	0.5%	74.5	0.4%	111.6	0.8%	24.3	0.6%	18.3	1.0%
1120	RESIDENTIAL, SINGLE UNIT, MEDIUM DENSITY	Planning Area	1,012.2	4.1%	1,021.5	4.9%	410.5	3.1%	109.9	2.5%	41.3	2.3%
1120	RESIDENTIAL, SINGLE UNIT, MEDIUM DENSITY	Preservation Area	265.0	1.1%	460.5	2.2%	260.1	2.0%	32.1	0.7%	27.9	1.6%
1130	RESIDENTIAL, SINGLE UNIT, LOW DENSITY	Planning Area	2,785.4	11.2%	1,758.9	8.4%	677.8	5.1%	188.1	4.3%	104.5	5.9%
1130	RESIDENTIAL, SINGLE UNIT, LOW DENSITY	Preservation Area	1,281.1	5.2%	1,149.1	5.5%	544.9	4.1%	109.6	2.5%	43.3	2.4%
1140	RESIDENTIAL, RURAL, SINGLE UNIT	Planning Area	6,084.8	24.5%	4,985.6	23.7%	2,850.0	21.7%	905.4	20.5%	334.6	18.8%
1140	RESIDENTIAL, RURAL, SINGLE UNIT	Preservation Area	4,757.3	19.2%	4,225.2	20.1%	2,437.3	18.5%	555.5	12.6%	180.0	10.1%
1150	MIXED RESIDENTIAL	Planning Area			2.5	0.012%	0.2	0.002%				
1200	COMMERCIAL/SERVICES	Planning Area	955.2	3.9%	804.5	3.8%	604.7	4.6%	282.8	6.4%	87.2	4.9%
1200	COMMERCIAL/SERVICES	Preservation Area	269.8	1.1%	185.8	0.9%	133.5	1.0%	30.0	0.7%	21.2	1.2%
1211	MILITARY INSTALLATIONS	Planning Area	2.7	0.0%	19.0	0.1%	14.0	0.1%	20.0	0.5%	1.3	0.1%
1300	INDUSTRIAL	Planning Area	488.4	2.0%	284.1	1.4%	239.3	1.8%	101.4	2.3%	27.4	1.5%
1300	INDUSTRIAL	Preservation Area	129.1	0.5%	100.8	0.5%	53.9	0.4%	37.1	0.8%	4.3	0.2%
1400	TRANSPORTATION/COMMUNICATION/UTILITIES	Planning Area	265.0	1.1%	65.6	0.3%	79.9	0.6%	91.9	2.1%	178.5	10.1%
1400	TRANSPORTATION/COMMUNICATION/UTILITIES	Preservation Area	345.0	1.4%	28.9	0.1%	17.2	0.1%	38.7	0.9%	6.4	0.4%
1410	MAJOR ROADWAY	Planning Area			2.0	0.0%	0.4	0.0%	1.5	0.0%	0.3	0.0%
1410	MAJOR ROADWAY	Preservation Area					0.2	0.0%		0.0%		
1420	RAILROADS	Planning Area					13.7	0.1%	10.9	0.2%		
1420	RAILROADS	Preservation Area							10.7	0.2%		
1440	AIRPORT FACILITIES	Planning Area			2.3	0.0%	16.5	0.1%	3.6	0.1%		
1440	AIRPORT FACILITIES	Preservation Area			0.6	0.0%	0.2	0.0%		0.0%		
1462	UPLAND RIGHTS-OF-WAY DEVELOPED	Planning Area			27.3	0.1%	16.7	0.1%	6.8	0.2%	2.5	0.1%
1462	UPLAND RIGHTS-OF-WAY DEVELOPED	Preservation Area			6.1	0.0%	8.9	0.1%				
1463	UPLAND RIGHTS-OF-WAY UNDEVELOPED	Planning Area			29.2	0.1%	35.2	0.3%	24.6	0.6%	9.0	0.5%
1463	UPLAND RIGHTS-OF-WAY UNDEVELOPED	Preservation Area			20.4	0.1%	31.3	0.2%	116.1	2.6%	111.5	6.3%
1499	STORMWATER BASIN	Planning Area			333.8	1.6%	208.2	1.6%	67.4	1.5%	31.8	1.8%
1499	STORMWATER BASIN	Preservation Area			163.8	0.8%	89.5	0.7%	15.0	0.3%	1.2	0.1%
1500	INDUSTRIAL AND COMMERCIAL COMPLEXES	Planning Area	17.5	0.1%	0.1	0.0%	2.1	0.0%	0.1	0.0%		
1500	INDUSTRIAL AND COMMERCIAL COMPLEXES	Preservation Area					0.2	0.0%	0.8	0.0%		
1600	MIXED URBAN OR BUILT-UP LAND	Planning Area			0.2	0.0%			0.1	0.0%		
1600	MIXED URBAN OR BUILT-UP LAND	Preservation Area							0.1	0.0%		
1700	OTHER URBAN OR BUILT-UP LAND	Planning Area	2,607.7	10.5%	1,544.8	7.4%	1,809.5	13.7%	678.7	15.4%	289.2	16.3%
1700	OTHER URBAN OR BUILT-UP LAND	Preservation Area	1,066.8	4.3%	741.0	3.5%	924.3	7.0%	248.1	5.6%	48.6	2.7%
1710	CEMETERY	Planning Area			12.1	0.1%	4.9	0.0%	25.4	0.6%		
1710	CEMETERY	Preservation Area			23.9	0.1%	1.8	0.0%	0.5	0.0%		
1800	RECREATIONAL LAND	Planning Area	575.0	2.3%	1,669.6	7.9%	709.1	5.4%	341.6	7.7%	73.5	4.1%
1800	RECREATIONAL LAND	Preservation Area	221.1	0.9%	327.3	1.6%	336.6	2.6%	162.4	3.7%	7.2	0.4%
1804	ATHLETIC FIELDS (SCHOOLS)	Planning Area	87.4	0.4%	40.9	0.2%	64.8	0.5%	35.9	0.8%	4.1	0.2%
1804	ATHLETIC FIELDS (SCHOOLS)	Preservation Area	22.4	0.1%	34.7	0.2%	19.8	0.2%	8.2	0.2%		
1810	STADIUM, THEATERS, CULTURAL CENTERS AND ZOOS	Planning Area					0.3	0.0%	1.2	0.0%		
1810	STADIUM, THEATERS, CULTURAL CENTERS AND ZOOS	Preservation Area					0.9	0.0%	0.4	0.0%		
	Sum	Planning Area	16,310.1	65.8%	13,464.9	64.1%	8,190.6	62.2%	3,026.0	68.5%	1,305.1	73.5%
	Sum	Preservation Area	8,477.1	34.2%	7,542.3	35.9%	4,972.3	37.8%	1,389.6	31.5%	469.8	26.5%
	Total Acres		**24,787.1**		**21,007.3**		**13,162.9**		**4,415.6**		**1,775.0**	
	Sum Acres Per Year	Planning Area	1,812.2		1,923.6		1,638.1		605.2		435.0	
	Sum Acres Per Year	Preservation Area	941.9		1,077.5		994.5		277.9		156.6	
	Total Acres Per Year		**2,754.1**		**3,001.0**		**2,632.6**		**883.1**		**591.7**	

New Jersey's Regional Planning Systems, a 2020 perspective

New Jersey's experiment with regional planning has set in motion three different approaches for coordinating regional-scale goals within a tenaciously held home-rule state. Analyzing the land use/land cover data of the past three decades that the three regional planning initiatives have come into existence provides a window into how successful the planning systems have been and where they may have come up short of their goals.

The **Pinelands Comprehensive Management Plan** was the first and is the most robust of the three regional coordination planning systems. The formation of the Pinelands CMP benefitted from a fortuitous convergence of elements that came together within a unique moment in time. The Pinelands initiative followed on the heels of the strong national environmental movements of the early 1970's that included the establishment of the EPA, the *Clean Water*, *Clean Air*, and *Endangered Species Acts*. The ecological significance of the unique pine forest environment was popularized by book author John McPhee's, *Pine Barrens* and stakeholders were galvanized by threats for major developments slated for the Pinelands including an international jetport and planned city of 250,000 people. The region had a relatively low residential population and was economically anemic compared with the rest of the state, dampening the political pushback. The plan that emerged had very clear objectives for protecting specific critical resources of the Pinelands and was overseen by a legally empowered commission. The resulting Pinelands Comprehensive Management Plan had the enforceable mechanism to enact the plan and has been guiding development in the decades since. The land use pattern that subsequently emerged saw the conversion of 22,216 acres of pineland upland forest, 8,963 acres of farmland and 442 acres of wetlands into new development. That rate of conversion is substantially slower than the rate of urbanization experienced in the remainder of the state and the rate has dropped further in the period following 2007. The data provides evidence that the CMP has been effective in mitigating the pace of acres developed throughout the entire region, slowed the loss of land resources, channeled much of the growth into the planned growth zones, led to more compact development, and fostered infill development within existing Pinelands settlements compared with the land outside of the CMP jurisdiction.

The degree to which the **NJ State Development and Redevelopment Plan** has been effective is more complex and nuanced to assess compared to the Pinelands CMP. The region of New Jersey under the jurisdiction of the State Planning area had significantly more challenging political and economic circumstances for coordinating stakeholders within the context of home rule through the voluntary process of cross examination. Its mission was broader than the Pinelands CMP focusing on the key provisions to "encourage development, redevelopment and economic growth in locations that are well situated with respect to present or anticipated public services or facilities and to discourage development where it may impair or destroy natural resources or environmental qualities," as well as to "reduce sprawl" and "promote development and redevelopment in a manner consistent with sound planning" (State Plan 2001). The land use change data documents the 264,108 acres of urban growth that occurred in the region of the state under the jurisdiction of the State Plan (removing the Pinelands Planning area, the Highlands Preservation area and the Hackensack Meadowlands). This growth came at the loss of 72,567 acres of forest, 156,804 acres of farmland loss and 49,402 acres of wetlands loss. Since 2007 the rate of urbanization in terms of annual acres developed and land resources lost slowed and the urban growth trended to be more compact than pre 2007 with greater proportions of growth occurring in the smart growth zones of PA-1 Urban, PA-2 Suburban and centers. The patterns of growth had demonstrably shifted to be less-sprawling. While it is difficult to know how much of the shift in growth pattern was attributable to the effect of the State Plan versus economic factors and shifts in demographics, we look to a pre-plan analysis that was conducted for insight.

In 1999, the NJ state legislature required an impact assessment to be conducted for the cost and benefits of implementing the next iteration of State Plan. In 2000 an impact assessment was conducted by the Rutgers Center for Urban Policy Research (Burchell 2000) projecting the cost and benefits to the year 2020. The assessment projected the outcomes that would occur if development followed "TREND" development growth of previous years or if it followed the State Plan "PLAN" until the year 2020. We have now arrived at that iconic year and with the land use analysis we can look at the physical pattern of land development with 2020 hindsight. The Rutgers impact assessment projected that TREND development would consume 355,000 acres of land by the year 2020 whereas PLAN development would consume 233,000 acres. Looking at the two decades of development from 1995-2015, New Jersey developed 234,899 acres, nearly spot on the projection under the PLAN assessment scenario. Another place to look for indicators of how the State Plan has fared in influencing land use is to revisit one of the 2001 State Plan vision statements for what NJ's built landscape would be like in the year 2020.

> [by the year 2020] "cities, towns, older metropolitan suburbs and even its older rural towns—have become vibrant places of prosperity and vitality. More and more people are now choosing to live in urban areas in order to better enjoy the many educational, cultural, economic, social, and recreational benefits derived from an urban lifestyle. We have revitalized our cities and towns in ways that not only meet immediate needs for housing, jobs, education and safety but also in ways that have made them more enjoyable and economically, environmentally and socially sustainable." (Office of Planning Advocacy 2020).

While much of the development growth that occurred over the past three decades can be arguably characterized as "sprawl" and many hundreds of thousands of acres of natural resource lands were lost in the areas covered by the State Plan, a substantial amount of development and redevelopment as indicated in the data, especially post 2007, are arguably consistent with the vision statement. Cities such as Jersey City, New Brunswick and Glassboro have been redeveloped and revitalized at significantly higher densities taking pressure off growth in rural fringe areas. A strong case can be made from the data that NJ's 2020 landscape would have been significantly more sprawling if the State Plan had not been in existence to help guide development with a regional perspective.

The **Highlands Regional Management Plan** is New Jersey's most recent regional planning initiative. It was able to incorporate lessons learned from both the Pinelands and State Plan. It has several elements that are handled in a similar vein to the Pinelands Comprehensive Management Plan in the Preservation area. It also maintains the State Plan in the planning areas of the region. However, the Highlands RMP is unique in a number of critical aspects. The Highlands population of 820,000 is nearly three times the population of the Pinelands. The Highlands is also a much wealthier region with some of the highest income census tracts in the state. The mandate for the Highlands is also organized around the very clearly defined goal of protecting the water supply for over half of New Jersey's residents, the majority of them living outside the Highlands region. To be effective, the Highlands Regional Management Plan had to effectively navigate the economic, political and environmental context of the stakeholders to the region.

Over the course of the three decades study (1986-2015) the Highlands Saw 63,372 acres of urban growth. However, 90% of that growth occurred before the 2008 RMP was in place. Of the 4,555 acres of growth that occurred in the Highlands after 2007, 78% was in the Highlands Planning Area and only 22% was in the Highlands Preservation Area compared with pre 2007 growth in which 65% occurred in the Highlands Planning Area and 35% occurred in the Highlands Preservation Area. The loss of natural resource lands to urban development in the Highlands also demonstrated a dramatic shift. Agriculture saw the loss of 35,108 acres of land from 1986-2015. Of that farmland loss, 4,555 acres (13%) occurred post 2007. Of the net 26,809 acres of upland forest lost 1986-2015, only 898 acres (3%) were lost post 2007 (although it's important to note that this represents a net loss of forest which includes conversion of some agricultural lands back to forest). Wetlands saw a 1986-2015 loss of 5,565 acres of which 162 acres (3%) was post 2007. Each of these land use changes evident in the data for area of the state under the jurisdiction of the Highlands Regional Management Plan demonstrates a shift in magnitude, location and density of urban development and subsequent land resource impacts.

More in-depth analysis is required to determine the degree to which the land use change in New Jersey's regional planning areas is an outcome of the planning systems versus the economic and social factors outside of the purview of the plans. Nonetheless, the data indicates that the patterns of development that have occurred throughout the Garden State have been significantly influenced by New Jerseys regional planning systems. It should be noted that these planning systems have operated under both Democratic and Republican governors with varying commitments to environmental protection and land use planning. Though their governing boards' composition and priorities may have shifted over the years based on gubernatorial appointments, once institutionalized, the Pinelands and Highlands plans have maintained their positive impact in shaping New Jersey's landscape.

6 Land Resource Impacts

Simple metrics for analyzing and communicating information about trends and status in our environment are often referred to as environmental indicators. Building on earlier work at the New Jersey Department of Environmental Protection (NJDEP) (Kaplan and McGeorge, 2001), we have employed a series of land resource impact indicators for New Jersey to measure the "ecological footprint" of urban growth. These indicators show that while the loss of economic activity and construction jobs has been a downside of the dramatic slowdown in the rate of urban development, the upside has been a dramatic decline in the loss of open space and natural resource lands to urbanization as well as a slowing of the amount of new impervious surface.

Deforestation

The open space land category that saw the greatest change to other land use/land cover categories was *upland forest* with 11,683 acres (18.2 sq. miles) converted statewide during T5 (2012 - 2015) (Table B.1). The data needs some clarification in that the conversion of forest in some locations has been partially offset by forest gain elsewhere. Thus in T5 the net change in forest was a decrease of 9,495 acres due to a significant number of acres of agricultural, barren and urban land uses that changed back into forest during T5 (i.e., 11,683 acres lost vs. 2,188 acres gained for a net change of -9,495 acres). Overall, the annual net rate of loss of forest land showed an uptick of 3,165 acres per year in T5 from a low of 579 acres per year in T4 (Table 2.2, Figure 2.2). Digging a little deeper reveals that the gross amount of forest land converted was in actuality lower in T5(2012-2015) than in T4(2007-2012) with 3,894 acres per year in T5 vs. 4,209 acres per year converted in T4 (Lathrop, Bognar and Hasse, 2016); this discrepancy was due to the large amount of “new” forest gained in T4 (i.e., areas that were mapped as non-forest in 2007 converting to forest by 2012). For example, 1,986 acres per year were estimated to convert from Agriculture to Upland Forest in T4, while only 341 acres per year were estimated to do so during T5 (2012-2015) (Table B.2). This finding suggests that the rate of agricultural land abandonment may be slowing.

Looking across the entire 29 year study period, New Jersey lost a net of 122,541 acres (191 sq. mi) of upland forest between 1986 and 2015 representing a 7.5% loss (Figure 6.1). During the majority of New Jersey’s history, upland forest was the predominant land category. However, the total amount of urban land in New Jersey surpassed the total amount of upland forest land by 2007. The conversion of upland forest to urban land uses is especially evident in the periphery of the Pinelands and across the central Highlands (Figure 4.2). In addition to the multiple ecosystem services provided by forests in terms of wildlife habitat, source water protection, stormwater runoff reduction, evapotranspirative cooling, the role of forests in the removal of carbon from the atmosphere and longer-term storage of that carbon is increasingly recognized as vital in helping to combat climate change. Along with wetlands, forests represent a major pool of stored carbon in the above- and belowground biomass and forest soils (Figure 6.2).

Given New Jersey's reentry into the Regional Greenhouse Gas Initiative (RGGI) and other state and local programs to enhance the forest carbon sequestration of carbon (i.e., removal of carbon from the atmosphere and subsequent storage in forest trees and soil), a closer examination of the implication of forest conversion was warranted. We cross-referenced the NJLUCLC change data with spatial mapped data of forest carbon provided by the USDA Forest Service, Forest Inventory & Analysis (FIA) Program (https://www.fia.fs.fed.us) Total forest ecosystem carbon density (Mg/ha) includes above- and belowground live trees, downed dead wood, forest floor, soil organic carbon, standing dead trees, understory above- and belowground pools. The carbon density was imputed from USFS FIA forest inventory plots surveyed between 2000-2009 (for more information, Wilson et al., 2013). Using the FIA mapped data, we estimated the total amount of carbon (Mg or metric ton) affected over T5 (2012-2015) as well as the entire 1985-2015 time period. During T5 (2012-2015), approximately 162,834 Mg (metric tons) of carbon storage from above- and below-ground biomass (Table 6.1) was potentially affected (i.e., trees cut down, stumps and roots dug up and removed. Based on the US Environmental Protection Agency Greenhouse Gas Equivalencies Calculator https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator), that loss of carbon is equivalent to the greenhouse gas emissions from 67,183,301 gallons of gasoline consumed. The loss of carbon storage over the entire 1986-2015 time period is equivalent to the greenhouse gas emissions from 1,416,614,831 gallons of gasoline consumed or from 2,672,921 passenger vehicles driven for one year. What is unclear is the ultimate fate of carbon stored in forest soils, a pool of carbon that is nearly equivalent in size to the biomass pool (Table 6.1), once a site has undergone conversion to urban development. After a building site is cleared of trees, and in many cases the topsoil, where much of the organic carbon is stored, is scraped and transported elsewhere. How much of the carbon is respired back to the atmosphere during this process is unknown.

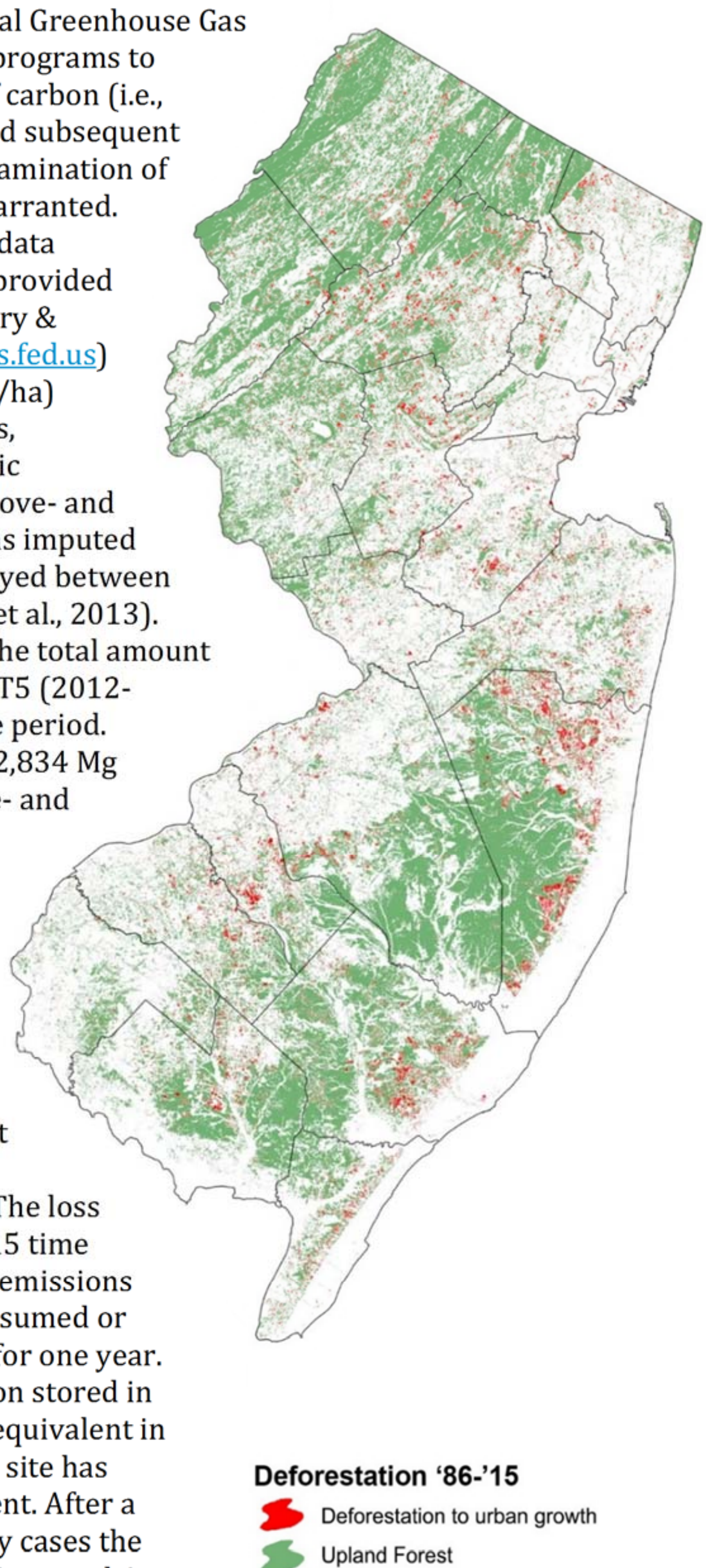


Figure 6.1 Upland Forest loss 1986-2015.

Figure 6.2 Example of forest clearing and bulldozing of forest soils.

Table 6.1 Potential loss of forest biomass from urban conversion

Time Period	Total Forest Loss (Acres)	Above Ground Carbon Storage Loss (Mg)	Below Ground Carbon Storage Loss (Mg)	Total Biomass Carbon Storage Loss (Mg)	Soil Carbon Storage Loss (Mg)	Total Carbon Storage Loss (Mg)
2012-2015	11,459	135,481	27,354	162,834	153,916	479,585
1986-2015	270,338	2,856,234	577,254	3,433,488	3,327,477	10,194,452

***Total forest includes wetland and upland forest*

Farmland Conversion

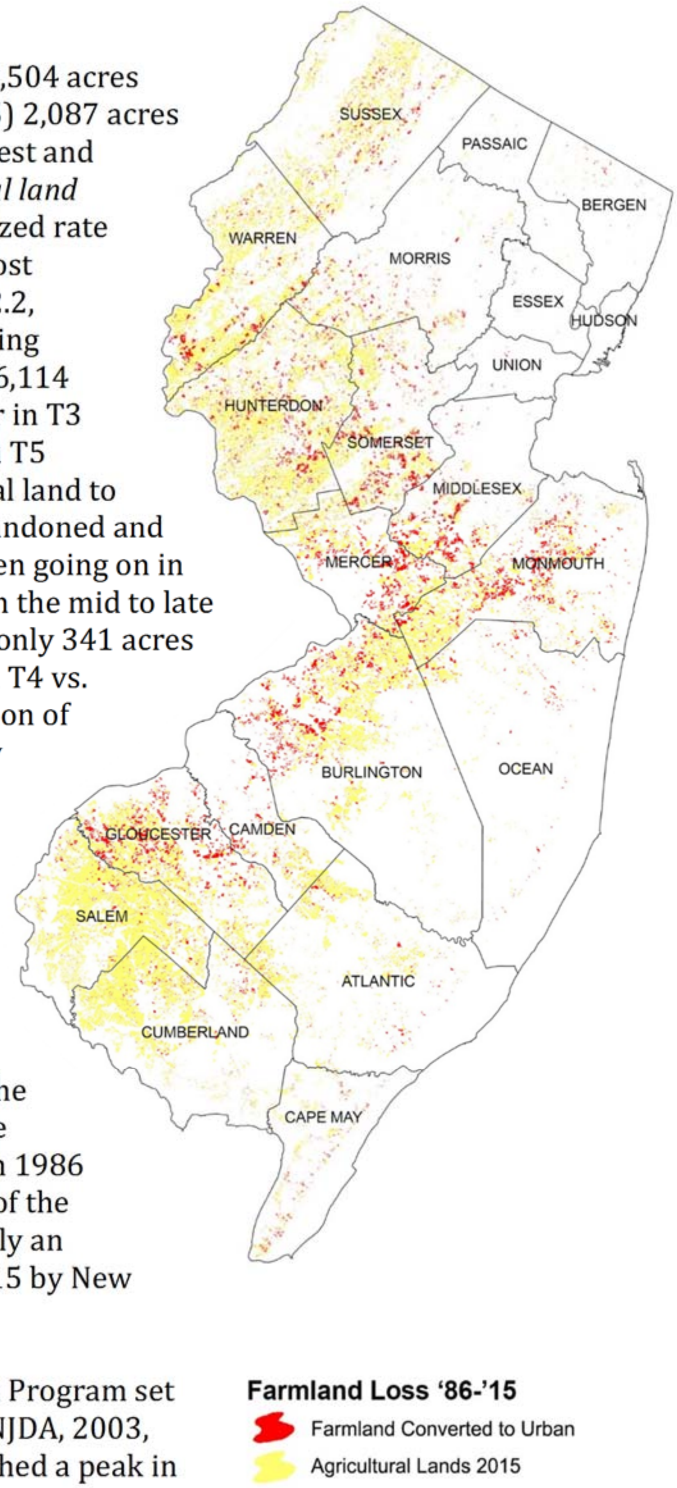


Figure 6.3 Farmland Loss to urbanization 1986 through 2012.

The area of Agriculture continues to decline with 543,504 acres mapped in 2015 (Figure 2.1). During T5 (2012 - 2015) 2,087 acres (3.3 sq. miles) of Agriculture converted to barren, forest and urban and other land uses. The net rate of *agricultural land* conversion has consistently declined from an annualized rate of 10,277 acres per year in T1 (1986- 1995) to the most recent 696 acres per year in T5 (2012-2015) (Table 2.2, Figure 2.2). This trend is closely related to the declining amount of farmland consumed by urbanization with 6,114 acres per year in T1, 5,149 in T2, 5,124 acres per year in T3 vs. 1,444 acres per year in T4 to 875 acres per year in T5 (2012-2015). In addition to conversion of agricultural land to urban land uses, agricultural land continues to be abandoned and allowed to regenerate to forest, a process that has been going on in New Jersey since the peak of agricultural expansion in the mid to late 1800's. However, this rate continues to decline with only 341 acres per year in T5 as compared to 1,986 acres per year in T4 vs. 2,435 acres per year in T3. Interestingly this conversion of agricultural land to forest was more than balanced by conversion of mapped Forest land to Agriculture at 721 acres per year. A closer look reveals the approximately two thirds of that Forest to Agriculture conversion is actually recently abandoned farmland (i.e. Old Field) that has been put back into active agriculture (Table B.3).

While the continued slowing of farmland loss is certainly a positive trend, it must be gauged against the reality of the magnitude of 200,878 acres (314 square miles) or ¼ of the states total farmland that existed in 1986 was converted to other uses over the 29 year period of the study (Figure 6.3). Over this same time period, nearly an equivalent 217,076 acres preserved statewide by 2015 by New Jersey's farmland preservation program (www.state.nj.us/agriculture/sadc/publications/). From 1995 through 2015, the Farmland Preservation Program set aside, on average, 9,444 acres of farmland per year (NJDA, 2003, 2015). However, the annual rate of preservation reached a peak in T3 at 12,438 acres per year (NJDA, 2003, 2007). During this most recent T5 ('12'-15) time period, 15,749 acres of farmland were preserved across the state; this equates to an annual rate of farmland preservation of 5,350 acres per year – less than half of its peak rate roughly ten years earlier (NJDA, 2012, 2015). Given the 543,504 acres of mapped Agricultural land (as of 2015), approximately 40% of the state's cropped/pastured farmland has been preserved (we acknowledge that this likely represents an overestimate, as farmland preservation properties may include non-cropped/pastured land such as forest or wetland).

Wetlands Change

New Jersey has a long history of wetlands protection. Coastal wetlands first received protection under the Wetlands Act of 1970, which was supplemented later with the Coastal Area Facility Review Act of 1973 (CAFRA). The New Jersey legislature passed the Freshwater Wetlands Protection Act in 1987 to "preserve the purity and integrity of freshwater wetlands from unnecessary and undesirable disturbance" (ANJEC, 2004). The overall NJDEP Level 1 annualized loss rate has demonstrated a steady decline over the past three decades with annualized rate of 3,002 acres per year in T1(1986 - 1995) to 763 acres per year in T5 (2012- 2015) (Table 2.2, Figure 2.2). However, there was an uptick in the loss of wetlands between T4 (2004-'12) and T5 (2012-'15). Examining the more detailed transition matrices (as defined by the H-L categorization, in Appendix B Table B.1 & B.2) reveals that over 50% (1434 acres) of the net change in natural wetlands (i.e., coastal, freshwater and forested wetlands) area statewide is due to the conversion of natural wetlands to *BARREN* during T5. In comparison, there was only a net change of 14% (378 acres) of natural wetlands converting to URBAN during T5. Somewhat alarming is the net change of 940 acres of different types of natural wetlands to the Disturbed Wetlands (*WETDIST*) category.

New Jersey prides itself on being a coastal state with the 'Shore' an integral part of the Jersey psyche. As elsewhere in the United States and the world, there has been an increasing concentration of population and development in New Jersey's coastal zone. One notable success story has been the near complete halting of the dredging, filling and development of coastal wetlands. Coastal wetlands – those wetlands along the tidal coastline where dominant vegetation is tolerant of saline conditions – were protected under the Wetlands Act of 1970, as well as the Coastal Area Facility Review Act of 1973 (CAFRA), and the Waterfront Development Law of 1914 (ANJEC, 2004). Prior to the 1970's, thousands of acres of New Jersey salt marshes were dredged and filled for lagoonal-style development (Lathrop and Bognar, 2001). The NJLULCC data set shows a steady decline in the rate of coastal wetland conversion to urban land uses. During the nearly three decades between 1986 and 2015, 1,046 acres of coastal wetlands (WETCOAST) were mapped as converting to urban uses with only 26 acres of that change occurring between 2012 and 2015. The NJLUCC mapping suggests that 311 acres per year of coastal wetlands (*WETCOAST*) converted to *BARREN* during T5 (Table B.2). Of the 934 acres of coastal wetlands converted to *BARREN* during T5, the vast majority (908 acres) was converted to beaches (through the process where sand beaches overwash, usually during major storm events, such as SuperStorm Sandy, and bury adjacent salt marsh).

Given the importance of coastal wetlands for the host of ecosystem services they provide, the Rutgers Center for Remote Sensing & Spatial Analysis has conducted a series of targeted studies to document past change and project potential future change. Coastal habitats are not spatially fixed, but rather are continually in spatial flux, responding and shifting to various forcing factors, including sea level rise (SLR). Through the process of vertical accretion of sediment and organic matter, the surface elevation of a salt marsh will rise in relation to sea level, *i.e.*, the marsh can continue to grow 'up' into a rising sea (Cahoon and Guntenspergen, 2010; McKee and Patrick, Jr. 1988; Titus, 1988). When sea level rises faster than the rate of marsh accretion, salt marshes are "drowned" and replaced by tidal mud or sand flats and eventually open water (Cahoon and Guntenspergen, 2010). Three key aspects that can govern salt marsh sustainability were considered: 1) shoreline erosion (i.e., horizontal change); 2) the maintenance of elevation (i.e., vertical change) of the marsh platform; and, 3) the conversion of adjacent upland and wetland areas to salt marsh under future sea level rise (referred to herein as marsh retreat zones). The methods employed to model future change in coastal wetlands and adjacent upland areas is described in greater detail in Appendix C.

Our comparison of the 1977 New Jersey Tidelands and LiDAR-derived shoreline maps for the year 2010 suggests that nearly 4,400 acres of salt marsh were converted to tidal flat or open water during the intervening 33 years. In some locations, the shoreline has retreated over 1,000'. To project potential future change, three scenarios of sea level rise (1, 2 and 3') out to the Year 2050 were modeled. Our results suggests that approximately 20% of New Jersey's salt marshes are highly vulnerable to conversion to tidal mud flat or open water or heightened "drowning" stress by 2050. We estimate that nearly 25,000 acres (or over 11%) of existing salt marsh is vulnerable to conversion to tidal flat or open water from continued marsh shoreline erosion (Table 6.2). An additional 19,000 acres (or nearly 9%) of interior marsh is vulnerable to biological stress or conversion under 1 feet of sea level rise. A recent Rutgers University report (Kopp et al., 2019) estimates that there is a >95% chance that sea level will rise by 0.7 feet and a >83% chance that sea level will rise 0.9 feet by 2050 (above a 2000 baseline). If sea level rise accelerates as some studies suggest then additional areas of salt marsh may be vulnerable. A proportion of the expected loss due to erosion and drowning may be balanced by new marsh created as upland/wetland forests or abandoned cropland are converted (through natural succession) to salt marsh We refer to those areas where new marsh may develop in the future as unimpeded marsh retreat zones. Our modeling of a 3' SLR scenario mapped 66,343 acres of marsh retreat zones statewide, though not enough to compensate for the expected losses (Table 6.2). We suggest that these marsh retreat zones should be high priority for conservation protection to allow New Jersey's salt marshes to "migrate" to provide some level of compensation for expected losses from sea level rise in the coming decades.

Impervious Surface

One of the more significant landscape impacts attributable to urbanization is the creation of impervious surface. In the environment, water is continually moving between the atmosphere, ground water aquifers, lakes and rivers. When land becomes developed, a portion of the parcel is necessarily covered with impervious surface such as asphalt and concrete. The construction of impervious surface changes the natural hydrologic cycle by impeding precipitation infiltration to groundwater while increasing the amount of surface runoff. Storm peaks are amplified in velocity and magnitude changing the load carrying and erosion characteristics of stream channels. These changes have significant environmental

Table 6.2. Area of predicted marsh change in acres and % of existing salt marsh. Note that these the baseline area of salt marsh area (215,279 acres) is slightly different that the NJLUCC figures (200,040) due to a coarser mapping and different source.

Class Type	**Area (ac)**	**Area (%) of existing salt marsh**
Lowest vulnerability: remains salt marsh	70,322	32.7
Low Vulnerability: salt marsh converts to tidal flat/open water at 3’ SLR	59,915	27.8
Moderate vulnerability: salt marsh converts to tidal flat/open water at 2’ SLR	41,008	19.0
High vulnerability: salt marsh converts to tidal flat/open water at 1’ SLR	19,236	8.9
Highest Vulnerability: salt marsh converts to tidal flat/open water from shoreline erosion	24,798	11.5
Freshwater tidal/interior marsh converts to salt marsh	6,664	
Unimpeded marsh migration at 1’ SLR	34,287	
Unimpeded marsh migration at 2’ SLR	16,045	
Unimpeded marsh migration at 3’ SLR	16,011	
Impeded marsh migration	4,543	

consequences including impacts to ground water recharge, frequency and magnitude of flooding, elevated non-point source pollutant levels and degraded biological activity (Arnold and Gibbons, 1996; Kennen, 1998; Brabec et al., 2002). In recognition of the deleterious effects that impervious surface has on watersheds, considerable efforts has been expended to design new development in a way to minimize impervious surface and to retrofit existing development to slow and infiltrate stormwater runoff.

The 2015 mapping effort entailed a major change in how impervious surface was mapped and % cover estimated. Previous NJLULC data sets estimated % impervious surface coverage for LULC polygons based on visual interpretation of digital imagery. Alternatively, for the 2015 data set, % impervious surface coverage was calculated from NJDEP’s 2015 LiDAR Impervious Surface project. This project utilized Geographic Object-Oriented Image Analysis (GEOBIA) with eCognition software for automated feature extraction. The differences in methodology between time periods preclude meaningful comparison of the 2015 impervious values with the 2012 impervious values. The new methodology indicates that New Jersey’s total impervious footprint as of 2015 was 725,840 acres or nearly 1,135 square miles of concrete and asphalt (Figure 6.4). The old methodology indicates a total of 518,346 acres of impervious in 2012, nearly 40% less than 2015. While some of this difference can be attributed to actual impervious surface increase, the magnitude of difference is a clear indication that the old visual estimation methodology significantly under counted impervious cover

To better estimate the actual impervious surface increase between 2012 and 2015, we compared only the land use polygons that had changed between 2012 and 2015 and that were also classified as type URBAN in 2015. We then assumed that all non-changed polygons had the same impervious surface in 2012 as 2015 and used the more accurate new 2015 impervious values as proxy for the 2012 values of non-changed land uses. Under this approach we estimate a corrected 2012 impervious cover of 719,537 acres increasing by 6,303 acres of new impervious cover between 2012 and 2015, an increase of 0.8%. This percentage increase in impervious cover is very similar to the urban land cover increased by 0.7% or 10,392 acres during the same period as well as in line to the ratio of previous land use change iterations supporting the results of our estimated 2012-2015 impervious increase.

Considering the importance of impervious surface as an environmental indicator and that the old impervious estimation method under counted impervious surface on a magnitude of 40%, there is an opportunity to use data from the new methodology to evaluate impervious surface change in a more robust manner than was previously possible. Bearing in mind the underestimate of actual impervious cover, the water quality in New Jersey's watersheds as indicated by impervious surface may be impacted as much as 40% more than previously calculated (Hasse and Lathrop 2008 p.37). As such, a more in-depth reevaluation of watershed-based impervious increase since 1986 is warranted. Looking ahead, 2015 may serve as a new benchmark in tracking the state's impervious surface coverage with the next iteration of the LULC dataset that will be based on 2020 imagery.

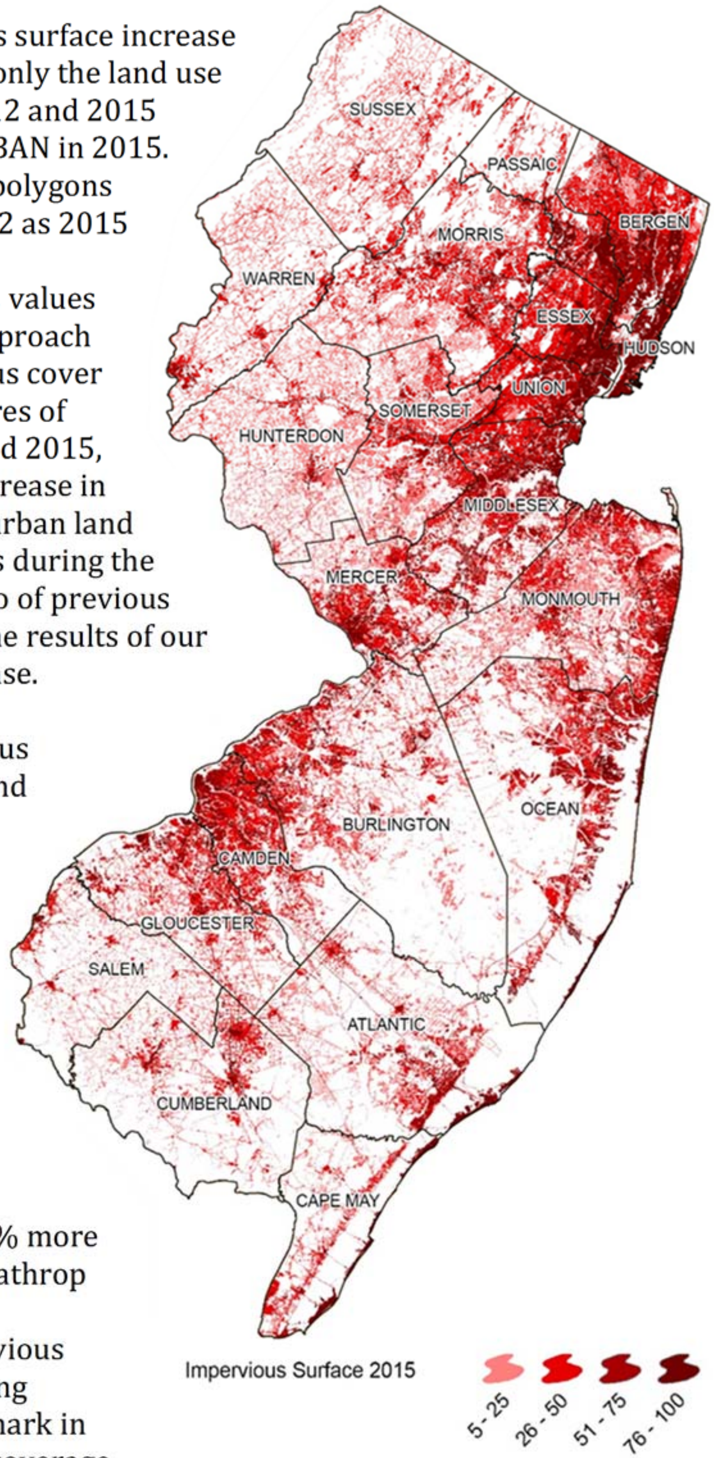


Figure 6.4 Percent Impervious Surface as of 2015.

7 Conclusions

This report presents one segment of ongoing research on landscape changes in New Jersey conducted at the Grant F. Walton Center for Remote Sensing & Spatial Analysis, Rutgers University and the Geospatial Research Lab, Rowan University. The objective of this collaborative research program is to monitor trends in land use/land cover change, analyze the implications of these changes and make this information available to a wide audience of interested stakeholders. The NJDEP 2015 Update represents the fourth installment charting change in land use/land cover change across the state of New Jersey between 1986-1995, 1995-2002, 200-2007, 2007-2012, and now 2012-2015.

Our analysis of the NJDEP 2015 Update land use/land cover data shows a continued leveling off of the rapid and extensive land use changes during the last two decades of the 20th century and the beginning of the 21st century. Given, the widespread effects of the Recession on the state's economy, job growth and housing market, it is not unexpected that the rate of new urban development slowed during the T4 (2007- 2012) time period. These newest data suggest that the rate of newly urbanized land during T5 (2012-2015) has declined even further. The declining rate of new urban development has taken some of the pressure off the "Race for Open Space" with the annual rate of conversion of agricultural land, upland forest and wetlands continuing to decline. However, other driving forces such as accelerating sea level rise are negatively effecting New Jersey's coastal salt marshes. Modeling the future distribution of salt marshes under sea level rise suggests that approximately 20% (or 44,000 acres) of New Jersey's salt marshes are highly vulnerable to conversion to tidal mud flat or open water or heightened "drowning" stress by the Year 2050. The continued conversion of upland and wetland forests to urban land uses is also concerning; forests and wetlands play a critical role in removing and storing additional carbon from the atmosphere. New Jersey's renewed participation in the Regional Greenhouse Gas Initiative (RGGI) and the investment of proceeds into climate change mitigation is a welcome development. Initiatives that will protect and enhance ecosystems such as salt marshes and forests are specifically highlighted for RGGI funding (NJDEP, 2020).

The most recent 2012 to 2015 Land Use Change data reveal that not only was there a dramatic slowdown statewide in overall acres developed, the residential footprint shrank in relative proportion compared to other land uses including *industrial, transportation, major roadway* and *other urban or built-up land*. The recession T4(2007-2012) period saw acres of residential development drop precipitously in overall magnitude. However, as the economy began to recover post 2011 as evident in the increasing certificate of occupancy data, the pattern of residential development exhibited a continued drop in the rate of acres consumed for residential land uses. While large-lot development was not completely defunct, consuming more than half of the residential land developed, it became a smaller piece of the residential development pie during T5. Higher-density residential types significantly increased their proportion of land development acres as well as their proportion of population housed. More units were being built on less land signaling a significant shift toward denser residential development. While our results support the notion that New Jersey may be entering a new "post-suburban" phase that reflects a stronger push towards smart growth and a focus on urban redevelopment (Hughes and Seneca 2014), the degree to which this shift in residential development is a meaningful divergence from previous trends or a short-term anomaly remains to be seen. Hughes and Seneca (2019) pose the question as to whether Generation Z (the generation born between 1996-2010), will follow the example of the millennials (the generation born between 1981-1995) in driving a higher-density urban resurgence, or ultimately return to the suburban-centric posture of the baby boom. We write this report at the same time that New Jersey and more broadly, the United States, is in the throes of the COVID19 pandemic. It is unclear how this traumatic event will affect the state's economy, auto vs. public transit vs. tele-computing commuting patterns, and the younger generations' residential land use choices once the pandemic passes. Simultaneously, widespread demonstrations protesting police brutality and systemic racism have cast a harsh spotlight on the ingrained inequity in safety, housing, health, employment and education opportunities across the nation. Clearly, land use planning and urban development/redevelopment has a critical role to play in helping to rectify these inequities. We expect the shock wave of these intertwined events will reverberate for years to come.

If anything positive has come out of this pandemic, it is the widespread appreciation for New Jersey's open space and natural resource conservation lands as vital to our quality of life, as a place for solace, exercise and fresh air. New Jersey has a long tradition of supporting public open space and a highly active coalition of state, non-profit and local conservation stakeholders that has protected well over a million acres of farms, forests and recreational lands over the past several decades. In a race against the urban growth documented in this report, New Jersey's efforts to conserve and protect its land base has been remarkable and will make a significant impact on the quality of life of future generations. On-going efforts to conserve the most critical remaining ecological, agricultural and recreational lands while creatively redeveloping our existing urban areas will be key to enhancing the state's ability to adapt to both climate and social change. The challenge in the years ahead will be to ensure that New Jersey is able to provide an expanding array of housing opportunities as well as public open space lands that are easily and equitably accessible to all of its inhabitants.

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Appendix A. Background Notes on the 2012 Land Use/Land Cover Data

The 2015 NJDEP Land Use/Land Cover (LULC) data set was produced by the visual interpretation of leaf off color infrared digital ortho-imagery with a spatial resolution of approximately 1 foot. Detailed metadata is available from the NJ DEP which documents the creation of each dataset (www.state.nj.us/dep/gis). Using the 2015 imagery along with the polygonal boundaries of the 2012 NJDEP, LULC changes that took place between 2012 and 2015 were interpreted and polygonal boundaries digitized. In the process, some earlier (i.e., 2012–era) interpretations and boundaries were refined with the higher resolution imagery and a slight change in interpretation/mapping protocols, leading to two sets of 2012 LULC boundaries, one from the T4 data set and one from the T5 data set. Thus there are discrepancies if one compares the area totals for the year 2012 from the T4 and T5 data sets. For example, the 'old' T4 2012 total for Barren Land = 48,826 while the 'new' T5 2012 total is 49,027 acres, a difference of 200.94 acres or approximately 0.41% (Table A.1 below). Thus to help control for these discrepancies, for the T5 analysis we are only comparing the "new" 2012 LULC boundaries with the 2015 data. Similar differences occur in comparing the earlier (i.e., 1986, 1995, 2002, and 2007) sets and similar methods are used to control for these differences. While it can be assumed that the 'new' T5 2012 dataset is more accurate than the 'old' 2012 dataset, errors and inconsistencies are inherent in all datasets and must be properly understood by the user.

Table A.1 Differences between the revised and the original 2012 Level I data.

Changes from Original to Revised 2012 Data		
NJDEP Level 1 Category	**Changes (Acres)**	**Percent Change**
URBAN	287.14	0.02%
AGRICULTURE	-222.50	-0.04%
FOREST	860.19	0.06%
WATER	-2,873.73	-0.35%
WETLANDS	1,818.53	0.18%
BARREN LAND	200.94	0.41%

The 2012-2015, 2007- 2012, 2002-2007, 1995-2002 and 1986-1995 LULC data sets were analyzed using ArcGIS software in a rasterized format; the original polygonal boundaries were gridded at a 10 foot resolution for subsequent analysis. For the purposes of this report, the area totals are reported in acres out to the ones place. We recognize that there are errors of both omission and commission in this data set (as with any photo-interpretation and LULC mapping exercise) and thus the reported acreages should be treated as estimates and not "absolute" amounts. As the metadata does not include a quantitative assessment of error, nor have we undertaken an independent assessment, it is difficult to determine what the error bars around any LULC acreage figure or change amount should be. To be conservative, only LULC changes more than 5% should be treated as significant.

The majority of statewide values in this report were created by creating summary pivot tables from the original merged polygon dataset. Acreage values for land use/land cover change by other geographic extents such as the smart growth zones and remaining available lands, was accomplished by rasterizing the data to a 10 foot cell size. The rasterization of vector data can also lead to summation differences compared with straight vector areal summations. However, these differences are minimal and of little significance at a state-wide scale.

Forest core habitat was defined as including upland and wetland forest, scrub/shrub and transitional forest/old field categories. A 100 meter buffer was generated extending from the edge of human altered land categories (i.e., urban, agriculture or barren (but excluding rock outcrops)) into the forest to define 'forest edge.' Forest edge areas were removed leaving the remaining forest core habitat. Forest areas adjacent to neutral habitat such as water or wetlands were not considered edge.

As wetlands can have overlap with other level 1 land use types (for examples, *agricultural wetlands*), the authors recast the wetlands categories depending on their Level III Anderson land use codes (Table A.2). The labels remain unchanged for URBAN, AGRICULTURE, FOREST, WATER and BARREN.

Table A.2 H-L wetlands categories.

H-L wetlands name	**Anderson Codes**
Coastal Wetlands WETCOAST	6110, 6111, 6112, 6120, 6130, 6141
Emergent Wetlands WETEMERG	6230, 6231, 6232, 6233, 6234, 6240, 6241, 6290
Forested Wetlands WETFOREST	6210, 6220, 6221, 6250, 6251, 6252
Urban Wetlands WETURB	1461, 1711, 1750, 1850
Agricultural Wetlands WETAGR	2140, 2150,
Disturbed Wetlands WETDIST	6500, 7430, 8000

Appendix B. Land Use Change Matrix

Over time, land use types change in many possible directions. While many acres of open space become urbanized, some urban lands can possibly change back into a non-urban category. Farmlands can convert to forest and vice versa and so on. In order to give a complete picture of the multiple directions of change occurring in New Jersey's dynamic landscape a land use change matrix is provided. Since wetlands can have overlap with other level 1 land use types (for examples, *agricultural wetlands*), the authors recast the wetlands categories depending on their Level III Anderson land use codes (see Appendix A for more detail). The labels remain unchanged for: URBAN, AGRICULTURE, FOREST, WATER and BARREN.

The following tables (Tables B.1 and B.2) provide the net and annualized land use change matrix for changes that occurred in the 2012 – 2015 dataset. These tables allow for the examination of all possible transitions between different land classes. Not only can the total acreage of a particular class be read at the final columns and bottom rows of the tables, the number of acres of change for each possible transition can also be traced. These tables can be studied and compared with the land use change matrix tables for the T1, T2, and T3 datasets, see Hasse and Lathrop 2008 p. 9-14.

Table B.1 H-L class land use/land cover total acres change matrix for T5(2012-2015).

Table B.1	H-L class LULC total acres change matrix (2012-2015)										
(In Acres)	2015										
2012	URBAN	AGRICULTURE	FOREST	WATER	WETCOAST	WETEMERG	WETFOREST	WETURB	WETAGR	WETDIST	BARREN
URBAN	1,553,557	479	394	0	1	2	0	1	0	14	4,703
AGRICULTURE	2,626	540,365	1,022	0	0	0	1	0	5	3	1,568
FOREST	4,556	2,162	1,516,550	5	1	1	2	1	1	6	4,949
WATER	21	2	12	806,404	122	112	3	1	2	47	836
WETCOAST	26	0	0	1	199,803	0	10	6	1	117	934
WETEMERG	64	3	0	0	0	108,118	19	27	115	627	230
WETFOREST	292	10	3	3	0	93	589,514	66	65	490	409
WETURB	73	3	0	0	0	2	0	14,620	8	6	66
WETAGR	159	8	4	1	0	123	13	41	71,905	42	117
WETDIST	152	11	3	0	6	265	23	32	118	5,328	210
BARREN	8,015	462	750	2	107	31	1	2	1	24	39,632
2015 Totals	1,569,541	543,504	1,518,738	806,415	200,040	108,748	589,586	14,795	72,222	6,704	53,653

	2012 Totals	Loss '12-'15	Gain '12-'15	Net Change
URBAN	1,559,149	5,592	15,984	10,392
AGRICULTURE	545,591	5,225	3,138	-2,087
FOREST	1,528,232	11,683	2,188	-9,495
WATER	807,563	1,159	11	-1,148
WETCOAST	200,897	1,094	238	-857
WETEMERG	109,204	1,086	630	-456
WETFOREST	590,943	1,429	72	-1,357
WETURB	14,778	158	175	17
WETAGR	72,414	509	316	-193
WETDIST	6,148	820	1,376	556
BARREN	49,027	9,395	14,021	4,626

T**able B.2** H-L class land use/land cover annualized acres change matrix for T5(2012-2015).

Table B.2	**H-L class LULC annualized acres change matrix (2012-2015)**										
(In Acres)						**2015**					
2012	**URBAN**	**AGRICULTURE**	**FOREST**	**WATER**	**WETCOAST**	**WETEMERG**	**WETFOREST**	**WETURB**	**WETAGR**	**WETDIST**	**BARREN**
URBAN		160	131	0	0	1	0	0	0	5	1,568
AGRICULTURE	875		341	0	0	0	0	0	2	1	523
FOREST	1,519	721		2	0	0	1	0	0	2	1,650
WATER	7	1	4		41	37	1	0	1	16	279
WETCOAST	9	0	0	0		0	3	2	0	39	311
WETEMERG	21	1	0	0	0		6	9	38	209	77
WETFOREST	97	3	1	1	0	31		22	22	163	136
WETURB	24	1	0	0	0	1	0		3	2	22
WETAGR	53	3	1	0	0	41	4	14		14	39
WETDIST	51	4	1	0	2	88	8	11	39		70
BARREN	2,672	154	250	1	36	10	0	1	0	8	
Annual Gain	**5,328**	**1,046**	**729**	**4**	**79**	**210**	**24**	**58**	**105**	**459**	**4,674**
Net An. Change	**3464**	**-696**	**-3165**	**-383**	**-286**	**-152**	**-452**	**6**	**-64**	**185**	**1542**

	An. Loss '12-'15	**An. Gain '12-'15**	**Net Change**
URBAN	1,864	5,328	3,464
AGRICULTURE	1,742	1,046	-696
FOREST	3,894	729	-3,165
WATER	386	4	-383
WETCOAST	365	79	-286
WETEMERG	362	210	-152
WETFOREST	476	24	-452
WETURB	53	58	6
WETAGR	170	105	-64
WETDIST	273	459	185
BARREN	3,132	4,674	1,542

Table B.3 Categories of Upland Forest converted to Agriculture for T5(2012-2015).

Upland Forest Converted to Agriculture (2012-2015)	**Acres**
CONIFEROUS BRUSH/SHRUBLAND	53
CONIFEROUS FOREST (>50% CROWN CLOSURE)	35
CONIFEROUS FOREST (10-50% CROWN CLOSURE)	9
DECIDUOUS BRUSH/SHRUBLAND	201
DECIDUOUS FOREST (>50% CROWN CLOSURE)	151
DECIDUOUS FOREST (10-50% CROWN CLOSURE)	83
MIXED DECIDUOUS/CONIFEROUS BRUSH/SHRUBLAND	111
MIXED FOREST (>50% CONIFEROUS WITH >50% CROWN CLOSURE)	28
MIXED FOREST (>50% CONIFEROUS WITH 10-50% CROWN CLOSURE)	1
MIXED FOREST (>50% DECIDUOUS WITH >50% CROWN CLOSURE)	44
MIXED FOREST (>50% DECIDUOUS WITH 10-50% CROWN CLOSURE)	3
OLD FIELD (< 25% BRUSH COVERED)	1,271
PHRAGMITES DOMINATE OLD FIELD	169
PLANTATION	2
Total	**2,161**

Appendix C. Methods for Coastal Wetland Projected Change

Shoreline erosion rates were determined by comparing the shoreline position changes between a baseline year during the 1970s and a contemporary year in the 2010s. The baseline shoreline was defined by the 1977 New Jersey Tidelands Claimed line. The NJDEP Tidelands claims map (http://www.nj.gov/dep/gis/tidelandsshp.html**)** depicts areas formerly water covered at or below mean high tide as of 1977. The contemporary shoreline for both Delaware and New Jersey was defined as the mean tide level (MTL) shoreline from V-Datum-corrected LiDAR-derived bathymetric/elevation data for the year 2010. VDatum is a software tool designed to vertically transform geospatial data among a variety of tidal, orthometric and ellipsoidal vertical data (NOAA 2017). The historical shoreline data were rasterized at a grid size of 10 m to match the spatial extent and resolution of the V-Datum corrected bathymetric/elevation data set. The perpendicular horizontal distance between the mapped baseline and contemporary shorelines was calculated for each contemporary shoreline grid cell and then converted to an average annual shoreline erosion rate in meters/year.

To project future marsh change under projected sea level rise (SLR), a marsh change data product provided by the NOAA Office for Coastal Management that was developed for the US Digital Coast Sea Level Rise Viewer (https://coast.noaa.gov/digitalcoast/tools/slr.html) was employed. This NOAA product was used, rather than a more site/state-specific implementation as this NOAA product is being used in New Jersey but also nationally for state to local scale planning and decision-making. The NOAA marsh change product, based on SLAMM, identifies coastal marsh areas (includes estuarine and brackish marsh areas dominated by *Spartina alterniflora, Spartina patens* and *Phragmites australis)* that may be vulnerable for conversion to either non-vegetated or open water. The NOAA implementation employs a “modified bathtub” approach that incorporates local and regional tidal variation of mean higher high water (MHHW) (NOAA, 2017). Marsh areas that are predicted to be submerged below Mean Tide Level are classed as converting to unconsolidated shore (i.e., non-vegetated mud/peat/sand flat). When the marsh elevation dips below the Mean Low Water threshold, the marsh is classed as converting to open water. The Digital Coast implementation did not explicitly incorporate marsh shoreline erosion as a separate modeled process nor does the adjacent estuary/bay morphology change.

Three scenarios of sea level rise (1’, 2’ and 3’) out to the Year 2050 were examined. Based on the consensus SLR estimates determined for New Jersey (Lathrop, Kopp and Kaplan, 2014), 2.5’, 5 and 7’ Year 2100 SLR scenarios were employed. These levels were then scaled to the Year 2050, equating to 1’, 2’ and 3’ of SLR (at 2050) using the NOAA guidance 2017 document. A ‘moderate’ vertical accretion rate of 4mm yr^{-1} (i.e., 4mm yr^{-1} over a 50yr time frame from 2000 to 2050) was chosen based on best available information as to present rates of marsh accretion over the broader MidAtlantic region (Titus *et al.,* 2009). This single accretion rate was applied over the entire state. This 2019 version of the New Jersey Marsh Retreat Change Maps replaces an earlier version produced in 2013.

The marsh shoreline erosion rate was projected from the 2010 MTL shoreline gridded map for each 10 m grid cell to establish an estimated 2050 marsh shoreline location. This method extrapolates the marsh shoreline erosion rate based on the rate measured at that location (i.e., each 10 m shoreline grid cell) and thereby incorporates the wave dynamics and substrate erodibility resident at that site. Recognizing that the past historical rate may not be entirely applicable to future rates due to varying conditions or characteristics of the marsh directly inland of the existing shoreline location, inclusion of degree of uncertainty is necessary. The grid cells determined to have the Highest Likelihood of future erosion were those cells intervening between the 2010/2015 shoreline and 120% of the distance to the projected 2050 shoreline. 120% of the projected distance, rather than 100%, was used to account for a degree of uncertainty in the estimated erosion rate, as well as partially accommodate the expected increase in the rate of sea level rise (which is expected to lead to enhanced erosion rates). The actual relationship between rising sea levels and increasing the rates of marsh edge shoreline erosion has not been quantified. If a grid cell was classed as either likely to convert at 1' SLR or within the projected erosion zone (i.e. 120% threshold distance of projected 2050 marsh shoreline), then it was classed as the Highest Likelihood of conversion.

The 1', 2' and 3' SLR projected 2050 change maps were combined with the marsh shoreline erosion maps to create a composite projected 2050 change map. The categories in this map are defined in the Table 1. Using geospatial analysis software, future marsh retreat zones were modeled for these same 1-3' sea level rise scenarios. Those portions of New Jersey's coastal wetland complex that are free to retreat inland as part of the natural landward migration process were mapped and labeled as **unimpeded marsh retreat zones**. Areas where future tidal marsh retreat are blocked by developed uplands, other coastal protection structures or roads were mapped and labeled as **impeded marsh retreat zones**. The marsh retreat zone maps were combined with the marsh change maps to provide a composite view of predicted salt marsh change as of the year 2050.