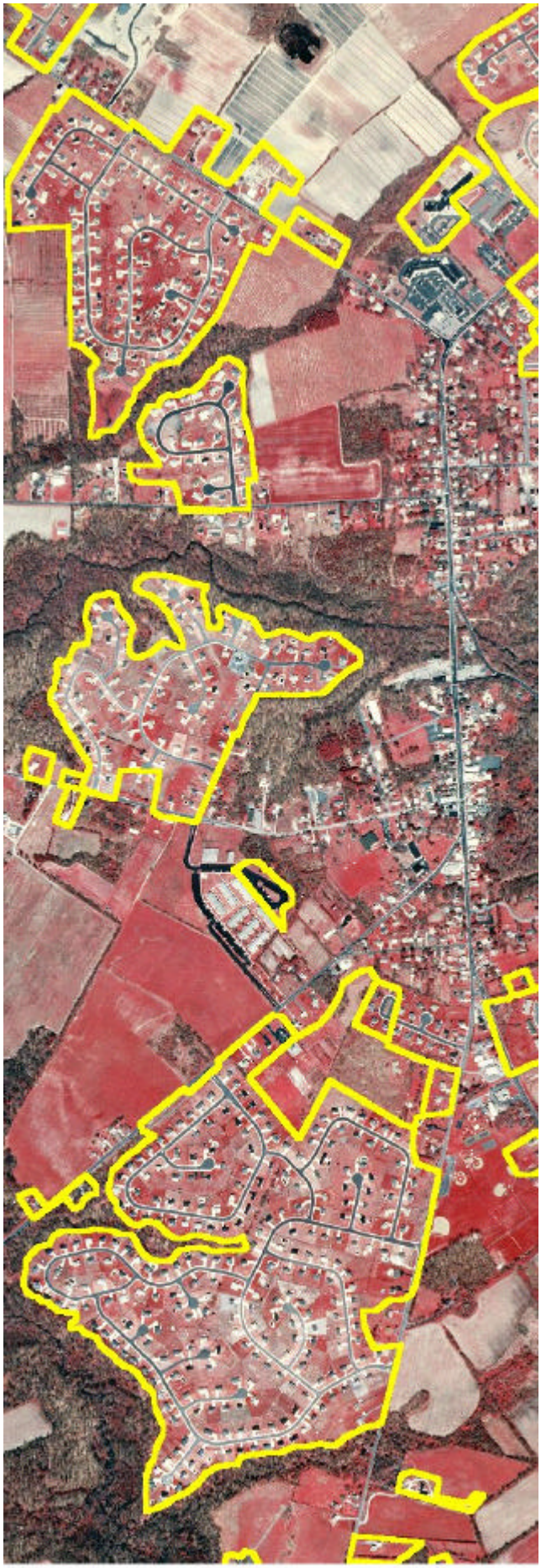
THE STATE UNIVERSITY OF NEW JERSEY
RUTGERS

CRSSA
CENTER FOR REMOTE SENSING & SPATIAL ANALYSIS



Measuring Urban Growth in NEW JERSEY

A Report on Recent Land Development Patterns Utilizing the 1986 – 1995 NJ DEP Land Use/Land Cover Dataset

John Hasse – Rowan University
Richard Lathrop, Director

Center for Remote Sensing & Spatial Analysis
Rutgers University

2001

MEASURING URBAN GROWTH IN NEW JERSEY

A Report on Recent Land Development Patterns Utilizing the 1986 – 1995 NJ DEP Land Use/Land Cover Dataset

John Hasse – Rowan University
Richard Lathrop, Director

Grant F. Walton Center for Remote Sensing & Spatial Analysis
Natural Resources & Environmental Sciences Building
Cook College, Rutgers University
14 College Farm Road
New Brunswick, NJ, USA, 08901-8551
TEL: (732) 932-1582
FAX: (732) 932-2587

Acknowledgements

The authors would like to acknowledge the New Jersey Department of Environmental Protection (NJDEP) for both the Land Use Land Cover (LULC) data, as well as collaborative analyses of the data and peer review. NJDEP's LULC data are the primary GIS data for this report. The data set production and quality assurance was managed by the NJDEP, Office of Information Resources Management, Bureau of Geographic Information and Analysis, Lawrence L. Thornton, Chief, and co-production manager with John M. Tyrawski. Analyses of the NJDEP data have included NJDEP scientists Marjorie Kaplan, Division of Science, Research & Technology, Ernie Hahn, Office of Natural Resource Restoration, and Jeff Tash, Division of Fish and Wildlife, Endangered and Nongame Species Program. Funding for the most recent update of the dataset was provided by the NJDEP Watershed Management Program and the NJDEP Division of Science, Research and Technology. The Production of the dataset was provided by Aerial Information Systems of Redlands, Ca, Lisa Cotterman, Manager. CRSSA and NJDEP continue to partner in development and analyses of additional data sets related to New Jersey's environment. Through these cooperative efforts, independent verification of the data are further assured.

CONTENTS

Introduction

Urban Sprawl has become one of the most important issues facing New Jersey at the onset of the new millennium. Housing developments and shopping malls encroach on lands that were formerly farm fields and forests. Changes to the landscape are occurring every day with significant implications for taxation, quality of life, water quality, agricultural viability, wildlife habitat and social equity. While changes to the landscape due to suburbanization are evident to most, measuring these landscape changes is a significant challenge. This report is an excerpt of research on measuring urban sprawl in New Jersey being conducted at Rutgers University. The primary data source employed in this analysis is the New Jersey DEP land use/land cover digital database, which contains detailed land use change information for the period of 1986 to 1995. This data set provides a unique window into the landscape changes that have been occurring in the Garden State at the end of the 20th century.

The changes revealed in the data set are remarkable. Every year New Jersey adds approximately 16,600 acres of new development while losing more than 9,600 acres of farmland, 4,200 acres of forest, and 2,600 acres of wetlands. Impervious surface is being created at the rate of 4,200 acres per year. The net new land developed during the nine year 1986 to 1995 period of this analysis was 135,764 acres, an area equal to the total land area of Union and Essex counties combined. Put on a more comprehensible scale, the daily urban growth rate in New Jersey was equivalent to adding 41 football fields worth of new urban land every day while losing 20 football fields of farmland, 9 football fields of forest and 6 football fields of wetlands. Impervious surface was created at the rate or 9 football fields of coverage per day. If development continues at this rate and if New Jersey successfully preserves a million acres of open space, the remaining available land would be developed in about 40 years. This development rate is likely to make New Jersey the first state in the nation to reach build-out. The following report is intended as a step in developing knowledge about New Jersey's changing landscape. It is our hope that a better understanding of these land development patterns will contribute to wiser land management policies and practices in New Jersey in the coming years.

1. NEW JERSEY'S LANDSCAPE AT THE END OF THE 20TH CENTURY

The current landscape of New Jersey is a reflection of physical geography (geology, climate, ecology) and cultural geography (i.e. how people live in a particular area, their customs, history, legal systems, economics and technologies, etc.). Geology has had a major influence on New Jersey's cultural and physical landscape. The soils along the western flank of the state are highly productive for many types of agriculture. The pine-oak forests of the Pine Barrens are largely confined to the porous, sandy soils of the outer coastal plain. Rocky, glacially carved hills in the highlands provide a rugged landscape of lakes and wetlands among forested ridges. New Jersey is uniquely situated between the major metropolitan areas of New York and Philadelphia, which have had a tremendous influence on how the landscape has developed. All of these geographic conditions results in the current land use/land cover pattern of New Jersey (Figure1).

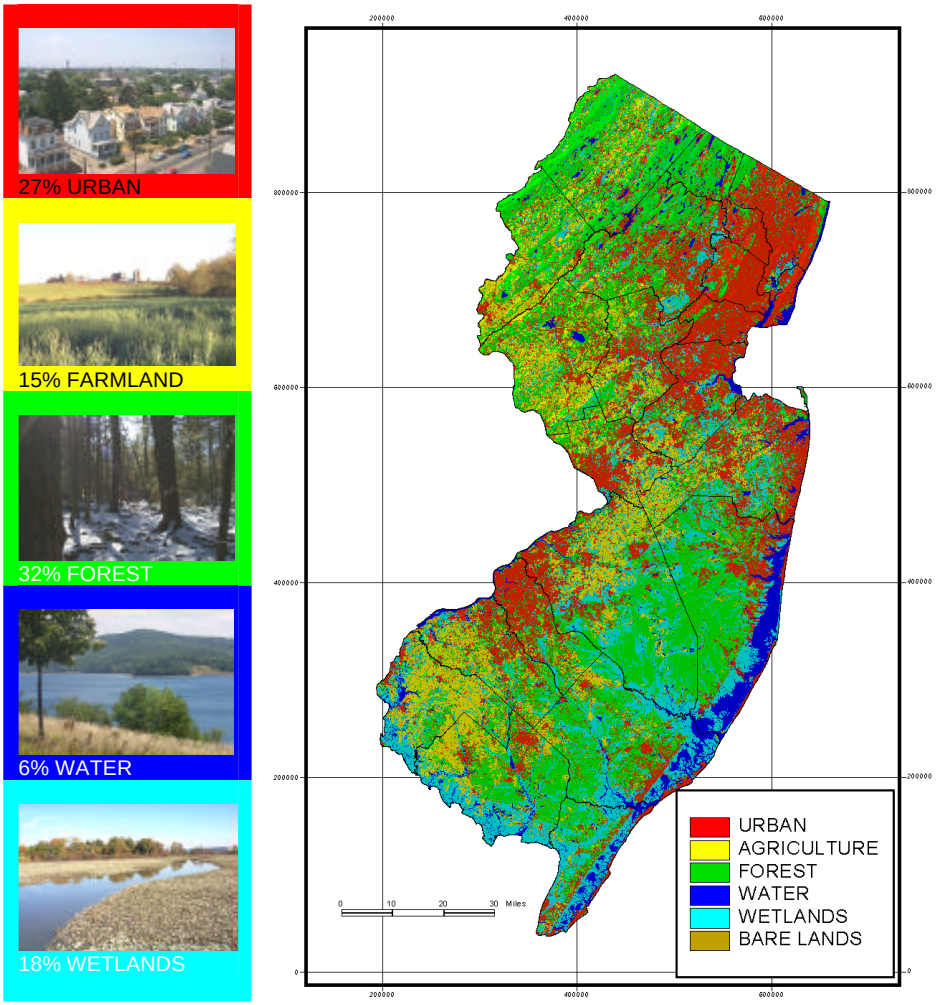


Figure 1. New Jersey Land Use 1995

The State of New Jersey occupies approximately 5 million acres. The land can be categorized into five major categories. Nearly 1.35 million acres of urban land (cities, towns & suburbs) exists in the State largely in the metro regions of Philadelphia and New York. 740,000 acres of agricultural lands can be found in New Jersey's farming belt. 1.6 million acres of forest exists largely in the Pine Barrens and the Highlands region. 917,000 acres of wetlands exists throughout the Pine Barrens, the Great Swamp, along the coastal and riparian estuaries and in thousands of smaller pockets throughout the state. Together these land use/land cover types describe the landscape of the Garden State.

Measuring Recent Landscape Change in the Garden State

Like all landscapes, New Jersey's unique land use/land cover pattern is constantly changing. These changes are evident in satellite imagery (Lathrop 2000) and aerial photography taken at different time periods (Figure 2). The New Jersey Department of Environmental Protection (NJDEP) has recently produce detailed land use/land cover data for the entire state utilizing multi-date aerial photography (NJDEP 2001). The data was developed to coincide with New Jersey's 20 watershed management areas (WMA's). This statewide dataset contains land use/land cover information from 1986 and 1995 as well as estimates of impervious surface coverage for each land use map unit (i.e., polygon). Figure 3 demonstrates a portion of the *Lower Delaware* (WMA18) dataset for the Mullica Hill, Gloucester County area. This report utilizes this and additional geodata sets (Appendix A) to analyze urban growth throughout New Jersey during the 1980's and 1990's state. Detailed summaries at various geographic scales provided in appendix B.

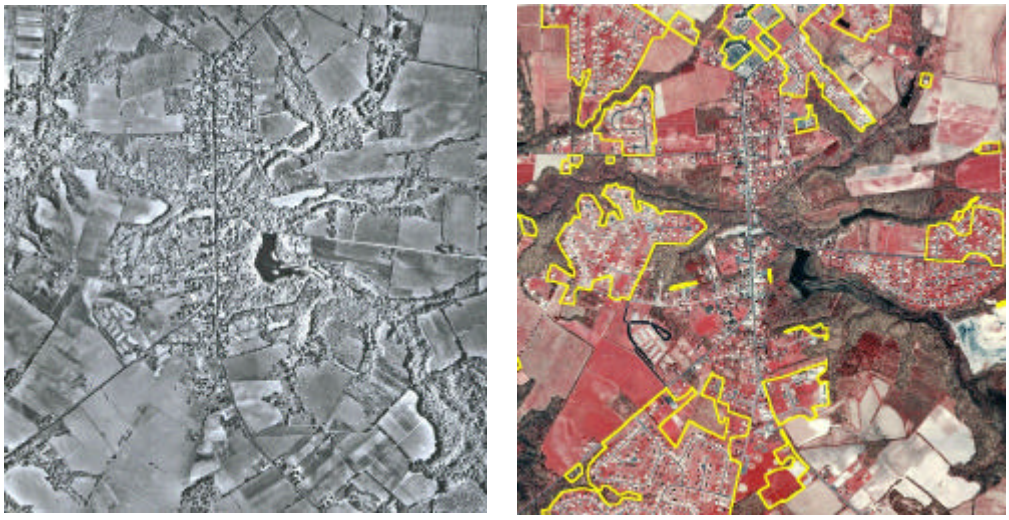


Figure 2 Multidate aerial photography of Mullica Hill, Gloucester County. The multi-date aerial photography above demonstrates landscape change over time. The panchromatic photograph on the left was taken in 1977. The color infrared photograph on the right was taken in 1995. Areas of new urban growth that occurred from 1986 to 1995 as delineated from the NJDEP dataset are outlined in yellow.

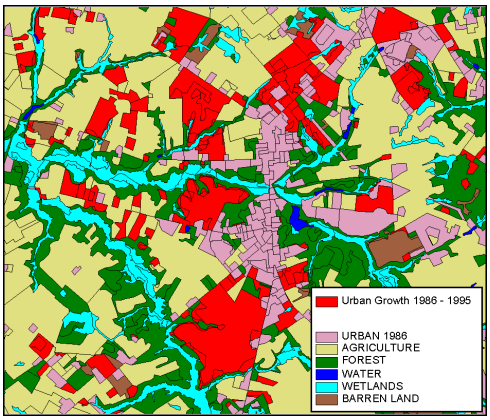


Figure 3 The NJDEP 1995 Land Use/Land Cover dataset for the Mullica Hill, Gloucester County area. Each map unit area (polygon) contains land use information for 1986 and 1995 as well as impervious surface estimates.

Summarizing Land Use Changes, Different Approaches

The NJDEP land use/land cover data set is a powerful resource for analyzing New Jersey's changing landscape. However, it must be noted that there are different approaches for extracting and analyzing the land use/land cover data, which can result in different land use and land cover change summations. The numbers presented here, for example, do differ somewhat from those reported on the NJDEP website, (www.state.nj.us/dep/gis/webstats.htm), even though both analyses are valid and based on the same NJDEP data set.

Part of the difference is due to the basic methodology used by CRSSA and NJDEP to undertake the analyses. The NJDEP data sets were produced as vector layers, and the analysis posted on their website was done using these vector layers directly. The CRSSA methodology first converts these vector layers to raster data, with the analysis then being done on the raster data sets. Vector-layers use points and lines to define features, while raster-layers define features using grid cells, which can be slightly less accurate than vector-based data.

The major cause of the different summations, however, is due to differences in how specific land use and land cover categories are grouped together for the analyses. While each area delineated in the NJDEP data set has been placed in a land use/land cover category in the data set, many areas could be placed in several other categories, depending on the intent of the analysis. Forested wetlands, for example, are included in the general category of Wetlands in the original data set. They could also be included in the general category of Forests, if the intent of the analysis was to determine the amount of all forested lands, regardless of the type. Similar situations exist for many of the land use/land cover categories delineated in the NJDEP data set.

LAND USE LABEL	ACRES 1986	ACRES 1995	ACRES CHANGE	PCT CHANGE
URBAN	1,208,338	1,342,263	+133,925	+11.1%
AGRICULTURE	744,354	659,018	-85,336	-11.5%
FOREST	1,641,535	1,602,869	-38,666	-2.4%
WATER	283,862	289,001	+5,139	+1.8%
NATURAL WETLANDS	940,554	917,505	-23,049	-2.5%
URBAN WETLAND	11,287	13,223	+1,936	+17.2%
AGRICULTURE WETLAND	84,991	83,698	-1,293	-1.5%
DISTURBED WETLAND	12,627	19,154	+6,527	+51.7%
TOTAL WETLANDS	*1,049,459*	*1,033,580*	*-15,879*	*-1.5%*
BARREN	57,113	57,935	+822	+1.4%

Table 1 New Jersey Statewide 1986 – 1995 land use change statistics incorporating expanded wetlands categories to facilitate NJDEP and CRSSA cross comparisons.

Some of the largest differences reported in the two analyses do involve the general category of Wetlands, and these differences can be attributed to differences in how the NJDEP and CRSSA view some of the specific wetland types included in the data set. Agricultural Wetlands, for example, are included in the Wetlands category in the NJDEP analysis, since these areas are regulated under the NJ Freshwater Wetlands Protection Act. Similarly, there are several types of other atypical wetlands that exist in urban settings, which are regulated under the NJ Freshwater Wetlands Protection Act, and included in the NJDEP analysis as Wetlands. Although not supporting typical wetland vegetation or wetlands that are managed to some degree (such as Right-of-Ways), these areas are viewed as important because they still exhibit some significant wetland functions, as well as provide potential sites for full wetland restorations.

In the CRSSA analysis, only typical wetland areas are included as Wetlands, since this analysis is based more on strict land use/land cover classifications. These are identified as Natural Wetlands in Table 1 included above. Both

the NJ DEP and the CRSSA land use summaries can be extracted from the table as presented. The amounts reported for Wetlands in the CRSSA analysis involve calculations done on only these typical natural wetland areas. The NJDEP includes these typical wetlands in their analyses, but also includes the atypical categories discussed above, because all of these wetland types are regulated as wetlands. They are shown in the table in the other Wetlands categories. Appendix E provides a similar land use change summary tabulation by watershed management area (WMA) utilizing the same wetlands subcategories as table 1. The remainder of this report, however, follows the CRSSA land use/land cover classification format.

It is important to note that both analyses are valid and supportable. Other analyses may, in fact, produce different summations than the NJDEP and CRSSA ones, again based on the intent of the analyses. Users of these analyses, and of the data sets, need to be aware of the different basis of these, and all, analyses when using these summary statistics.

New Jersey's Changing Land Use

Analysis of the NJDEP dataset reveals the remarkable degree of landscape change that occurred in New Jersey at the end of the 20th century (Figure 3 and Table 2). The analysis reveals that the net new land developed in New Jersey during the nine-year period of 1986 to 1995 was 135,764 acres representing an 11.1% net increase in developed land statewide. Farmlands experience a net loss of 86,884 acres representing a 10.5 % net loss in agricultural lands. Forest land was reduced by 38,240 acres representing a 2.3 net % loss of forested lands. The wetlands lost during the analysis was 23,781 acres representing a 2.5 % net loss of wetlands. The magnitude of the raw acres of landscape change can be difficult to grasp. Put in a more comprehensible context, in the 9 year period of this analysis the state added an amount of new urban and suburban development equal to the total land area of Union and Essex counties combined. The amount of farmland lost from 1986 to 1995 was equal to or an area 27% larger than all the remaining farmland in Cumberland County. The total net amount of forest lost in New Jersey was equivalent to an area slightly larger than New Jersey's portion of the Delaware Water Gap National Recreation Area. In spite of wetlands regulations the amount of wetlands lost in the 9 year period of analysis was equivalent to an area of wetlands 1/3 larger than the total area of the Hackensack Meadowlands.

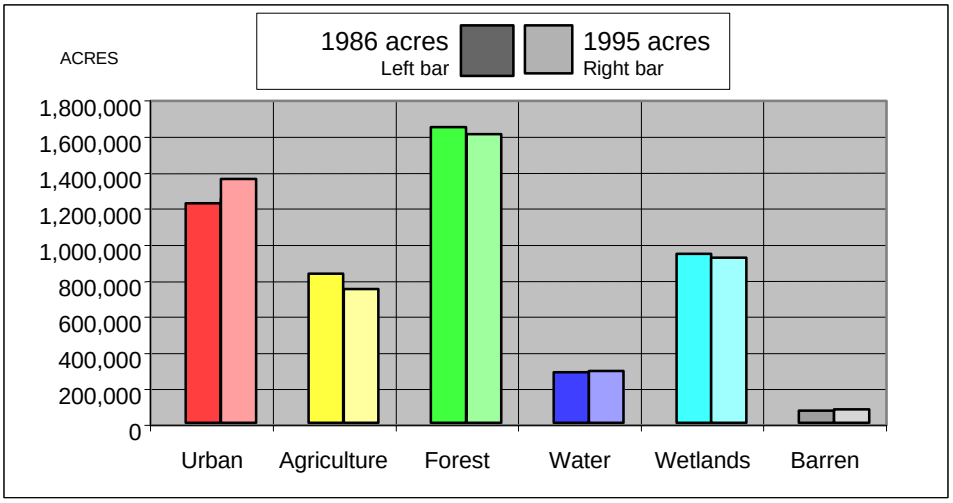


Figure 3. 1986 to 1995 Landscape Change in Acres in New Jersey

	1986 ACRES	1995 ACRES	86-95 CHANGE IN ACRES	86-95 PERCENT CHANGE	ANNUAL CHANGE IN ACRES	DAILY CHANGE IN ACRES
Urban	1,219,748	1,355,512	135,764	11.1%	15,085	41.3
Agriculture	829,598	742,714	-86,884	-10.5%	-9,654	-26.4
Forest	1,641,129	1,602,889	-38,240	-2.3%	-4,249	-11.6
Water	283,874	289,014	5,140	1.8%	571	1.6
Wetlands	941,149	917,368	-23,781	-2.5%	-2,642	-7.2
Barren	69,145	77,146	8,001	11.6%	889	2.4
Total	4,984,643	4,984,643				

Table 2. Net change in acres for New Jersey's 6 major land categories between 1986 and 1995. Annual and daily landscape change statistics help to make the changes more comprehensible. An acre of land is 43,560 square feet or slightly smaller than a football field.

Land Use Change Dynamics

The previous description of annual and daily change portrays the net total amounts of land change in each land use category. However land use change is more complex than the net change totals might indicate. All land use categories will add acres in some areas while loosing acres in others. During the 1986 to 1995 period of analysis, 254,955 acres of land changed in a discernible fashion throughout the state (Table 3). It must be kept in mind that while most of this change is a true depiction of landscape dynamics, some of the change can be attributed issues related to interpretation and mapping methods employed by the dataset.

	ACRES LAND INCREASE	ACRES LAND DECREASE	NET CHANGE
Urban	149,904	14,140	135,764
Agriculture	12,443	99,327	-86,884
Forest	48,903	87,143	-38,240
Water	8,586	3,446	5,140
Wetlands	1,901	25,682	-23,781
Barren	33,785	25,784	8,001

Table 3 - Land Change Table. All categories of land gain and lose acres over time throughout the state. Net change for each category is calculated by subtracting the acreage of land loss from acreage of land gained.

While urban growth was responsible for the lion's-share (58.6%) of changed land use type increase, other types of land use increase also occurred (figure 4). New forested areas were responsible for 19 % of land gained, 13.2% of land gained was barren and 4.9 % of land gained was agriculture.

Land use decreases show the other side of the land change equation (figure 5). Forty percent of the quarter million acres of changed land change was attributed to agricultural land use decrease. Forestland represented 34 % of land use decrease while wetlands and barren lands each contributed 10% of the decreased land use.

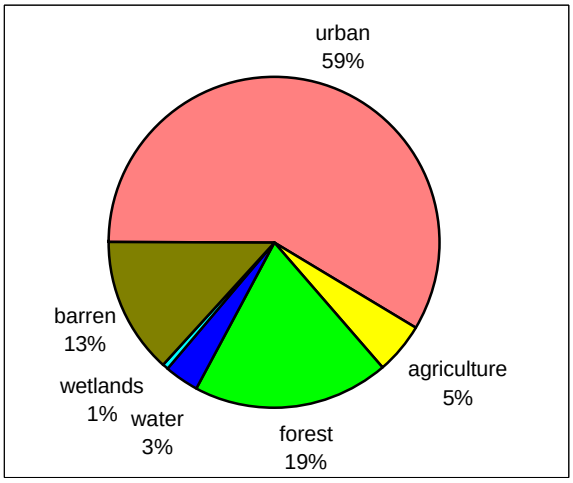


Figure 4 - Changed Land Use Increases

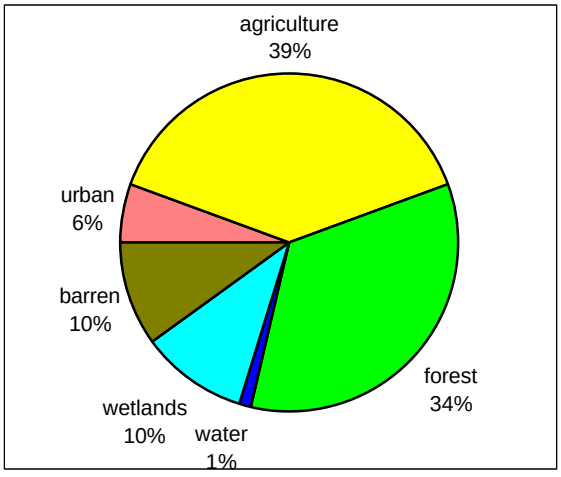


Figure 5 - Changed Land Use Decreases

Land Use Change Matrix

Even as the majority of landscape change can be attributed to urbanization, all categories of land can potentially change to all other types. A ranked land use change matrix (Table 4) shows the types of change as they occurred in decreasing amounts. Four of the top five greatest categories of landscape change were due to urbanization. However the third most significant change (31,551 acres) was due to the conversion of agricultural land to forestland. This is likely attributed to regeneration of forest from fallow fields as a result of agricultural abandonment, often a precursor to future development.

RANK	1986 - FROM LAND TYPE		1995 - TO LAND TYPE	ACRES CONVERTED
1	Forest	⇒	Urban	67,108
2	Agriculture	⇒	Urban	57,552
3	Agriculture	⇒	Forest	31,551
4	Barren	⇒	Urban	14,112
5	Wetlands	⇒	Urban	10,979
6	Forest	⇒	Barren	10,536
7	Agriculture	⇒	Barren	9,637
8	Urban	⇒	Forest	9,075
9	Wetlands	⇒	Barren	8,222
10	Barren	⇒	Forest	8,130
11	Forest	⇒	Agriculture	7,721
12	Wetlands	⇒	Water	4,083
13	Urban	⇒	Barren	3,152
14	Wetlands	⇒	Agriculture	2,289
15	Water	⇒	Barren	2,238
16	Barren	⇒	Water	2,218
17	Urban	⇒	Agriculture	1,683
18	Forest	⇒	Water	1,563
19	Water	⇒	Wetlands	926
20	Barren	⇒	Wetlands	665
21	Barren	⇒	Agriculture	659
24	Agriculture	⇒	Water	520
23	Forest	⇒	Wetlands	215
24	Urban	⇒	Water	202
25	Water	⇒	Urban	153
27	Wetlands	⇒	Forest	109
27	Water	⇒	Agriculture	91
28	Agriculture	⇒	Wetlands	67
29	Water	⇒	Forest	38
30	Urban	⇒	Wetlands	28

Table 4- Ranked Land Use Change Table. This table shows the acreage of land that changed from each land category. While the majority of the land change can be attributed to urban growth, the third largest category of change was agricultural land conversion to forestland indicating the difficulty of agricultural viability in modern day New Jersey.

Detailed Urban Growth Patterns

A more detailed examination of the land use data shows the types of changes occurring in the development process (Table 5). Residential development was responsible for 65.6% of urban growth whereas commercial industrial and mixed urban land uses combined constituted only 24.9% of new growth. Transportation/utility and recreational lands comprised 3.3% and 4.1% of urban growth respectively.

NJ DEP Land Use Code	Urban Land Use Label	Acres Developed	Pct Total
1140	Residential, Rural, Single Unit	45,448ac	30.32%
1700	Other Urban or Built-Up Land	22,696ac	15.14%
1130	Residential, Single Unit, Low Density	21,434ac	14.30%
1120	Residential, Single Unit, Medium Density	20,194ac	13.47%
1110	Residential, High Density, Multiple Dwelling	11,099ac	7.40%
1200	Commercial / Services	9,137ac	6.10%
1800	Recreational Land	6,146ac	4.10%
1300	Industrial	5,352ac	3.57%
1400	Transportation/Communication	4,977ac	3.32%
1750	Managed Wetland in Maintained Lawn Greenspace	1,003ac	0.67%
1850	Managed Wetland in Built-Up Maintained Rec Area	767ac	0.51%
1804	Athletic Fields (Schools)	747ac	0.50%
1211	Military Reservations	429ac	0.29%
1461	Wetland Rights-of-Way (Modified)	208ac	0.14%
1150	Mixed Residential	123ac	0.08%
1500	Industrial / Commercial Complexes	113ac	0.08%
1214	No Longer Military, Use To Be Determined	8ac	0.01%
1600	Mixed Urban or Built-Up Land	4ac	0.00%

Table 5 - Ranked detailed urban growth. For a detailed explanation of land use types and method of delineation see the NJDEP metadata for the 1995 land use/land cover dataset available at www.state.nj.us/dep/gis

As indicated, the majority of urban growth that occurred during the period of analysis was attributed to residential development. One particular type of residential development stands out as the most land consumptive particularly in the rural countryside. Rural single unit residential growth was responsible for nearly 46,800 acres of new development in New Jersey occurring at twice the rate of land consumption as the next category of residential development. This development is typified by large lot single residential homes with septic and private wells (Figure 6).

Figure 6 - Rural single unit residences consumed the majority of land for development in New Jersey accounting for 45,448 acres or 30% of the urban growth.

2. LANDSCAPE IMPACTS OF URBAN GROWTH

New Jersey's robust urban growth is a result of many factors including population growth and a vigorous economy. Indeed, many economic indicators designed to show the health of the local economy, such as new housing starts, are based on land development growth. However, unchecked urban growth can also have significant undesirable impacts on the health of the local landscape. Some of the most significant undesirable landscape impacts of unrestrained urban growth include farmland loss, habitat loss, wetlands loss, increased impervious surface and loss of open space. The following section explores these impacts.

Farmland Loss to Urban Growth

Agriculture is a major activity in the Garden State. Cash sales of agriculture are estimated at $829.5 million. When all farming and food related activity is considered, agriculture is the third largest segment of the New Jersey economy contributing $56 billion (NJDA 2000). Despite the fact that in some ways New Jersey farmers benefit from close proximity to a large and wealthy population, the conflicts cause by encroaching urban development make it difficult to continue farming over the long term. Soaring land values and operating costs coupled with multiple conflicts stemming from the incompatibility of farming with new residences make it difficult to farm successfully in New Jersey (Adelaja and Schilling 1999). The result is that many farms discontinue farming activities and are eventually sold for development.

During the 1986 to 1995 study period, 99,327 acres of farmland were lost. To put this in context, this amount of farmland loss exceeds all the farmland currently remaining in Cumberland County. 58% of the farmland loss was attributed directly to new urban growth (Figure 7), 31% of the loss was attributed to reforestation, and 10% of the loss was attributed to farmland which became barren, possibly indicating transition to development. However, there were some new agricultural lands created during the study period. A sum of 12,443 acres of new farmland were created mostly from lands formerly classified as forested.

What is perhaps more significant is the loss of prime farmland. While prime farmland accounted for 53% of all farmland under the plow in 1986, it accounted for 60% of the development that occurred on farmland. This suggests that prime farmland is more vulnerable to urbanization than non-prime farmland. The loss of prime farmland will accelerate the loss of agricultural viability in New Jersey.

Figure 7 – A former peach orchard in Gloucester County makes way for a new housing subdivision. Urban development was responsible for 58% of farmland loss from 1986 to 1995.

Forest Loss to Urban Growth

The largest single type of landscape change that occurred to development growth in New Jersey over the last decade was the urbanization of forested lands. A total of 67,108 acres of forested land were converted to urban land uses during the nine-year period of analysis. This is an amount of forest loss equal in size to Stokes State Forest, Worthington State Forest, High Point State Forest and the Delaware Water Gap National Recreation Area combined. Much of the ex-urban growth (single rural units beyond the suburban fringe) occurred in forested lands as forested lots draw a premium price from new homebuyers (figure 9). Such ex-urban development can lead to forest core area reduction and forest fragmentation, which may have significant implications for wildlife habitat sustainability and forest land management. Forest loss also has implications for soil erosion, flooding and air quality.

Figure 9 - This color infrared aerial photograph of a new subdivision in South Harrison Township, Gloucester County, demonstrates the fragmentation of a patch of forest that can occur when forestland is developed. 67,108 acres of forest land were developed from 1986 to 1995 in New Jersey. Forest was the single largest land category to be developed during this time period.

While the total amount of forest land lost to urban growth was 67,108 acres the net loss of forest land was only 38,240 acres. This was attributed to the significant amounts of land that became reforested. The majority of reforested land (31,551acres) occurred on former agricultural lands. Areas formerly classified as urban received 9,075 acres of reforestation. Formerly barren lands contributed 8,130 acres of new forest land.

Wetlands Loss

Comprising one fifth of the state's land, wetlands are a vital component of the New Jersey landscape. Wetlands are important for wildlife habitat, flood mitigation, and water purification. Coastal wetlands have been protected since 1970. Disturbance of fresh water wetlands has been regulated since the 1987 New Jersey Freshwater Protection Act. While this regulation has been successful in reducing the magnitude of wetlands loss compared to pre-regulatory days, there has still been a significant continual loss of wetlands. A total of 25,781 acres of wetlands were lost from 1986 to 1995 (figure 10), an area 1/3 larger than the Hackensack Meadowlands. 43% of the loss was attributed to direct urbanization, 32 % was due to wetlands becoming barren (likely in transition to development), 16% of wetland loss was due to water inundation (such as new reservoir creation) and 9% was attributed to wetlands being utilized for agricultural lands.

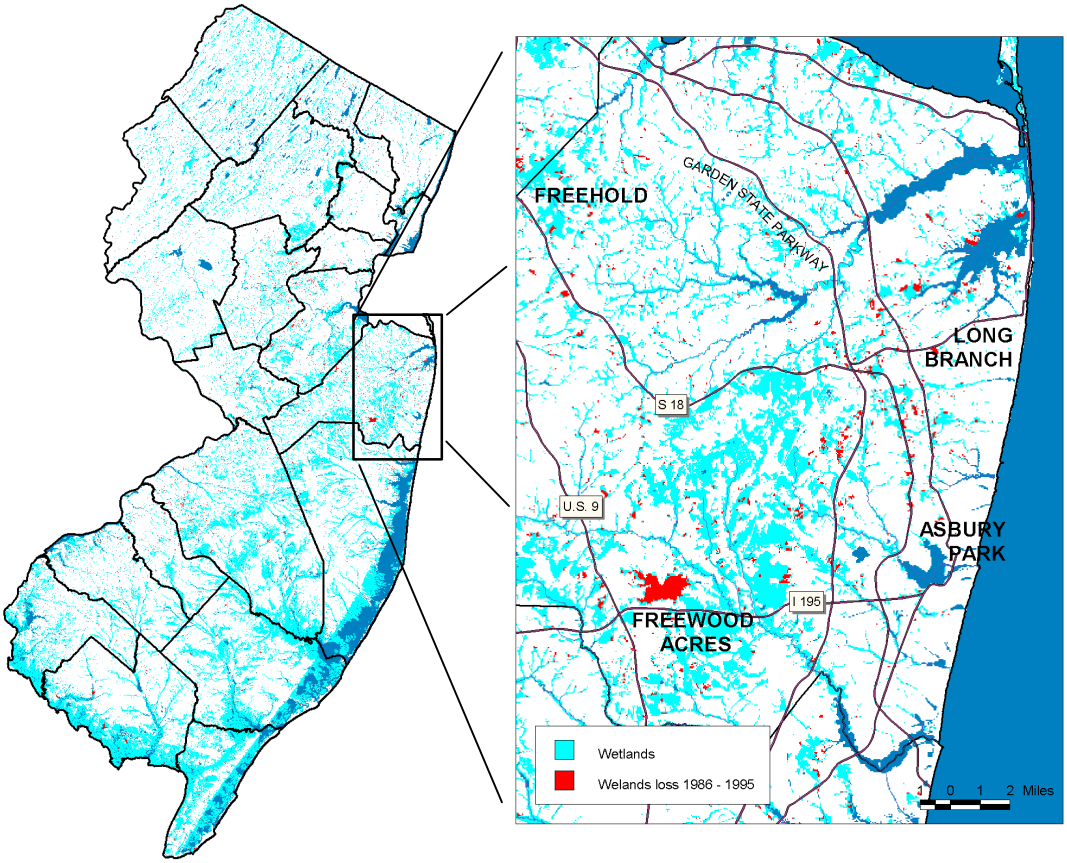


Figure 10 - Wetlands Loss. New Jersey has over 917,000 acres of wetlands (cyan color). Even with wetlands regulations in place New Jersey lost 23,781 acres or 2.5% of its wetlands from 1986 to 1995 (red color). The inset map shows an example of the scattered pattern of wetlands loss in Monmouth County, a hot spot for wetlands loss during the study.

Tidal salt marshes (i.e. coastal wetlands) comprise 20% of NJ's wetlands but were subjected to less loss and urbanization than non-coastal wetlands. Coastal wetlands lost 2,207 out of 192,051 total acres (a loss of 1.2%) where as non-coastal wetlands lost 22,809 out of 748,483 total acres (a 3.1% loss).

There was also a significant difference in the urbanization of coastal versus non-coastal wetlands. Of the wetlands that were lost in each category, urbanization was responsible for 5.8% of coastal loss but was responsible for 45.5% of non-coastal wetlands loss. New Jersey's Coastal Wetlands Law of 1970 appears to have been largely successful in halting the loss of tidal salt marshes due to human development.

Impervious Surface Increase

In nature water is continually flowing between the atmosphere, ground water aquifers, lakes and rivers. When open land becomes developed, a portion of the parcel is necessarily covered with impervious surface such as asphalt and concrete (Figure 11). The creation of impervious surface changes the natural hydrologic cycle with significant environmental implications. When impervious surface is created, precipitation can no longer adequately infiltrate into aquifers, streams experience increased flooding, non-point source pollutant levels increase and biological activity is degraded.

Figure 11 - Impervious Surface is created with new urban growth. Impervious surface has great implications for water quality and flooding as non-point source pollution and runoff are greatly increased.

Research has shown that the water quality and environmental condition of a watershed is directly related to the amount of impervious surface within the watershed (Arnold & Gibbons 1995). Watersheds with less than 10% impervious surface cover are generally considered unimpacted. At levels greater than 10% impervious surface watersheds show signs of impact. As impervious surface reaches 30% and beyond, water quality is usually seriously degraded.

Impervious surface also has important implications for flooding and ground water recharge. The natural hydrologic regime of a watershed is significantly changed when impervious surface is created as ground water infiltration is reduced and surface runoff is increased. Storm peaks are amplified in magnitude and speed within a stream channel changing the load carrying and erosion characteristics. The increase in impervious surface that has been occurring with urban expansion is changing the flooding characteristics of New Jersey's streams and rivers. A recent example of flooding in the Raritan River during Hurricane Floyd in 1999 (figure 13) suggests significant implication for the role of impervious surface in intensifying the flooding event. The North and South Branch of the Raritan River watershed had expanded its impervious surface by 2,723 acres (an increase of 18.8 %) between 1986 and 1995. While the 11 inches of precipitation that fell in parts of the basin clearly was an exceptional event, the Raritan flood was potentially exacerbated by increased impervious surface within the watershed (Robinson 2001).

Currently, the New Jersey landscape is covered with 458,610 acres of impervious surface or 9.2% of the state's total land area (Figure 12). This is equivalent to a wall to wall slab of concrete the size of Camden, Gloucester and

Hudson counties combined. During 1986 to 1995 more than 38,200 acres of new impervious surface were added to the New Jersey landscape or an area roughly equivalent to a parking lot with 6 million parking spaces. Impervious surface is being created at the rate of 4,244 acres per year or approximately 8.8 football fields of impenetrable ground cover per day. Growth trends of the 1980 and 90's added one acre of impervious surface for every 4 acres of development. In other words newly developed land is, on average, 25% impervious surface.

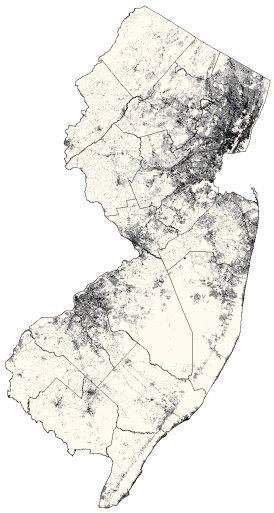


Figure 12 - Impervious surface. This map depicts the pattern of impervious surface in NJ. Darker shades of gray represent higher percentage of impervious cover.

Figure 13 - Flooding of the Raritan River at New Brunswick in 1999 after hurricane Floyd dropped more than 11 inches of rain in some parts of the Raritan basin. The North and South Branch of the Raritan River watershed had increased its impervious surface by 2,723 acres (an increase of 18.8 %) between 1986 and 1995 exacerbating the magnitude of the flooding.

Figure 14 illustrates the impervious surface conditions for New Jersey's watersheds. 13 watersheds representing 6.4% of New Jersey's watershed land area are currently 30% or greater impervious surface indicating that the stream has become degraded. 37 watersheds representing 22.3 % of New Jersey's watershed land area are between 10 and 29.9 percent impervious surface indicating that the stream has been impacted. 27 watersheds representing 21% of New Jersey's land area are between 5 and 9.9 percent impervious suggesting impending water quality impacts. The remaining 71 watersheds representing 51% of New Jersey's land area are less than 5 percent impervious surface indicating relatively non-impacted quality.

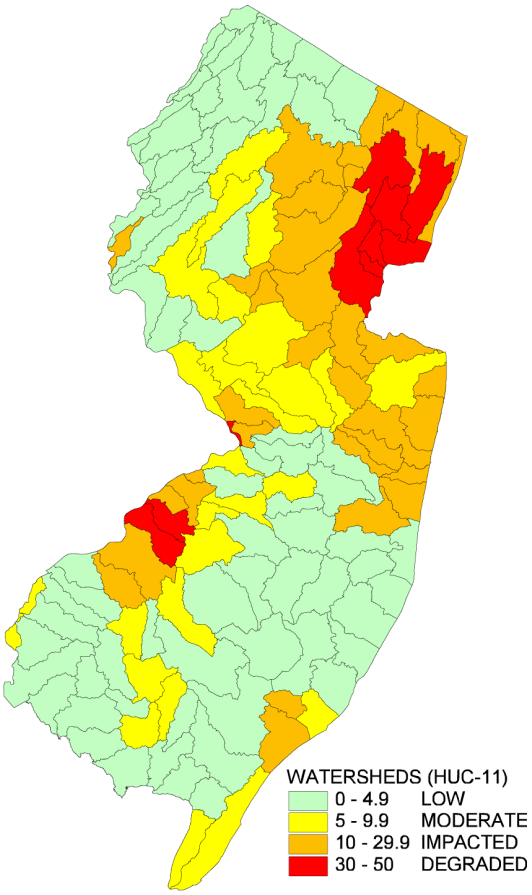


Figure 14 - Impacted and degraded watersheds as indicated by impervious surface cover. Watersheds with over 30% impervious surface coverage (colored red) are considered degraded. Watersheds with between 10 and 30% impervious surface coverage (orange) can be considered impacted. Watersheds with 5 – 10% impervious surface (yellow) have impending water quality issues.

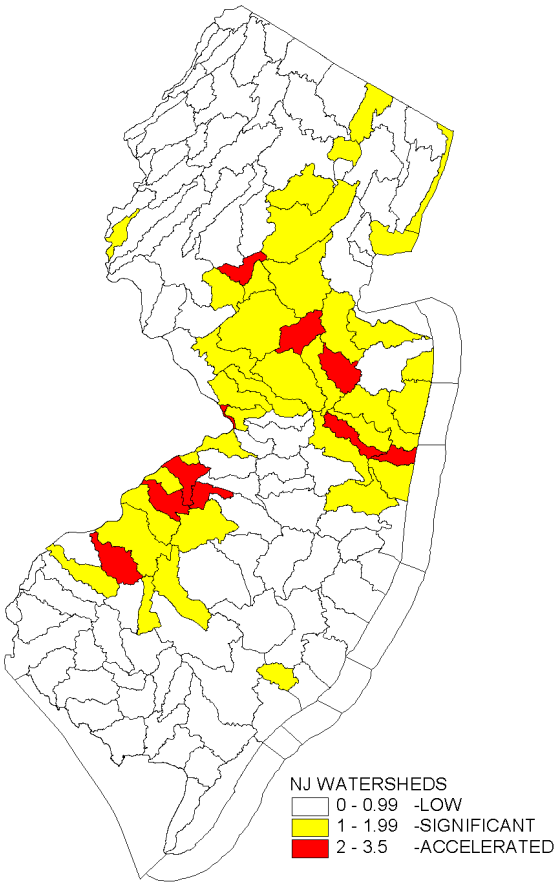


Figure 15 - Impervious surface increase. Many watersheds experienced a significant increase in impervious surface from 1986 to 1995. Watersheds that increased their total impervious surface coverage by 1 to 2 percent are colored yellow. Watersheds that have experienced greater than 2 percent increase in total impervious surface coverage are colored red.

The amount of impervious surface has been increasing in step with urban growth. During the 1986 to 1995 study period 36 watersheds increased their total impervious surface coverage by one to two percent and 10 watersheds increased their total impervious surface coverage by more than 2 percent (Figure 15). These rapidly growing watersheds are at greatest risk for experiencing degradation of water quality. Impervious surface will likely become one of the fundamental factors for sound land management practice in the future. While the 10 and 30 percent thresholds have become generally accepted rules of thumb for correlating water quality with impervious surface, further research is needed to elucidate the unique relationship of impervious surface to water quality particular to the various physiographic regions of New Jersey.

3. REGIONAL ANALYSIS OF LANDSCAPE CHANGE

The preceding statewide analysis of landscape change provides an interesting overview of New Jersey's landscape trajectory. However, the changes to the landscape are not occurring in the same pattern throughout the state. The following section provides a look at New Jersey's landscape change as it differs between physiographic provinces, counties, watershed management areas and municipalities. Tabulation tables for each of these scales of analysis are provided in appendix C, D, and E.

Physiographic Region-Level Analysis

New Jersey consists of five vastly different physiographic regions which are largely defined by the underlying geology. Each region has widely diverging natural and human landscape characteristics and it is helpful to analyze and compare landscape conditions and processes separately across the five regions.

Ridge & Valley

The Ridge and Valley province is the most northern of New Jersey's five regions. Dominated by the forested Kittatinny Ridge and the great limestone valley, the Ridge and Valley province is still comparatively undeveloped. This can be attributed in part to the large amount of federal and state public lands protecting the Kittatinny Ridge, its comparative distance from the New York City and substantial grassroots land preservation efforts. The Ridge and Valley region occupies 7% of NJ's land area but contains less than 1 percent of NJ's population. While total developed land as well as absolute urban growth remains the lowest of the five regions, the Ridge and Valley province is experiencing a significant percentage increase in urban growth.

RIDGE & VALLEY	
Land area	335,113 ac
Percent land area of NJ	6.7%
1990 Population	66,604
Percent of NJ pop	0.9%
Urban Density (persons per acre of urbanized land)	1.93

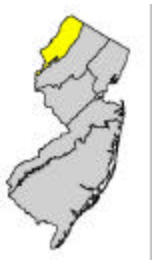


Figure 16A - Land statistics in the Valley & Ridge Province

	URBAN	AGRICULTURE	FOREST	WATER	WETLANDS	BARREN
1986	28,188	80,422	177,692	10,179	3,7311	1,300
1995	34,593	73,263	178,423	10,198	36,535	2,080
Change	6,405	-7,159	731	19	-776	780
% Change	22.7%	-8.9%	0.4%	0.2%	-2.1%	60.0%

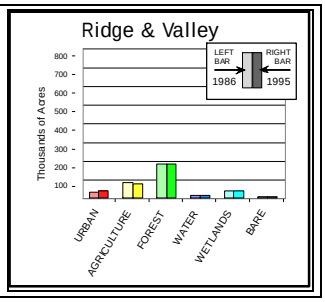


Figure 16B - Landscape change in the Valley & Ridge Province

Highlands

The Highlands province is a rugged terrain of forested ridges bisected by long narrow valleys. While the northern half is largely forested, the unglaciated valleys of the southern Highlands are important for agriculture. Numerous lakes occur in the glaciated northern half of the province and a number of these water bodies and the watersheds that drain into them are managed as drinking water supplies for northern New Jersey communities. The diverse landscape of the Highlands is recognized as ecologically significant and in need of a comprehensive management strategy. 18,568 acres of new urban growth occurred in the Highlands during the study period. The Highlands occupy 13% of New Jersey's land area and house 6% of its population.

HIGHLANDS	
Land area	641,348
Percent land area of NJ	12.9%
1990 Population	484,466
Percent of NJ pop	6.3%
Urban Density (persons per acre of urbanized land)	3.50

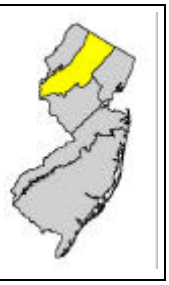


Figure 17A - Land statistics in the Highlands Province

	URBAN	AGRICULTURE	FOREST	WATER	WETLANDS	BARREN
1986	120,026	86,470	350,417	23,941	55,079	5,403
1995	138,594	75,674	340,833	25,342	53,578	7,315
Change	18,568	-10,796	-9,584	1,401	-1,501	1,912
%Change	15.5%	-12.5%	-2.7%	5.9%	-2.7%	35.4%

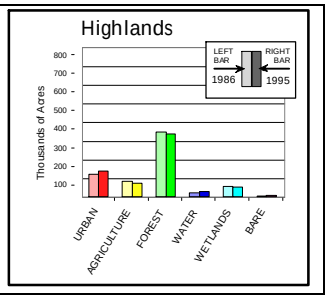


Figure 17B - Landscape change in the Highlands Province

Piedmont

New Jersey's Piedmont province consists of stretches of rolling shale hills interspersed with Triassic igneous formations such as the Watchung and Sourland mountains. The Piedmont region is often divided into two subsections; the northern glaciated section with associated glacial features such as the Hackensack Meadowlands and the Great Swamp Refuge; and the non-glaciated rolling lands of the southern piedmont. Soils are widely variable for agriculture. The Piedmont is home to the majority of New Jersey's population, housing 51 % of New Jersey's residents on 20 % of its land area. The Piedmont continues to grow adding 33,128 acres of new urban land.

PIEDMONT	
Land area	1,011,212 ac
Percent land area of NJ	20.3%
1990 Population	3,909,755
Percent of NJ pop	50.6%
Urban Density (persons per acre of urbanized land)	7.46

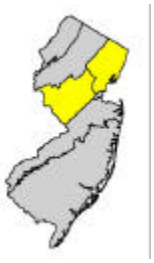


Figure 18A - Land statistics in the Piedmont Province

	URBAN	AGRICULTURE	FOREST	WATER	WETLANDS	BARREN
1986	490,706	162,610	207,244	36,879	102,155	11,619
1995	523,834	139,912	201,381	37,122	96,520	12,445
Change	33,128	-22,698	-5,863	243	-5,635	826
% Change	6.8%	-14.0%	-2.8%	0.7%	-5.5%	7.1%

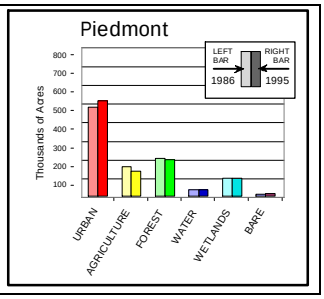


Figure 18B - Landscape change in the Piedmont Province

Inner Coastal Plain

The Inner Coastal Plain boasts New Jersey's most agriculturally fertile land. It also boasts the greatest amount of farmland loss losing 29,647 acres during the 1986 to 1995 period. The Inner Coastal Plain houses 22 percent of New Jersey's population on 16% of its land area. The urban growth of the Inner Coastal Plain is due in large part to the fact that it lies in close proximity to the transportation corridor between metropolitan Philadelphia and New York City.

INNER COASTAL	
Land area	816,463 ac
Percent area of NJ	16.4%
1990 Population	1,721,110
Percent of NJ pop	22.3%
Urban Density (persons per acre of urbanized land)	5.55

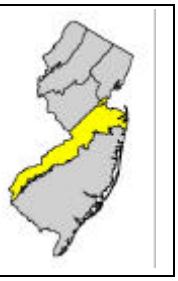


Figure 19A - Land statistics in the Inner Coastal Province

	URBAN	AGRICULTURE	FOREST	WATER	WETLANDS	BARREN
1986	275,232	229,660	108,752	39,767	144,999	17,461
1995	310,356	200,013	107,143	40,348	138,802	19,209
Change	35,124	-29,647	-1,609	581	-6,197	1,748
% Change	12.8%	-12.9%	-1.5%	1.5%	-4.3%	10.0%

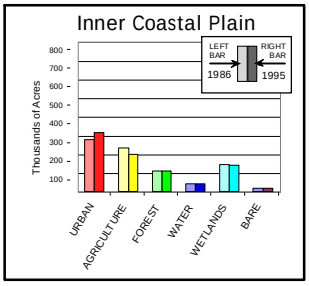


Figure 19B - Landscape change in the Inner Coastal Province

Outer Coastal Plain

The Outer Coastal Plain consists of largely flat sandy terrain. While some soils in the Outer Coastal Plain can be highly productive for agriculture, the majority are nutrient-poor. This province is dominated by the nationally significant Pine Barrens and extensive coastal wetlands. Urban growth increased in the Outer Coastal Plain by 42,533 acres largely at the expense of both agricultural and forested lands. This was the largest amount of urban growth of any province, however, that should be gauged against the fact that the Outer Coastal Plain occupies 44% of NJ's land area and houses 20% of the state's population.

OUTER COASTAL	
Land area	2,180,170 ac
Percent area of NJ	43.7%
1990 Population	1,548,003
Percent of NJ pop	20.0%
Urban Density (persons per acre of urbanized land)	4.45

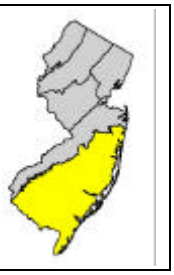


Figure 20A - Land statistics in the Outer Coastal Province

	URBAN	AGRICULTURE	FOREST	WATER	WETLANDS	BARREN
1986	305,565	270,433	797,019	172,141	601,589	33,345
1995	348,098	253,850	775,102	175,958	591,847	35,237
Change	42,533	-16,583	-21,917	3,817	-9,742	1,892
% Change	13.9%	-6.1%	-2.7%	2.2%	-1.6%	5.7%

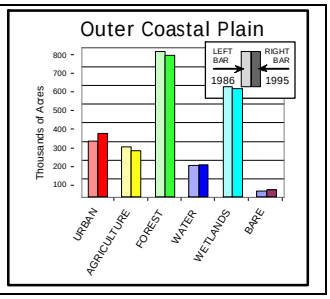


Figure 20B - Landscape change in the Outer Coastal Province

County Level Land Use Change Analysis

New Jersey's county-level land management activities vary widely, reflecting differences in political atmosphere, financial resources, demographics, and the particular needs of each county. While most land development activities such as zoning are managed at the local municipal level, many other land use related activities such as farmland preservation and open space acquisition are facilitated by county offices. Some counties such as Hunterdon, Monmouth, and Burlington have invested millions in land management infrastructure including Geographic Information Systems (GIS) and digital parcel mapping.

The unique circumstance of each county is also evident in the dissimilar patterns of landscape change demonstrated from county to county. The most rapidly urbanizing counties (figure 21) included Burlington, Monmouth, Hunterdon, Somerset Ocean and Morris. The greatest farmland loss (figure 22) occurred in Hunterdon, Burlington, Monmouth, Gloucester, and Mercer Counties. The greatest forest loss (figure 23) occurred in Morris, Ocean and Atlantic counties. The greatest wetlands losses (figure 24) occurred in Monmouth, Middlesex and Burlington counties. A detailed county landscape change table is included in Appendix C.

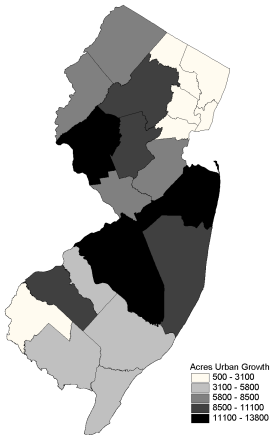


Figure 21- Urban Growth by County

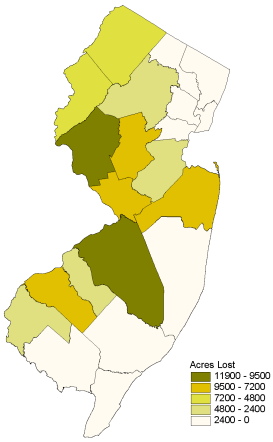


Figure 22 - Farmland Loss by County

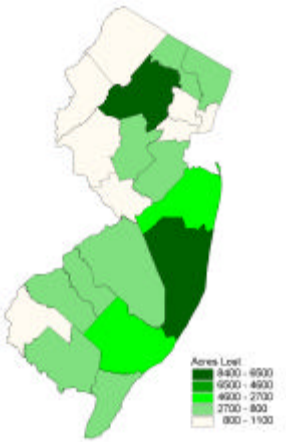


Figure 23 - Forest Loss by County

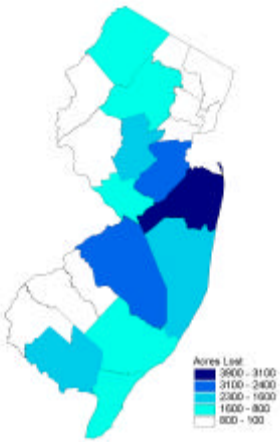


Figure 24 - Wetlands Loss by County

Watershed Management Area-Level Analysis

New Jersey's 21 counties have held official regional political jurisdiction for several hundred years. However, the geometric political borders have proven inadequate for sound environmental land management. A new approach to environmental management in New Jersey was initiated in the 1990's to manage environmental issues on a watershed-by-watershed basis. Watershed-based management is beneficial because any activity within a watershed can affect the environment of the entire watershed.

According to delineations made by the US Geological Survey, New Jersey has 152 watersheds (HUC11). The New Jersey Department of Environmental Protection (NJDEP) has aggregated these watersheds into 20 watershed management areas (WMA). Each of the 20 WMA's has unique natural and cultural characteristics as well as different land use patterns.

We have classified the WMA's into five categories depending on the amount of developed land within each watershed (figure 25). The map categories range from *mostly rural* (less than 15 % urbanized) to *largely urbanized* (greater than 45% urbanized). Each class will likely have different priorities of land management as they are in different stages of urbanization.

Figure 26 depicts the percentage urban growth in each WMA. The lowest growth WMA's have already been largely developed whereas some of the more rural WMA's such as WMA1 and WMA2 have, until recently, been sparsely developed and are now rapidly growing in relative terms. The moderate growth WMA's are largely in southern New Jersey and contain a mixture of largely urbanized WMA's such as WMA18 which are beginning to exhaust available land and more rural and mixed WMA's that are growing at a steady clip but relatively less dramatically than their northern counterparts.

Both the proportion of developed lands and the rate of urban growth should be considered in determining the land management strategy of each WMA. Appendix D details the landscape change statistics on a Watershed Management level.

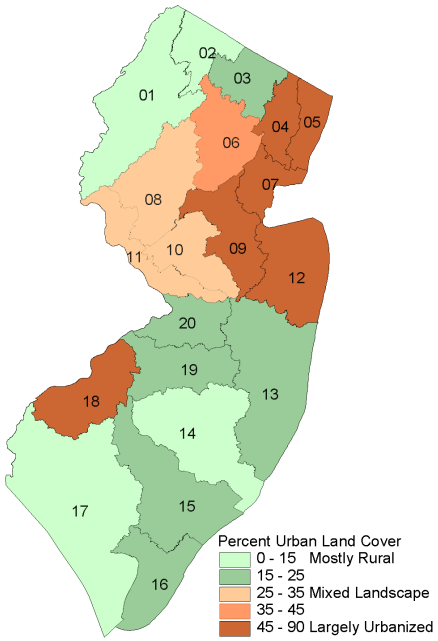


Figure 25 - Watershed Management Areas Percent Total Urbanized Land Use 1995.

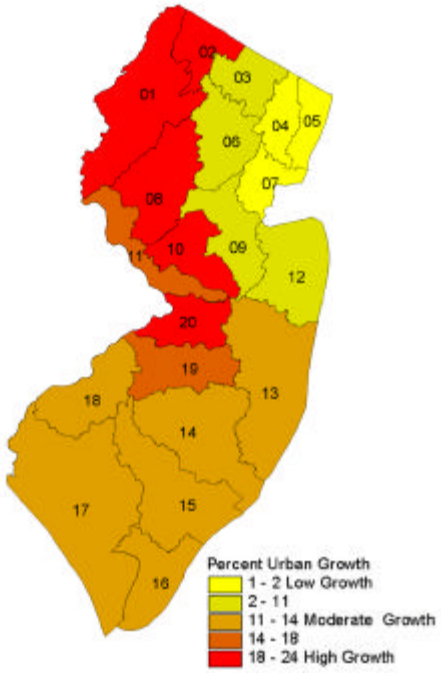


Figure 26 - Watershed Management Areas Percent Urban Growth from 1986 to 1995.

Municipal Report Card on Landscape Change

New Jersey is a strong *home-rule* state. Land use regulation is largely determined on the local municipal level. Municipalities must compete with one another for limited financial resources and rely heavily on local land taxation to fund schools and municipal services. Balancing land resource protection against the pressures of continued urban growth and the fiscal realities of modern society make local land use planning a formidable challenge. Still many municipalities have made significant progress in addressing the onslaught of urban sprawl while others have been overwhelmed by rampant urban growth.

A full listing of land use change for New Jersey's 566 municipalities is provided in Appendix E. The following lists provide the top ten municipalities for each land use change as follows.

Top 10 municipalities for total acres of new growth (figure 27); top ten municipalities for acres of farmland loss (figure 28); top ten municipalities for acres of forest loss (figure 29); and top ten municipalities for acres of wetlands loss (figure 30).

URBAN GROWTH

RANK	MUNICIPALITY	ACRES URBANIZED 1986 - 1995
1	West Windsor Twp. (Mercer)	2,717 ac
2	Raritan Twp. (Hunterdon)	2,266 ac
3	Readington Twp. (Hunterdon)	2,176 ac
4	Washington Twp. (Gloucester)	2,071 ac
5	Mount Laurel Twp. (Burlington)	2,032 ac
6	Jackson Twp. (Ocean)	1,975 ac
7	Franklin Twp. (Somerset)	1,905 ac
8	Manalapan Twp. (Monmouth)	1,878 ac
9	Dover Twp. (Ocean)	1,782 ac
10	Millstone Twp. (Monmouth)	1,782 ac

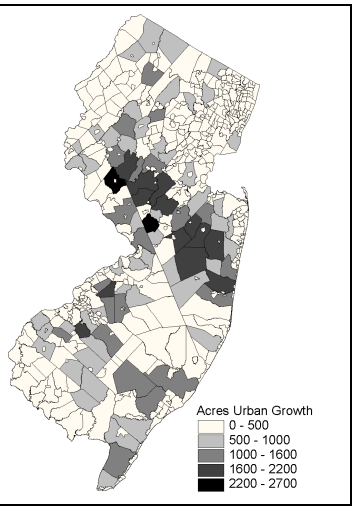


Figure 27 - Top ten municipalities for urban growth. Urban Growth by Municipality

FARMLAND LOSS

RANK	MUNICIPALITY	ACRES FARMLAND LOSS 1986 - 1995
1	West Windsor Twp. (Mercer)	2,539 ac
2	Hopewell Twp. (Mercer)	2,392 ac
3	Montgomery Twp. (Somerset)	2,090 ac
4	Raritan Twp. (Hunterdon)	2,054 ac
5	Readington Twp. (Hunterdon)	1,810 ac
6	Franklin Twp. (Somerset)	1,722 ac
7	Mount Laurel Twp. (Burlington)	1,558 ac
8	Washington Twp. (Gloucester)	1,534 ac
9	Millstone Twp. (Monmouth)	1,528 ac
10	Freehold Twp. (Monmouth)	1,427 ac

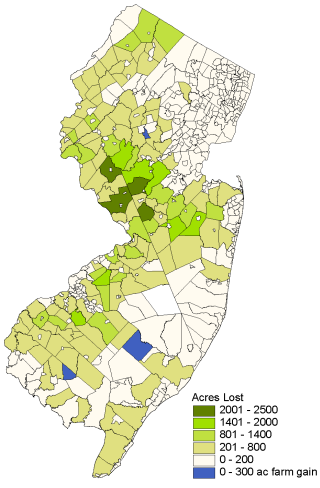


Figure 28 - Top ten municipalities for farmland loss 1986 - 1995. Farmland Loss by Municipality

FOREST LOSS

RANK	MUNICIPALITY	ACRES FOREST LOSS 1986 - 1995
1	Dover Twp. (Ocean)	1,369 ac
2	Galloway Twp. (Atlantic)	1,327 ac
3	Jackson Twp. (Ocean)	1,187 ac
4	Randolph Twp. (Morris)	1,070 ac
5	Egg Harbor Twp. (Atlantic)	995 ac
6	Berkeley Twp. (Ocean)	950 ac
7	Hamilton Twp. (Atlantic)	923 ac
8	Lakewood Twp. (Ocean)	851 ac
9	Rockaway Twp. (Morris)	829 ac
10	Brick Twp. (Ocean)	790 ac

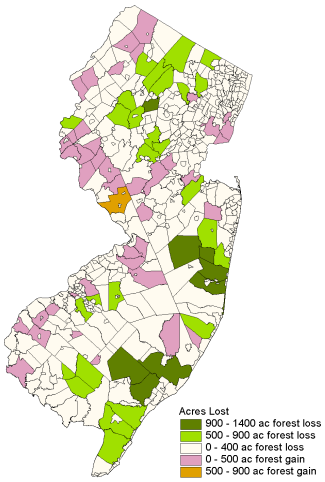


Figure 29 - Top ten municipalities for forest loss 1986 - 1995. Forest Loss by Municipality

WETLANDS LOSS

RANK	MUNICIPALITY	ACRES WETLANDS LOSS 1986 - 1995
1	Howell Twp. (Monmouth)	1,227 ac
2	Downe Twp. (Cumberland)	469 ac
3	Franklin Twp. (Somerset)	461 ac
4	South Brunswick Twp. (Middlesex)	427 ac
5	Manalapan Twp. (Monmouth)	417 ac
6	Old Bridge Twp. (Middlesex)	402 ac
7	Mount Laurel Twp. (Burlington)	399 ac
8	Edison Twp. (Middlesex)	342 ac
9	Monroe Twp. (Middlesex)	319 ac
10	Warren Twp. (Somerset)	316 ac

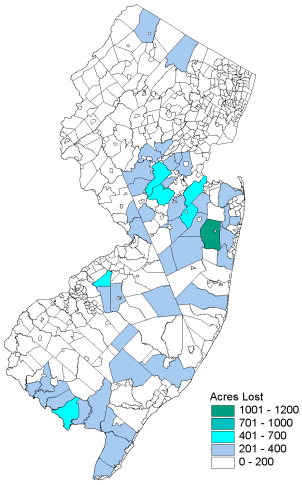


Figure 30 - Top ten municipalities for wetlands loss 1986 – 1995 Wetlands Loss by Municipality

4. URBAN GROWTH, PLANNING & INFRASTRUCTURE

Urban Growth Patterns and the New Jersey State Plan

Sprawl is not a new phenomenon in the Garden State. New Jersey has been struggling with problems associated with large-scale development growth for many decades. In an effort to limit the negative consequences of poorly planned and implemented development, the New Jersey Office of State Planning has been developing a statewide management plan (NJOSP 2001). The New Jersey State Development and Redevelopment Plan (NJSDRP) has been under development since the 1980's evolving through a number of iterations through a process called *cross acceptance*. The plan delineates five zones of land use; 1) PA1 Metropolitan Planning Area, 2) PA2 Suburban Planning Area, 3) PA3 Rural Planning Area, 4) PA4 Rural Planning Area, 5) PA4B Rural/Environmentally Sensitive Planning Areas, 6) PA5 Environmentally Sensitive Planning Area (figure 31). The planning areas prescribe the type of development and land preservation that is most appropriate for each zone.

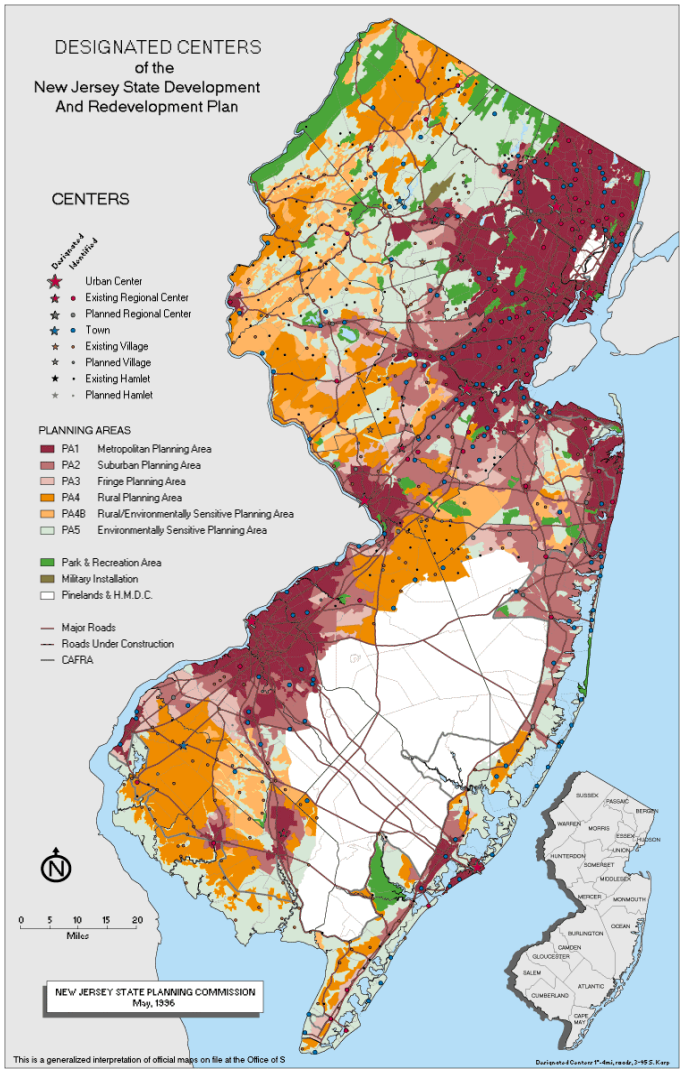


Figure 31. The New Jersey State Development and Redevelopment Map (source: NJ Office of State Planning)

Studies focusing on implementation of the state plan indicate its potential for curbing the fiscal, social and environmental costs of sprawl in New Jersey (Burchell 2000). Analyzing the actual urban growth for the State Development and Redevelopment Plan reveals patterns of new development in environmentally sensitive and rural lands during the last decade (Table 7). Of the 135,000 acres of new development that occurred from 1986 to 1995, 13.6% occurred in the environmentally sensitive planning PA5, 14.5 % of growth occurred in rural planning area PA4 and 10.2% occurred in the environmentally sensitive rural planning area PA4B. Although the goals and objectives envisioned in the state plan of channeling growth toward centers and away from sensitive lands have been hailed by both researchers and planners, this analysis demonstrates that the non-regulatory status of the SDRP has had limited success in meeting those goals.

PLANNING AREA	AVAILABLE ACRES IN 1986	URBAN ACRES IN 1986	URBAN GROWTH 1986-1995	PCT OF TOTAL GROWTH
01.PA1 Metropolitan Planning Area	131,662	624,914	20,053	15.5%
02.PA2 Suburban Planning Area	251,620	196,456	40,431	29.8%
03.PA3 Fringe Planning Area	112,579	41,522	12,020	8.9%
04.PA4 Rural Planning Area	419,758	74,599	19,688	14.5%
06.PA5 Environmentally Sensitive Planning	317,494	137,580	18,497	13.6%
07.Park and Recreation Area	12,581	10,057	842	0.6%
08.Water	80	267	-2	0.0%
09.Pinelands and H.M.D.C.	371,308	86,825	9,436	7.0%
10.Military	11	1,071	-	0.0%
05.PA4B Rural/Environmentally Sensitive	241,131	46,155	13,780	10.2%

Table 7. Land development in the NJ SDRP planning areas.

Urban Growth Patterns and Sewered Areas

Water and sewer infrastructure play a great role in how the New Jersey landscape develops. Residential development in regions serviced by public wastewater treatment can develop at much higher densities than in regions that rely on individual private septic system. Higher density growth leaves more open space intact. The growth patterns show a significant amount of growth in both sewered and nonsewered areas. However the types of growth were substantially different.

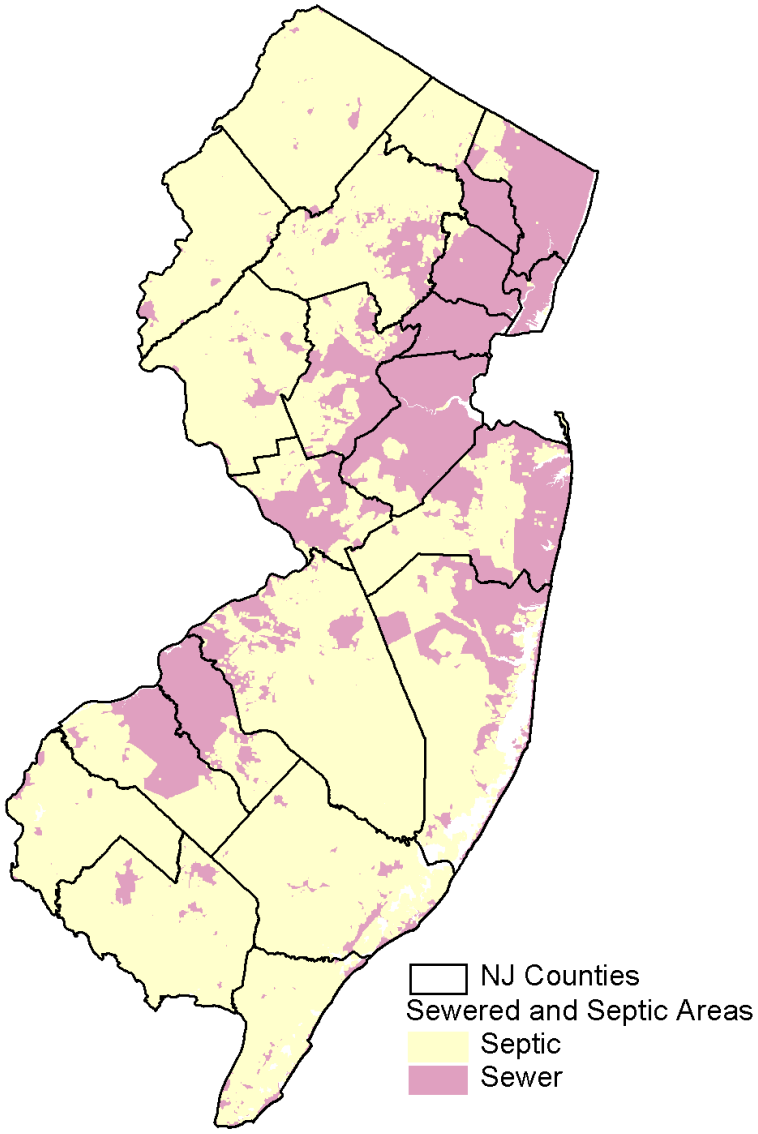


Figure 32 - Existing Sewered Areas in New Jersey

Table 8 illustrates the difference in development type between sewered and non-sewered areas. A similar amount of urban growth occurred within sewered areas (73,055acres) as occurred in non-sewered areas (76,803 acres). However, growth in sewered areas included the full spectrum of urban land use types whereas growth in nonsewered areas was predominantly residential. Non-sewered areas urbanized at a far lower density than sewered areas effectually using up more land per capita.

DEP LU95	URBAN LAND USE TYPE	SEPTIC AC GRTH	SEWER AC GRTH	TOTAL ACRES	PCT IN SEPTIC	PCT IN SEWER
1110	Residential, High Density, Multiple Dwelling	1,370	9,728	11,098	12.3%	87.7%
1120	Residential, Single Unit, Medium Density	3,263	16,931	20,194	16.2%	83.8%
1130	Residential, Single Unit, Low Density	11,710	9,724	21,434	54.6%	45.4%
1140	Residential, Rural, Single Unit	39,581	5,867	45,448	87.1%	12.9%
1150	Mixed Residential	-	123	123	0.0%	100.0%
1200	Commercial / Services	2,348	6,786	9,134	25.7%	74.3%
1211	Military Reservations	217	209	426	50.9%	49.1%
1214	No Longer Military, Use To Be Determined	-	8	8	0.0%	100.0%
1300	Industrial	1,410	3,942	5,352	26.3%	73.7%
1400	Transportation/Communication	2,211	2,754	4,965	44.5%	55.5%
1461	Wetland Rights-of-Way (Modified)	158	50	208	76.0%	24.0%
1500	Industrial / Commercial Complexes	51	62	113	45.1%	54.9%
1600	Mixed Urban or Built-Up Land	-	4	4	0.0%	100.0%
1700	Other Urban or Built-Up Land	10,852	11,840	22,692	47.8%	52.2%
1750	Managed Wetland in Maintained Lawn Greenspace	272	731	1,003	27.1%	72.9%
1800	Recreational Land	2,899	3,243	6,142	47.2%	52.8%
1804	Athletic Fields (Schools)	247	500	747	33.1%	66.9%
1850	Managed Wetland in Built-Up Maintained Rec Area	214	553	767	27.9%	72.1%

Table 8 - Detailed urban growth in sewered and nonsewered areas. The majority of growth in non-sewered areas was attributed to low density residential development.

Urban Growth in the Pinelands Management Area

The New Jersey Pine Barrens is a unique pine and oak forest located in the region of sandy soils of southern New Jersey's Outer Coastal Plane. Occupying 1.1 million acres of relatively undeveloped forest, the Pine Barrens is internationally recognized as an exceptional and valuable ecosystem. It is also located above the Kirkwood-Cohansey aquifer, one of the most significant and pristine ground water aquifers in the northeast. In recognition of the significance of this environmentally sensitive resource, the area was protected as part of the Pinelands National Reserve.

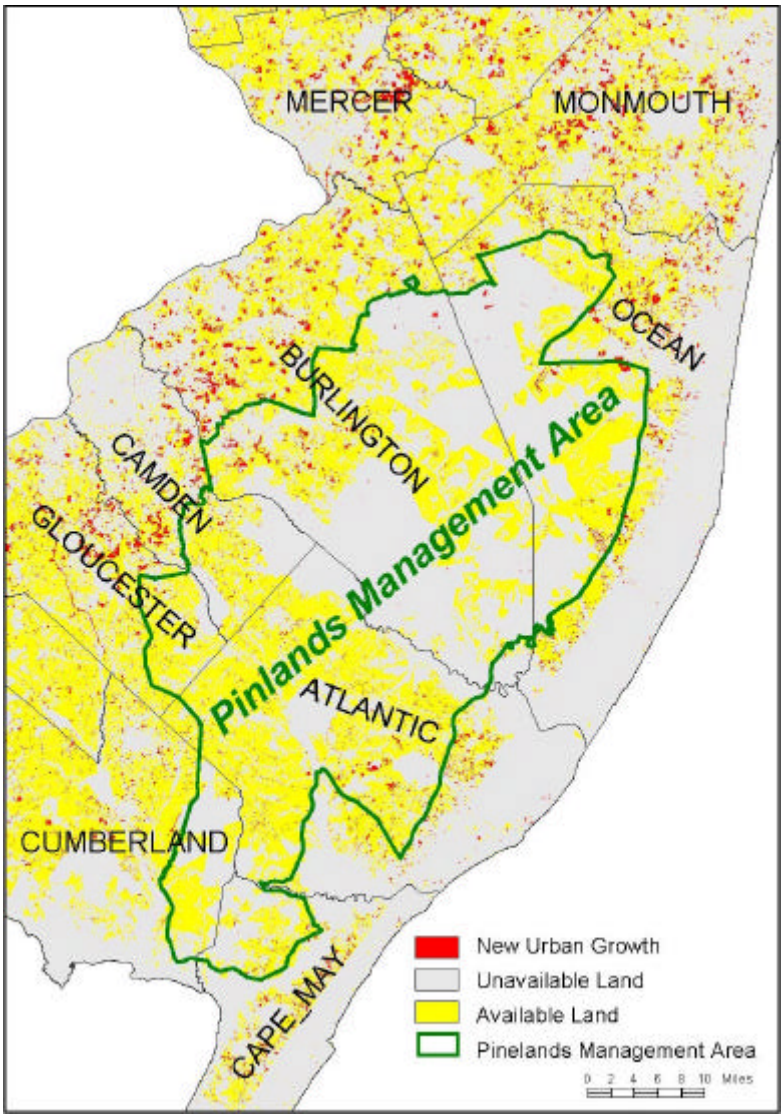


Figure 33 - Development in Pinelands Management Area

The Pinelands are a unique experiment in land management in New Jersey. Parts or all of 56 municipalities and 7 counties fall under the jurisdiction of the Pinelands Commission. Studies have indicated that the Pinelands Comprehensive Management Plan has been somewhat effective at controlling urban growth (Soleki & Walker 1999). Analysis of recent growth within the Pineland Management Area (figure 33) provides corroborating evidence for the effectiveness of the Pinelands management strategy.

Analyzing the rates of development of available land for portions of counties within the Pinelands versus portions outside the management area illustrates the propensity for urban growth to occur on lands not under the jurisdiction of the Pinelands Commission. Each of the counties which have land controlled by the PCMP had proportionately less of their available land within the Pinelands developed as compared to lands outside of the Pinelands (Table 9). This suggests an overall growth controlling effect of the PCMP.

PINE_COUNTY	URB86	URB95	URBAN GROWTH	AVAILABLE LAND 1986	% GROWTH OF AVAILABLE
ATLANTIC-NON PCMP	22,262	24,763	2,501	28,210	8.9%
ATLANTIC-PINELANDS	25,786	28,962	3,176	135,748	2.3%
BURLINGTON-NON PCMP	51,533	62,549	11,016	88,856	12.4%
BURLINGTON-PINELANDS	26,239	29,016	2,777	94,825	2.9%
CAMDEN-NON PCMP	57,178	60,657	3,479	21,800	16.0%
CAMDEN-PINELANDS	8,111	9,017	906	22,385	4.0%
CAPE_MAY-NON PCMP	24,288	27,412	3,124	26,914	11.6%
CAPE_MAY-PINELANDS	1,994	2,374	380	13,288	2.9%
CUMBERLAND-NON PCMP	31,520	35,509	3,989	120,104	3.3%
CUMBERLAND-PINELAND	1,133	1,264	131	17,838	0.7%
GLOUCESTER-NON PCMP	45,410	53,896	8,486	96,356	8.8%
GLOUCESTER-PINELANDS	5,044	5,317	273	19,608	1.4%
OCEAN-NON PCMP	67,584	76,993	9,409	74,507	12.6%
OCEAN-PINELANDS	10,410	11,991	1,581	64,522	2.5%

Table 9. Development in counties regulated by the Pinelands Comprehensive Management Plan. The white rows show development in parts of the counties unregulated by the PMCP.

The Pinelands Management Plan, however, did not simply stop all urban growth within the Pinelands. 15,667 acres of urban growth occurred between 1986 and 1995. What is significant about the urban growth within the Pinelands is where it occurred. Analyzing the location of the growth within the various Pinelands Management Planning Areas (Figure 34) provides evidence that PCMP has been effective at channeling urban growth away from sensitive lands and into designated growth areas. The majority of growth occurred in the *Regional Growth* and *Rural Development Areas* of the PCMP, whereas the Preservation Area, Agricultural Production Area and Special Ag Production Area combined received less than 5% of the total growth (Table 10). Within the Pinelands Management Area sensitive lands remain reasonably intact while planned growth areas and existing towns and villages received the majority of new development growth.

PINELANDS MANAGEMENT ZONE	%OF TOTAL AVAILABLE LAND	1986-1995 GROWTH IN ACRES	PERCENT OF TOTAL GROWTH RECEIVED
Agricultural Production Area	11.2%	522	3.3%
Federal or Military Facility	N/A	356	2.3%
Forest Management Area	31.0%	2,131	13.6%
Pinelands Town	2.9%	833	5.3%
Pinelands Village	4.0%	784	5.0%
Preservation Area	10.7%	220	1.4%
Regional Growth Area	15.5%	6,788	43.3%
Rural Development Area	20.1%	4,019	25.7%
Special AG Production Area	4.7%	14	0.1%

Table 10 - Urban growth in the various Pinelands Planning Management Zones.

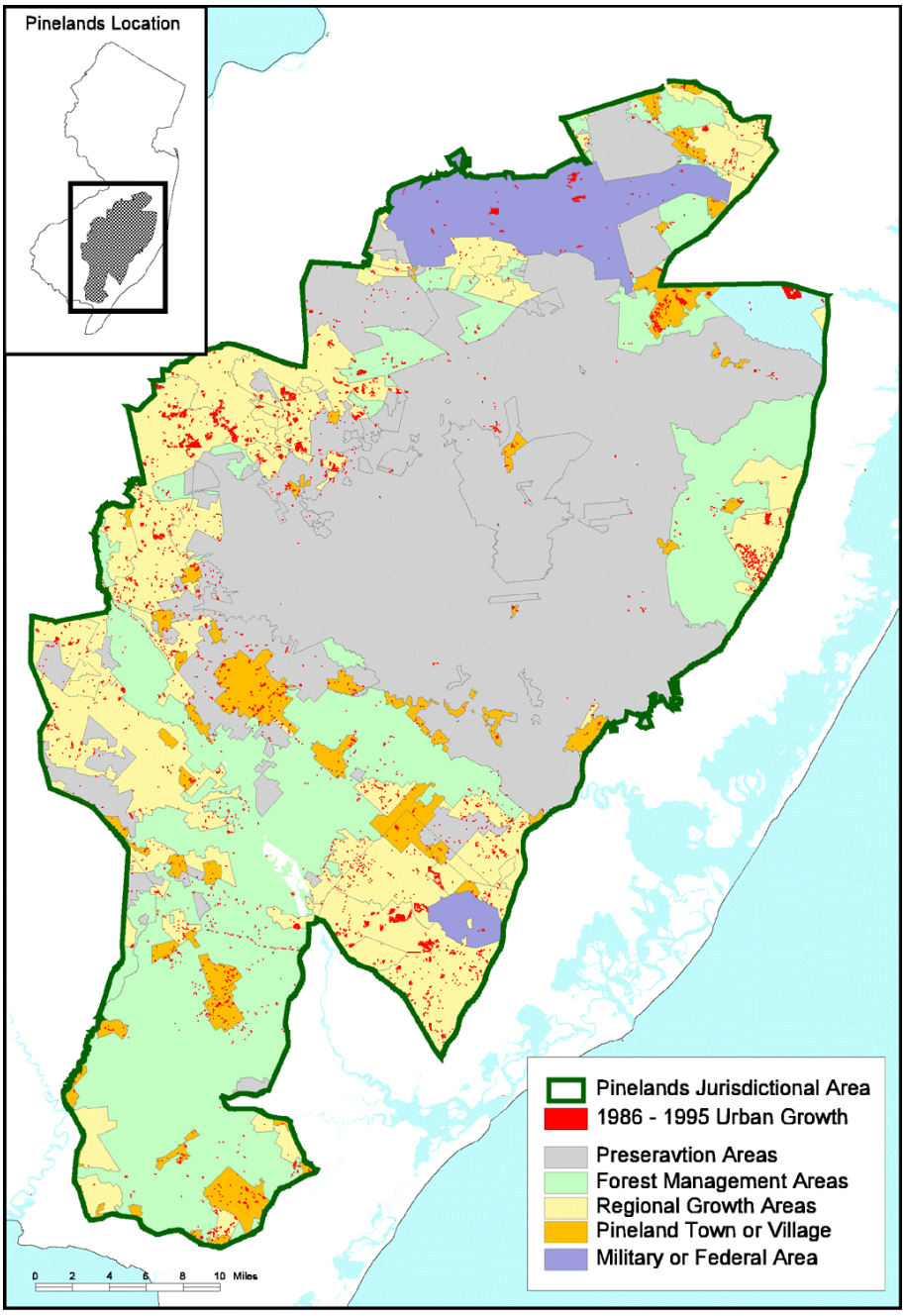


Figure 34 - Urban Growth in the Pinelands planning regions. Areas of new growth (red) by and large occurred in the planned growth areas (yellow and orange) leaving preservation areas (gray) largely undisturbed.

5. REMAINING AVAILABLE LANDS

An open space coverage was produced by combining the NJDEP federal and state preserved open space layers (figure 35) and additional open space data developed at CRSSA. The coverage also includes farmland preservation parcels as of March 2000 acquired from the NJ Department of Agriculture. The total lands estimated as preserved or protected in New Jersey as of 2000 was 1,056,171 acres.

The available lands coverage (figure 36) was created by overlaying all non-developable lands including the preserved open space layer (mentioned above), steep slopes above 15%, water, wetlands and already developed lands. The total land estimated by this method was 1,765,436 acres. While this is a reasonable estimate of remaining available lands it is likely that there is actually somewhat less land available due to underestimates of open space and other constraints on a given property's developability such as lot configuration and road access.

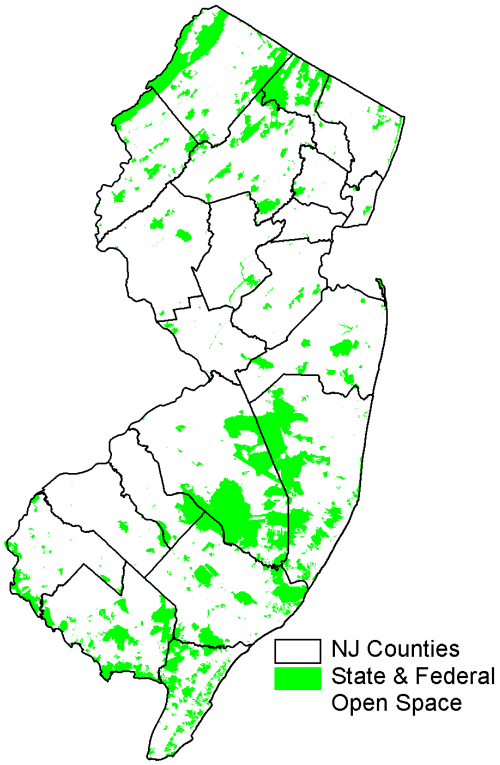


Figure 35 - State and Federal Open Space

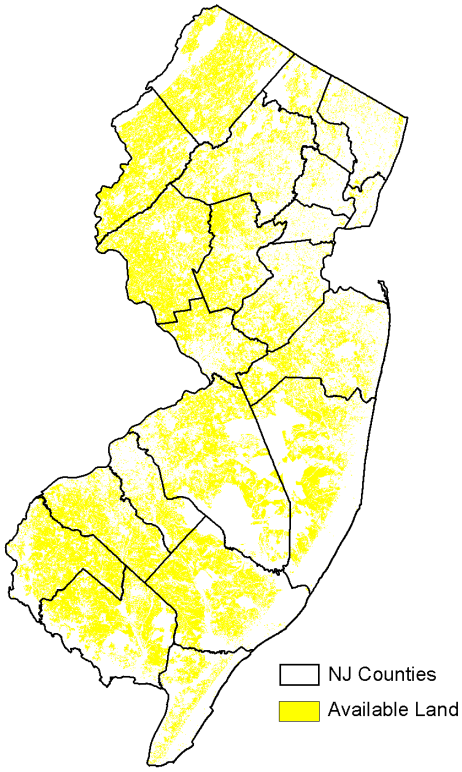


Figure 36 - Remaining Available Lands

Running Out of Land

New Jersey's urban growth pressure is likely to make it the first state in the nation to reach build-out. The geospatial technologies utilized in this research provide a powerful method for analyzing how landscapes have changed in the recent past, however, predicting future landscape change is a much more tenuous endeavor. Urban growth is affected by multiple factors not withstanding economic conditions, political trends, cultural values and changes in technology. Nonetheless, a projection of current rates of growth help to put the land management circumstances facing New Jersey into perspective. Any projection must consider multiple factors. Some factors will have the effect of making build-out occur sooner and some will delay the date of build-out. The follow discussion explores some of the factors that should be considered in projecting build-out. The reader is left to decide which factors and to what degree they will affect the actual build-out date.

1) *New Jersey's growth trajectory* - It is estimated that there are 1.76 million acres of available undeveloped land in New Jersey. If the state is successful at preserving 1 million acres of additional open space then at the current 16,600 annual acres rates of growth the remaining 0.76 million acres of available land will be entirely urbanized within 41 years. This 41-year figure is the time at which if the growth rate were to remain at 16,600 acres per year, every acre of available land not preserved as open space will be converted to urban land use. However, total urbanization of all available land is not a realistic scenario and many of the following additional factors will also influence New Jersey's build out scenario.

2) *Will NJ really preserve 1 million acres?* - New Jersey's total land area is almost 5 million acres. There are currently just less than 1 million acres of protected open space. If New Jersey is successful at preserving an additional million acres, then nearly 40% of New Jersey's land will be protected open space. This amount of preservation is unprecedented and represents the most ambitious land preservation effort anywhere in the United States. But is it realistic that 1 million acres can and will be preserved? Ultimately it will come down to economics. As land becomes scarcer through development and open space purchase, property prices will increase. The increase in property value will result in New Jersey's open space dollars diminishing in preservation power. Unless additional future funding sources are found to supplement New Jersey's Open Space Trust Fund, it is questionable whether the full 1 million acre goal will be met. For example if New Jersey successfully preserves only 75% of its million acre goal then build-out of the remaining 1,014,169 available acres would be reached in 56 years (all other factors held constant).

3) *Build-out not 100% urban* - Parcels do not become 100% urbanized at build-out, especially in rural areas. For example, in Hunterdon County (a county with available county-wide parcel mapping) we estimated that build-out in 1 acre, 3 acre and 5 acre zoning resulted in urban coverage of 88%, 64%, and 55% respectively. If New Jersey's entire remaining available land was urbanized in a similar pattern at 1, 3, or 5 acre zoning then build-out would occur in 36, 25 and 20 years respectively (all other factors held constant).

4) *Sewered versus non-sewered areas* - Land outside of sewered areas builds-out at lower densities than within sewered areas. Analysis of Hunterdon County build-out in sewered areas versus non-sewered areas suggests a build-out of approximately 89% total urban land cover within sewered areas versus approximately 61% total urban land cover in non-sewered areas. If New Jersey follows this same pattern for proposed statewide future sewered areas and non-sewered areas (NJ OSP) then build-out will be reached in 28 years (all other factors held constant).

5) *Open space, wetlands and steep slopes* - 1 million acres of additional open space is likely to include some wetlands and steep slopes. This overlap of protected land would result in more land being available for development, which would prolong build-out. For example approximately 36% of New Jersey's current open space is wetlands or steep slopes. If the future million acres of open space will include the same proportion of wetlands and steep slopes as current open space, then the million acres of open space would protect 64% or 640,000 acres of available buildable land. This would leave 1.125 million acres of available land and build-out would occur in 62 years at current growth rates (all other factors held constant).

6) *Some development occurs on wetlands* – While coastal wetlands have been regulated since 1970 and fresh water wetlands since 1987, there is still a significant amount of development that occurs on wetlands. From 1986 to 1995 there was an annual loss of 1,220 acres or wetlands. If the current amount of wetlands continues to be lost every year then build-out would occur be prolonged to 45 years as more land will be developed at build-out (all other factors held constant).

7) *Method of urban growth delineation* – There are various approaches for delineating urban growth within a region. The 16,600 acres per year figure used in this report was derived from the 1995 NJ DEP land use/land cover dataset, which delineated land use change from aerial orthographic photography. The delineation relied on expert photo interpretation and contains a high measure of precision. However, as with all methods of land analysis, there are limitations and potential inaccuracies. Other recent urban growth studies of New Jersey that utilized different methodologies concluded with different rates of urban growth. The New Jersey Office of State Planning estimated 18,000 acres of urban growth per year (NJOSP 2000), a rate that would reach total build-out of the 0.7 million acres of available land in 34 years. A

previous satellite-based CRSSA landscape change analysis (Lathrop 2000) estimated a growth rate of 20,217 acres per year, which would result in a build-out condition in 30 years. The US Department of Agriculture conducts a nation-wide natural resource inventory every 5 years. Their most recent estimate of development in New Jersey was 42,720 acres per year, which would result in build-out in 17 years (note: the methods utilized in the USDA analysis are based on a sampling methodology that is widely divergent to the other remote sensing-based methods mentioned and therefore problematic to directly compare). These differences are due to both the limitations of each technology as well as differences in classification scheme. For example land uses labeled "urban" in one method may not be considered "urban" in another method.

8) *Non-linear rate of development* – The rate of development in New Jersey is not likely to be linear. The analysis presented in this research only compares urban growth between two dates and then extrapolates that forward. Three or more consecutive periods of urban growth would present a more complete picture of the trajectory of urban development. One of the urban growth delineation methods mentioned above does contain multi-temporal data. The USDA Natural Resource Inventory is conducted every five years and shows dramatic variability over each period. In New Jersey, the USDA development rate went from 44,780 acres per year during 1982 to 1985 to 15,400 acres per year during 1987 to 1992 to 42,720 acres per year from 1992 to 1997. When averaged out over 15 years, the development rate is 34,180 acres per year. This illustrates that development will not occur in a linear fashion into the future but will significantly fluctuate year to year. However, the overall trend is likely to increase for a while and then level off and decrease as remaining land becomes less available and therefore more expensive. This will undoubtedly affect build-out. For example, if the current 16,600 acres increased by 1% annually for 15 years and then remained constant for 10 years and then decreased by 1% annually, build-would be reached in 36 years (all other factors held constant).

9) *Adjusting for the Pinelands and Hackensack Meadowlands* – The New Jersey Pinelands and the Hackensack Meadowlands are two special regions for land management in New Jersey. Regional regulatory authority for land management within Pinelands and Meadowlands has resulted in a significantly slower pattern of urban growth within these areas than rest of New Jersey. During the 1986 to 1995 analysis, the Pinelands and the Hackensack Meadowlands developed 2.5% of their available land whereas the rest of the state developed 8.4% of its available lands. If the Pinelands and the Meadowlands are removed from the analysis then the amount of available land remaining in the rest of the state would be 1,361,600 acres and the rate of growth for this area was 13,923 acres per year. Lands outside of the Pinelands and Meadowlands account for 79% of New Jersey's total available land area. If a proportionate amount of the million acres of open space (790,000 acres) are preserved in the lands outside the Pinelands and Meadowlands then the remaining available lands (571,596 acres) being developed at the rate of 13,923 acres per year will reach build-out in 36 years (all other factors held constant).

10) *Variable geography of build-out* – Some places in New Jersey will reach build-out sooner than others. The most remote counties will likely be the last ones to run out of land. At current county by county growth rates Salem, Cumberland, Atlantic and Sussex Counties will not reach build-out until well into the next century. As land becomes scarcer in the more urbanized counties, however, these rural counties can expect to see an increase in growth effectively accelerating the arrival of build-out. Nonetheless, some remote areas of these counties may be unlikely to reach total build-out in the foreseeable future.

11) *Other socioeconomic factors* - Many other socioeconomic factors will significantly affect the actual date at which New Jersey runs out of land. Some of these include economic and employment trends. For example, the continued suburbanization of corporate enterprises along with the increasing popularity of telecommuting will lead to higher demand for ex-urban development putting greater pressures on the rural landscape. Alternately, the growing popularity for the redevelopment of some of New Jersey's urban areas such as Jersey City and New Brunswick may indicate a growing trend for urban redevelopment and a lessening of the pressure for development of rural open spaces. Infrastructural improvements such as new roadways and sewer service areas will also have an important effect on where and when build-out will occur. On the other hand, more than half the development that occurred in New Jersey during this analysis occurred on non-sewered lands suggesting that sewer infrastructure may be less of a factor influencing build-out than previously thought.

12) *D*emography - Demographic changes will also affect New Jersey's future build-out as population is projected to increase by 1.6 million by 2025 and immigration is expected to increase by 1.2 million significantly diversifying the population (US Census Bureau 1997). Cultural trends will also influence future development. For example, growing anti-sprawl sentiment is leading to many smart growth initiatives throughout the state while at the same time the popularity for large homes on expansive rural lots seems to be increasing. The adoption of the New Jersey State Development and Redevelopment Plan will have an important influence on the rate and pattern of future urban growth (Burchell 2000). These and potentially other socioeconomic and demographic factors will all influence New Jersey's final build-out date. The fluctuating nature of socioeconomic factors makes incorporating them in a build-out projection extremely difficult. However, these ancillary variables may prove to be the most significant factors in determining New Jersey's actual build-out.

Exploring these multiple factors that will likely play into NJ's build-out trajectory is not intended to be a prediction of the exact build-out scenario that will occur, but rather a conceptual exercise to help put the magnitude of New Jersey's current growth rate into perspective. Even if the exact date cannot be foreseen with certainty from this vantage point, it is efficacious to approach land management by keeping in mind that near total build-out will likely be approached in New Jersey sometime within the middle of this century. The more important question to be asked is not when build-out will be reached but what will New Jersey's built-out landscape look like and how will it function for both New Jersey's human and nonhuman community. What will be the viability agriculture, wildlife habitat, water quality and wetlands for that final landscape? And what steps need to be taken now to ensure the healthiest possible landscape in the future. Planning from the perspective of impending build-out can help to guide prudent land management decisions in the present.

6. CONCLUSION

This report presents one segment of ongoing research on landscape changes in New Jersey that is being conducted at the Grant F. Walton Center for Remote Sensing & Spatial Analysis, Rutgers University. The objective of this 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. Our analysis of the NJDEP land use/land cover data shows that New Jersey underwent rapid and extensive land use changes during the latter part of the 20th century. Land planning is at a critical juncture. The land development and open space decisions that we make now will determine the shape of our future landscape, affecting the quality of life for generations of citizens to come.

References

Adelaja, Adesoji O. and Schilling, Brian J. Innovative Approaches to Farmland Preservation. Furuseth, Owen and Lapping, Mark, editors. Contested Countryside: the Rural Urban Fringe in North America. 1999.

Arnold, Chester L. Jr. and Gibbons, James C. Impervious Surface Coverage - The Emergence of a Key Environmental Indicator. Journal of the American Planning Association. 1996; 62(2):243-258.

Burchell, Robert (Rutgers University). The Costs and Benefits of Alternate Growth Patterns: The Impact Assessment of the New Jersey State Plan. New Brunswick, NJ: Center for Urban Policy Research; 2000 Sep.

Niles, L. J. and Valent M. (New Jersey Department of Environmental Protection, Division of Fish, Game and Wildlife). The Landscape Project for the Protection of Rare Species, Project Report. Trenton, NJ; 1999.

NJ DEP Green Acres. Accessed 2000 Oct 19. Available at: http://www.state.nj.us/dep/greenacres.

NJ Department of Agriculture. Accessed 2000 Oct 19. Available at: http://www.state.nj.us/agriculture.

NJ Department of Environmental Protection. Accessed 2000 Nov. Available at: www.state.nj.us/dep.

NJ Office of State Planning. Accessed 2001 Mar. Available at: www.state.nj.us/osp.

NJ Pinelands Commission. Accessed 2000 Oct 19. Available at: http://www.state.nj.us/pinelands.

Robinson, David A. Hurricane Floyd Rainfall in New JerseyFrom the Hudson to the Hamptons: Snapshots of the New York Metropolitan Area. 2001 Mar. p149-153. Supplement to the 2001 Annual Meeting of the Association of American Geographers, New York, NY.

Walker, Robert T. and Solecki, William D. Managing Land Use and Land Cover Change: The New Jersey Pinelands Biosphere Reserve. Annals of the Association of American Geographers. 1999; 89(2):220-237.

Appendix A Datasets Utilized

Land Use/Land Cover 1995 source: NJ Department of Environmental Protection. Available on-line at www.state.nj.us/dep/gis

Watershed Management Areas source: NJ Department of Environmental Protection. Available on-line at www.state.nj.us/dep/gis

State Open Space source: NJ Department of Environmental Protection. Available on-line at www.state.nj.us/dep/gis

Federal Open Space source: NJ Department of Environmental Protection. Available on-line at www.state.nj.us/dep/gis

Digital Elevation Model (DEM) 1:24K source: United State Geological Survey. Information on-line at www.usgs.gov

Watershed Basins (HUC 11) dissolved from subwatershed coverages (HUC14). source: NJ Department of Environmental Protection. Available on-line at www.state.nj.us/dep/gis

New Jersey Physiographic Provinces source: NJ Department of Environmental Protection. Available on CD Rom Series 2, Vol. 1

New Jersey Counties source: NJ Department of Environmental Protection. Available on-line at www.state.nj.us/dep/gis

New Jersey Municipalities source: NJ Department of Environmental Protection. Available on-line at www.state.nj.us/dep/gis

New Jersey State Development and Redevelopment Plan #1 & #2 source: NJ Office of State Planning. Available on-line at www.state.nj.us/osp

New Jersey Existing and **Future Sewered Areas** source: NJ Office of State Planning. Available on-line at www.state.nj.us/osp

New Jersey Digital Othorphoto Quarter Quads (DOQQ's) available on CD ROM from New Jersey Department of Environmental Protection office of maps and publications 609-777-1038

Protected Open Space source: Center for Remote Sensing and Spatial Analysis, compiled from various sources by and for an advanced course in geomatics, Cook College, spring 2000.

Farmland Preservation 2000 source: State Agricultural Development Commission.

Pineland Comprehensive Management Planning Areas source: The New Jersey Pinelands Commission

Appendix B – Methods

Method of Analysis

The NJDEP land use/land cover dataset was produced as 20 separate Arcview ™ Shapefiles corresponding to the NJDEP Watershed Management Areas (WMA's) (NJDEP 2001). The movement of the NJDEP toward watershed-based management and the sizable file size required due to the detailed nature of the data resulted in the WMA-based development of the data.

To analyze state-wide trends the 20 WMA datasets were combined into one statewide shapefile. The resulting state-wide land use shapefile contained an unwieldy 594,558 polygons. The shapefile was then converted into a state-wide grid to facilitate analysis. The grid cell size chosen was 208.71 feet which is the equivalent of 1 acre per grid cell. A one acre cell size was chosen for efficiency of summarizing land use since the count of cells corresponds to exact acreage amounts. The conversion of the shapefiles to grid resulted in some reduced accuracy in summation of land acreage, however, a check of shapefile versus grid acreage summaries for WMA's 02, 10, and 18 (a rural, mixed and urbanized selection of WMA's) resulted in summation differences of less than ½ of 1 percent for all land use categories except water which had summation inaccuracies of approximately 1 percent. The land acreage summaries within this analysis should therefore be accurate within 1 percent, however smaller units of measure such as municipalities may have slightly larger inaccuracies with a one acre raster analysis versus the original polygon shapefile theme.

The NJDEP land use dataset contains land use classification codes for each land use polygon for 1986 and 1995 adapted from the Anderson land use/land cover classification system (Anderson, et. al. 1976). There is also a detailed label and general land category label for 1986 and 1995. However, the dataset's general label (*Type 86* and *Type 95*) have a different labeling criteria for land types than the Anderson label (*LU86* and *LU95*). In order to keep the analysis consistent between levels of detail, only the Anderson land use codes were used in this analysis (see page 4).

Impervious surface statistics were also analyzed by conversion to grided data format. The impervious surface estimates were coded to a grid coverage at one acre cell size. The percentage of impervious surface then represented the portion of the cell estimated to be impervious. Summaries of the total impervious surface areas for various dataset features could then be calculated by summarizing zones.

Estimated Available land was produced by combining obtainable data for lands which are not available for future development. This included State, Federal and other open space layers; steep slopes above 15% grade (derived from a statewide seamless 30meter Digital Elevation Model), lands already developed and delineated wetlands and water. The resulting grid was then summarized by various datasets to provide an estimate of available lands remaining.

Appendix C - County-Level Land Change Table

COUNTY	CO_FIPS	AREA_AC	AVAIL_AC	IS_AC	URBAN	AGRICULTURE	FOREST	WATER	WETLANDS	BARE LAND
ATLANTIC 1986	1	390,906			48,048	28,724	152,624	36,187	120,948	4,611
ATLANTIC 1995	1	"	158,281	15,687	53,725	27,754	148,490	36,563	119,773	4,837
BERGEN 1986	3	157,914			107,602	757	28,980	9,470	10,156	1,036
BERGEN 1995	3	"	16,005	42,457	109,737	546	27,231	9,420	9,770	1,297
BURLINGTON 1986	5	523,899			77,772	99,602	192,223	13,058	136,746	4,764
BURLINGTON 1995	5	"	169,889	29,282	91,565	88,859	190,350	13,343	134,152	5,896
CAMDEN 1986	7	145,499			65,289	13,668	39,847	4,075	19,835	2,883
CAMDEN 1995	7	"	39,800	27,220	69,674	10,850	38,288	4,079	19,378	3,328
CAPE_MAY 1986	9	182,519			26,282	10,224	39,115	21,851	81,557	3,597
CAPE_MAY 1995	9	"	36,707	9,340	29,786	8,925	37,205	22,378	80,468	3,864
CUMBERLAND 1986	11	321,428			32,653	70,399	105,734	14,105	94,699	4,039
CUMBERLAND 1995	11	"	133,822	10,737	36,773	68,488	103,359	15,892	92,765	4,352
ESSEX 1986	13	82,840			62,622	307	10,957	2,258	6,316	422
ESSEX 1995	13	"	7,002	28,702	63,161	227	10,538	2,287	6,074	595
GLOUCESTER 1986	15	215,471			50,454	65,113	53,339	9,574	32,239	4,687
GLOUCESTER 1995	15	"	107,214	17,011	59,213	56,914	52,257	9,677	31,493	5,852
HUDSON 1986	17	39,759			22,603	-	2,559	10,690	2,120	1,799
HUDSON 1995	17	"	2,960	15,030	23,471	-	2,797	10,701	2,058	744
HUNTERDON 1986	19	279,943			46,114	107,204	99,429	6,102	19,675	1,612
HUNTERDON 1995	19	"	155,445	10,819	57,471	95,278	100,522	6,157	19,248	1,460
MERCER 1986	21	146,329			53,214	41,675	26,507	2,783	20,349	1,881
MERCER 1995	21	"	56,054	19,806	61,051	33,626	27,265	2,906	19,396	2,165
MIDDLESEX 1986	23	206,508			94,465	26,762	30,483	8,979	39,377	6,566
MIDDLESEX 1995	23	"	53,376	42,682	102,448	22,738	29,008	9,165	36,720	6,553
MONMOUTH 1986	25	309,750			111,093	62,339	59,522	9,748	61,904	5,267
MONMOUTH 1995	26	"	90,512	38,304	124,728	53,827	56,786	10,597	58,029	5,906
MORRIS 1986	27	307,228			98,807	18,855	134,213	10,213	42,469	2,852
MORRIS 1995	28	"	82,050	33,895	109,658	16,105	125,853	10,361	41,161	4,271
OCEAN 1986	29	485,328			77,994	10,829	200,841	83,515	100,765	11,649
OCEAN 1995	30	"	128,039	30,507	88,984	9,200	193,258	83,563	99,214	11,374
PASSAIC 1986	31	125,859			43,612	534	63,185	8,412	8,874	1,307
PASSAIC 1995	32	"	20,731	18,674	45,233	405	61,554	9,002	8,472	1,258
SALEM 1986	33	222,384			20,769	95,457	36,087	10,624	56,623	2,569
SALEM 1995	34	"	117,167	5,622	23,667	92,622	36,425	10,805	55,893	2,717
SOMERSET 1986	35	195,015			63,406	47,738	53,679	2,178	24,320	3,795
SOMERSET 1995	36	"	83,164	20,562	74,403	40,087	51,534	2,232	22,640	4,220
SUSSEX 1986	37	343,248			35,725	56,406	194,889	12,658	41,511	2,251
SUSSEX 1995	38	"	139,438	9,541	42,811	50,090	194,177	12,790	40,609	2,963
UNION 1986	39	67,373			54,581	230	7,363	1,761	3,120	337
UNION 1995	40	"	4,815	24,733	55,061	134	7,100	1,778	2,883	436
WARREN 1986	41	232,207			26,617	72,775	109,550	4,661	17,532	1,203
WARREN 1995	42	"	119,149	8,025	32,860	66,039	108,887	5,272	17,087	2,193

Appendix D - Watershed Management Area Land Change Table

WMA	WMA_NAME	ACRES	AVAIL_AC	IS_AC	URBAN	AGRICULTURE	FOREST	WATER	WETLAND	BARE LAND
01	Upper Delaware 1986	477,236			53,960	107,843	254,940	15,299	41,992	3,203
	Upper Delaware 1995	"	477,249	15,408	65,068	97,509	253,201	16,045	40,983	4,431
02	Wallkill 1986	133,379			16,297	28,444	64,965	4,189	18,518	966
	Wallkill 1995	"	133,384	4,600	19,604	24,935	65,130	4,247	18,090	1,373
03	Pompton, Wanaque, Ramapo 1986	152,239			34,217	1,146	91,856	9,607	14,179	1,234
	Pompton, Wanaque, Ramapo 1995	"	152,248	11,638	37,138	904	88,952	10,233	13,652	1,360
04	Lower Passaic and Saddle 1986	120,640			98,726	401	13,784	2,393	4,452	884
	Lower Passaic and Saddle 1995	"	120,646	43,184	99,958	255	12,792	2,424	4,093	1,118
05	Hackensack and Pascack 1986	105,633			71,955	321	12,142	11,915	7,719	1,581
	Hackensack and Pascack 1995	"	105,642	33,631	73,057	215	11,650	11,865	7,590	1,256
06	Upper Passaic, Whippany, and Rockaway 1986	231,346			93,369	7,230	83,900	6,756	37,675	2,417
	Upper Passaic, Whippany, and Rockaway 1995	"	231,361	33,622	101,066	5,819	77,959	6,794	36,526	3,183
07	Arthur Kill 1986	114,910			87,575	200	10,330	10,442	4,817	1,546
	Arthur Kill 1995	"	114,922	42,875	88,717	103	10,288	10,473	4,353	976
08	North and South Branch Raritan 1986	299,710			66,485	90,720	111,251	6,011	22,963	2,281
	North and South Branch Raritan 1995	"	299,725	17,142	81,067	79,073	108,497	6,099	22,324	2,651
09	Lower Raritan, South River, and Lawrence 1986	225,028			105,856	23,714	42,485	5,207	40,992	6,775
	Lower Raritan, South River, and Lawrence 1995	"	225,057	44,225	117,004	19,136	39,497	5,330	37,451	6,611
10	Millstone 1986	182,130			46,150	61,730	39,301	1,946	29,749	3,255
	Millstone 1995	"	182,131	16,010	57,387	50,455	39,971	2,033	28,354	3,931
11	Central Delaware 1986	174,026			39,528	65,071	45,613	3,421	19,287	1,107
	Central Delaware 1995	"	174,092	13,268	45,456	58,045	46,828	3,526	18,533	1,639
12	Monmouth 1986	212,985			93,512	24,693	37,191	12,587	40,857	4,486
	Monmouth 1995	"	213,023	32,942	101,453	20,049	35,375	13,107	38,134	5,208
13	Barnegat Bay 1986	425,107			77,891	7,725	163,639	74,862	90,073	11,083
	Barnegat Bay 1995	"	425,108	30,444	88,622	6,345	156,131	74,740	88,608	10,828
14	Mullica 1986	401,268			21,168	31,520	189,118	27,546	129,203	2,795
	Mullica 1995	"	401,269	5,745	24,054	30,463	187,890	27,684	128,113	3,146
15	Great Egg Harbor 1986	376,738			54,418	24,542	156,265	28,327	108,010	5,314
	Great Egg Harbor 1995	"	376,749	18,148	61,181	22,866	151,399	28,504	106,986	5,940
16	Cape May 1986	154,042			21,977	9,409	29,414	17,195	73,401	2,875
	Cape May 1995	"	154,042	7,718	24,908	8,373	27,934	17,465	72,289	3,302
17	Maurice, Salem, and Cohansey 1986	560,923			62,732	173,301	147,176	24,685	146,192	6,378
	Maurice, Salem, and Cohansey 1995	"	560,925	18,800	70,792	167,439	145,031	26,595	143,618	6,989
18	Lower Delaware 1986	250,460			103,861	60,312	37,598	13,425	27,926	7,233
	Lower Delaware 1995	"	250,461	43,701	115,772	50,426	36,000	13,446	26,695	8,016
19	Rancocas 1986	224,503			39,641	42,886	82,076	4,618	52,991	2,291
	Rancocas 1995	"	224,531	14,163	46,647	38,157	80,326	4,832	51,802	2,739
20	Assiscunk, Crosswicks, and Doctors 1986	161,936			30,430	68,389	28,082	3,442	30,153	1,441
	Assiscunk, Crosswicks, and Doctors 1995	"	161,944	11,370	36,560	62,146	28,036	3,572	29,174	2,449

Appendix E - Watershed Management Area-Level Land Change Table with Expanded Wetlands Classification

W_M_A	YEAR	URBAN	AGRICULT	FOREST	WATER	WETLAND NATURAL	WETLAND URBAN	WETLAND AGRICULT	WETLAND DISTURB	BAREN
wma 01	1986	53,620	101,042	254,938	15,299	41,981	340	6,801	437	2,777
wma 01	1995	64,654	90,537	253,201	16,045	40,983	414	6,972	852	3,579
wma 02	1986	16,165	24,460	64,965	4,189	18,514	132	3,984	188	782
wma 02	1995	19,432	20,917	65,130	4,247	18,090	172	4,018	333	1,040
wma 03	1986	34,024	825	91,856	9,607	14,177	193	321	400	836
wma 03	1995	36,922	638	88,952	10,233	13,652	216	266	447	913
wma 04	1986	98,527	383	13,779	2,393	4,450	199	18	188	698
wma 04	1995	99,734	232	12,792	2,424	4,093	224	23	244	874
wma 05	1986	71,859	310	12,142	11,915	7,714	96	11	107	1,479
wma 05	1995	72,948	204	11,650	11,865	7,590	109	11	120	1,136
wma 06	1986	92,226	6,144	83,900	6,756	37,668	1,143	1,086	790	1,634
wma 06	1995	99,857	4,793	77,959	6,794	36,526	1,209	1,026	1,107	2,076
wma 07	1986	87,333	196	10,321	10,442	4,811	242	4	269	1,283
wma 07	1995	88,432	103	10,288	10,473	4,353	285	-	339	637
wma 08	1986	65,912	86,638	111,251	6,011	22,939	573	4,082	268	2,037
wma 08	1995	80,409	75,072	108,497	6,099	22,324	658	4,001	472	2,179
wma 09	1986	104,495	20,259	42,481	5,207	40,910	1,361	3,455	1,311	5,546
wma 09	1995	115,402	15,865	39,497	5,330	37,451	1,602	3,271	1,935	4,676
wma 10	1986	45,410	55,423	39,301	1,946	29,687	740	6,307	492	2,825
wma 10	1995	56,462	44,585	39,971	2,033	28,354	925	5,870	1,036	2,895
wma 11	1986	39,226	59,302	45,613	3,421	19,253	302	5,769	352	789
wma 11	1995	45,013	52,520	46,828	3,526	18,533	443	5,525	573	1,066
wma 12	1986	92,124	21,105	37,189	12,587	40,713	1,388	3,588	857	3,773
wma 12	1995	99,868	16,655	35,375	13,107	38,134	1,585	3,394	1,215	3,993
wma 13	1986	77,055	7,170	163,639	74,862	90,033	836	555	717	10,406
wma 13	1995	87,707	5,735	156,131	74,740	88,608	915	610	1,165	9,663
wma 14	1986	20,973	25,775	189,118	27,546	129,178	195	5,745	205	2,615
wma 14	1995	23,850	24,346	187,890	27,684	128,113	204	6,117	717	2,429
wma 15	1986	53,623	22,806	156,265	28,327	107,989	795	1,736	542	4,793
wma 15	1995	60,263	21,050	151,399	28,504	106,986	918	1,816	1,048	4,892
wma 16	1986	21,398	7,810	29,414	17,195	73,361	579	1,599	424	2,491
wma 16	1995	24,243	6,844	27,934	17,465	72,289	665	1,529	872	2,430
wma 17	1986	61,490	158,981	147,176	24,685	146,149	1,242	14,321	1,564	4,857
wma 17	1995	69,415	153,153	145,031	26,595	143,618	1,377	14,287	2,077	4,912
wma 18	1986	103,573	57,306	37,598	13,425	27,887	288	3,006	2,800	4,472
wma 18	1995	115,280	47,748	36,000	13,446	26,695	492	2,678	3,218	4,798
wma 19	1986	39,361	30,738	82,076	4,618	52,974	280	12,148	354	1,954
wma 19	1995	46,274	26,100	80,326	4,832	51,802	373	12,057	633	2,106
wma 20	1986	30,021	57,898	28,082	3,442	30,144	409	10,491	391	1,059
wma 20	1995	36,042	51,873	28,036	3,572	29,174	499	10,273	885	1,564