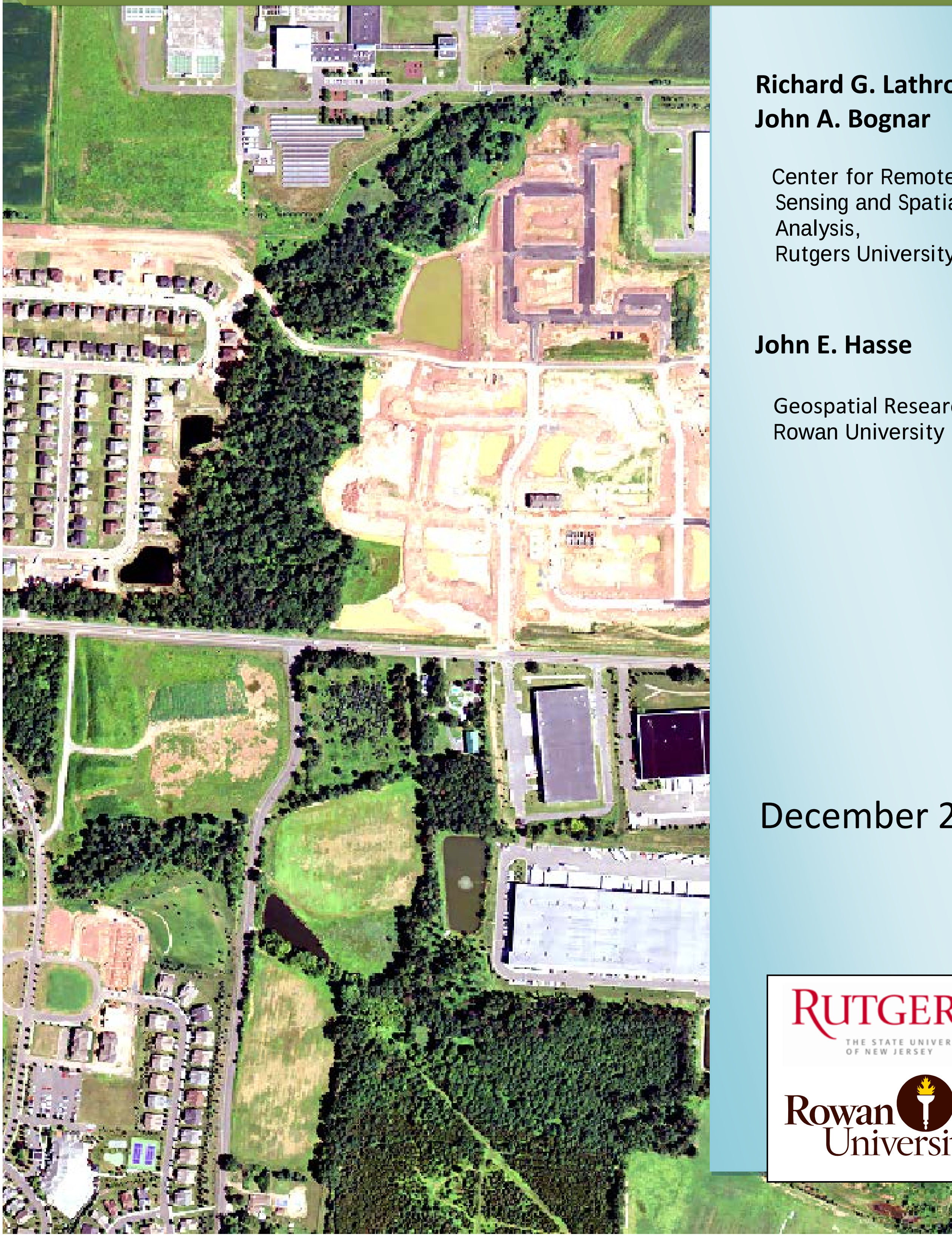
Changing Landscapes in the Garden State:

Land Use Change in NJ 1986 thru 2012



Richard G. Lathrop and
John A. Bognar

Center for Remote
Sensing and Spatial
Analysis,
Rutgers University

John E. Hasse

Geospatial Research Lab,
Rowan University

December 2016

RUTGERS
THE STATE UNIVERSITY OF NEW JERSEY

Rowan University

Changing Landscapes in the Garden State:

Land Use Change in NJ 1986 thru 2012

Richard Lathrop, Director
John Bognar, GIS Coordinator

Grant F. Walton Center for Remote Sensing & Spatial Analysis
Natural Resources & Environmental Sciences Building
School of Environmental & Biological Sciences, Rutgers University
14 College Farm Road
New Brunswick, NJ, USA, 08901-8551
TEL: (732) 932-1582
FAX: (732) 932-2587
WEB: http://crssa.rutgers.edu

John Hasse, Director

Environmental Studies
Geospatial Research Laboratory
Department of Geography
Rowan University
201 Mullica Hill Road
Glassboro, NJ 08028
TEL: (856) 256-4811
FAX: (856) 256-4670
WEB: http://gis.rowan.edu

Acknowledgments

The authors would like to acknowledge the New Jersey Department of Environmental Protection (NJDEP) for the Land Use Land Cover (LULC) data, as the primary data set analyzed in 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, co-production managers Craig Coutros and John M. Tyrawski.

Funding for this project was provided by the New Jersey Agricultural Experiment Station and the USDA National Institute of Food and Agriculture Hatch program.

1 Introduction

Using high-precision aerial photography, the state has created one of the most comprehensive inventories of land composition of any state. The land use mapping initially developed by the NJ DEP in 1986 has just been updated to give a picture of land use patterns and changes in the Garden State up through 2012.

This report is part of an ongoing series of collaborative studies between Rutgers and Rowan Universities examining New Jersey's urban growth and land use change. The DEP New Jersey Land Use/Land Cover Change (NJLULCC) data set utilized for the analysis represents a detailed mapping of the land use and land cover as depicted in high resolution aerial photography that was acquired in the spring of 2012. The imagery was then classified and mapped (Figure 1.1) providing a window into how the Garden State has developed over the past several decades (from 1986 through 2012) and the subsequent consequences to its land base. It views land development patterns from several different angles providing a "report card" on urban growth and open space loss.

New Jersey has a long history as having the highest population density, as well as having the highest percentage of its land area in urban land uses of any state in the United States. New Jersey's population pressure stems from its geographic location, wedged between the nation's largest and 6th largest cities, New York and Philadelphia. These factors have resulted in New Jersey maintaining its status as one of the most rapidly urbanizing states in the nation throughout the past several decades. By the year 2012, over 31% of the state's 5 million acre territory had become urbanized, surpassing any other land use type in total number of acres.

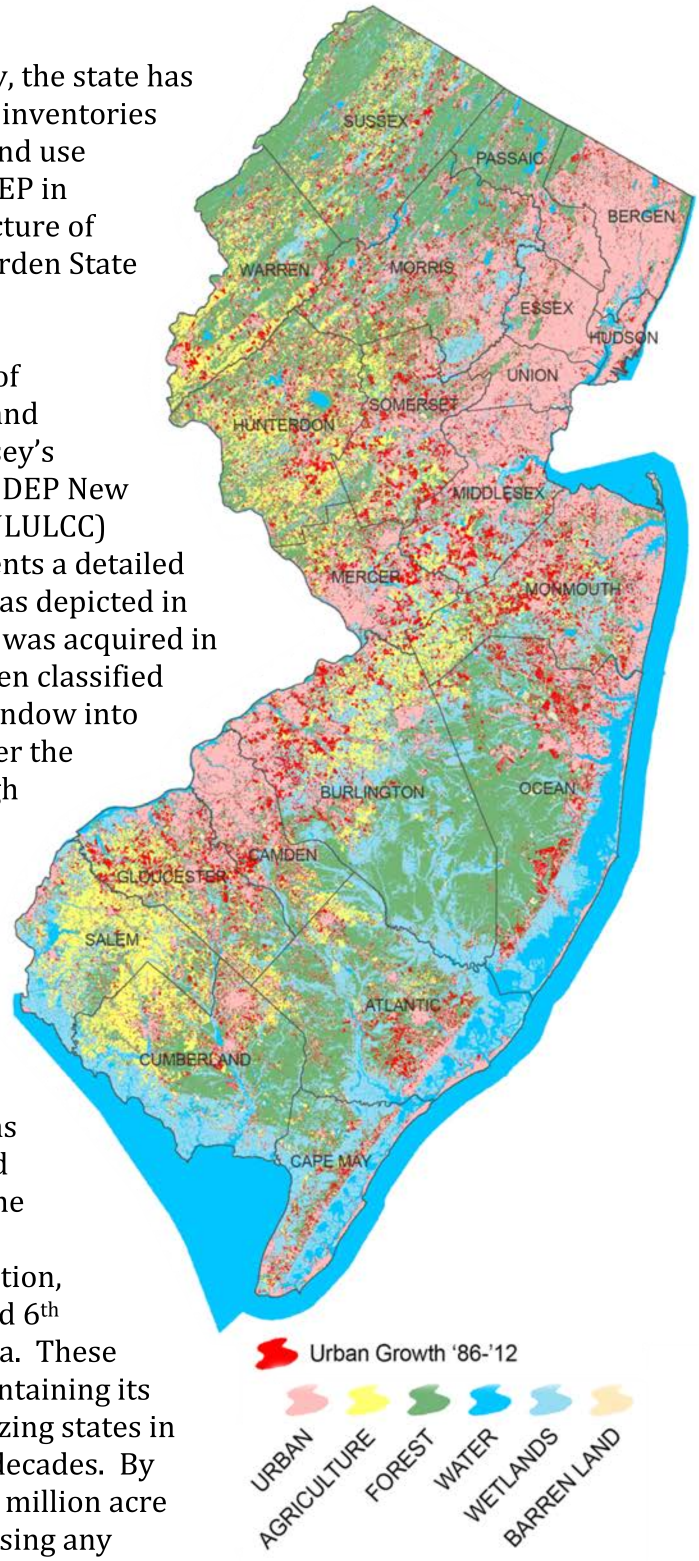


Figure 1.1 Land use and urbanization in New Jersey 1986 through 2012.

2 Basic Level I Land Use Changes

This report relies on the 2012 New Jersey Land Use/Land Cover (LU/LC) dataset released by the New Jersey Department of Environmental Protection (NJDEP) in 2015 (NJDEP, 2015a). Employing the 2012 LU/LC dataset, a Level 1 analysis looks at the broadest categories of landscape change that have occurred statewide over time. A Level 1 analysis groups all land into six broad categories of land use/land cover: *urban*, *agriculture*, *forest*, *water*, *wetlands*, and *barren*. Since the LU/LC datasets utilized in this study were produced for the years 1986, 1995, 2002, 2007 and 2012 an accounting of the number of acres within each of the Level 1 category reveals the changes over this 26 year time period (Table 2.1; Figure 2.1). It should be noted that this most recent mapping of land use in 2012 also included a remapping of land use in 2007. Thus comparing earlier versions of 2007 land use mapping data set vs. the updated 2007 version in the 2015 release, one will find substantive differences in some categories of land use/land cover (please Appendix A for greater detail).

Looking first at *urban (i.e., developed)* land, the analysis reveals that New Jersey continued to urbanize but its historic high pace of development slowed during this last mapping time period. Between the year 2007 and 2012 (T4) New Jersey expanded the amount of urban land by 24,250 acres to a statewide total of 1,558,862 acres total urban land (Table 2.1). Since the time spans between dates in the datasets are different, annualizing the rates of change allows for more direct comparison. Given that the total territory of the state hasn't changed over the time period of interest, when development increases there must also be a corresponding decrease in other categories of land. Normalizing the number of new acres of development by the 5 year time period provides a rate of 4,850 acres of new urban development per year (Figure 1.2; Table 2.2). This represents a 70% decrease in the rate of development from the previous land use mapping period of T3 ('02-'07) when urban development grew at a pace of 16,422 acres per year (Figure 2.2).Given the timing of the Great Recession with a start in 2008 and continuing economic slowdown through the end of the 2012 time period, this slowdown in the rate of urban development is not unexpected.

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

	1986 (acres)	**1995 (acres)**	**2002 (acres)**	**2007* (acres)**	**2012 (acres)**	**26 year Change**	**26 yr % Change**
Urban	1,208,553	1,334,542	1,452,503	1,534,612	1,558,862	+350,309	+29%
Agriculture	744,382	652,335	594,696	559,615	545,813	-198,569	-26.7%
Forest	1,641,279	1,616,522	1,568,809	1,531,128	1,527,372	-113,907	-6.9%
Water	783,260	800,610	803,185	811,468	810,437	+27,177	+3.5%
Wetlands	1,049,269	1,022,253	1,005,636	994,836	992,566	-56,703	-5.4%
Barren	57,223	56,698	59,138	52,216	48,826	-8,397	-14.7%

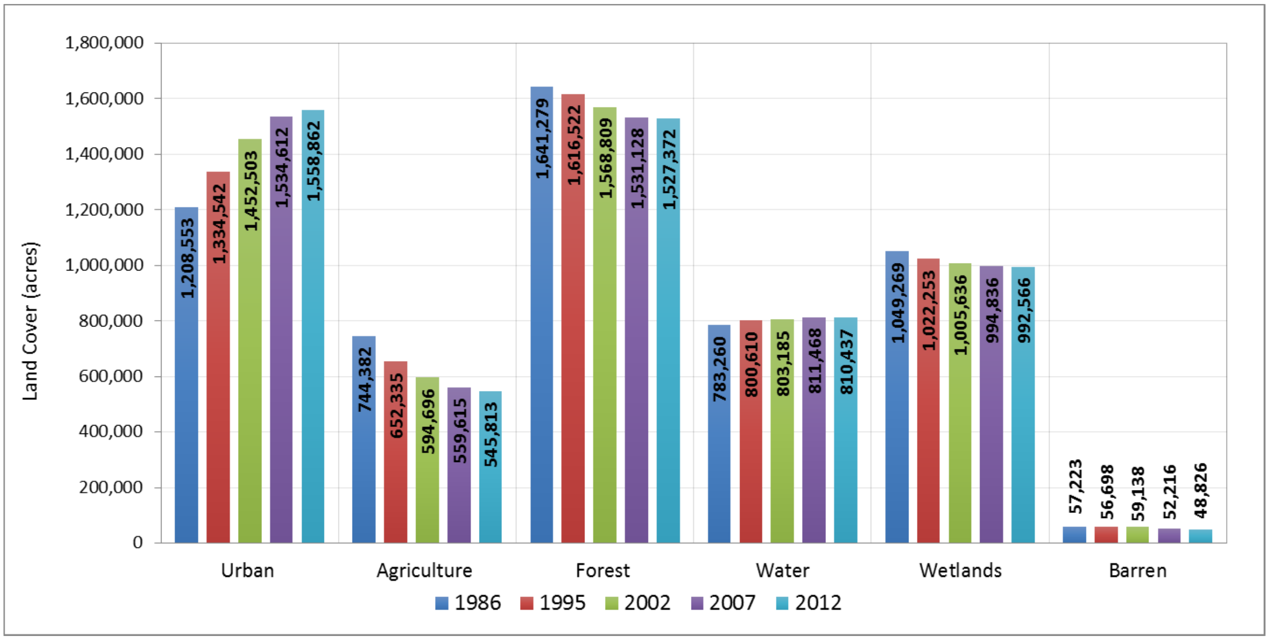


Figure 2.1. Change in each Level 1 category over the 1986, 1995, 2002, 2007 and 2012 time periods.

During the 26 year period since the datasets were first compiled, New Jersey urbanized a massive 350,309 acres (547 sq. mi) of land adding 29% to the state's pre 1986 urban footprint. At the same time, New Jersey added 1.25 million residents to reach a population of over 8.8 million, an increase of only 16% during the same 1986 to 2012 time period. Examining the 1986 to 2007 time period, population growth increased by 14% while urban growth increased by 27%. In other words, NJ's urban growth rate was nearly twice as fast as its population growth rate during the first two decades under consideration. However, looking at only the last 5 years of available data (2007 to 2012), this pattern has switched with a population growth of 2.2% (from 8.68 million in 2007 to 8.87 million in 2012) and an urban growth of 1.6%. (from 1.53 to 1.56 million acres). That is to say that the five year period from 2007 to 2012 saw urbanization occurring at less than the growth rate of population for the first time (during the time period under consideration).

Table 2.2 Annualized rates of land use change.

		Annualized rates of change		
	T1('86-'95)	**T2('95-'02)**	**T3('02-'07revised)**	**T4('07revised-'12)**
Urban	13,999	16,852	16,422	4,850
Agriculture	-10,227	-8,234	-7,016	-2,760
Forest	-2,751	-6,816	-7,536	-751
Water	1,928	368	1,657	-206
Wetlands	-3,002	-2,374	-2,160	-454
Barren Land	-58	349	-1,384	-678

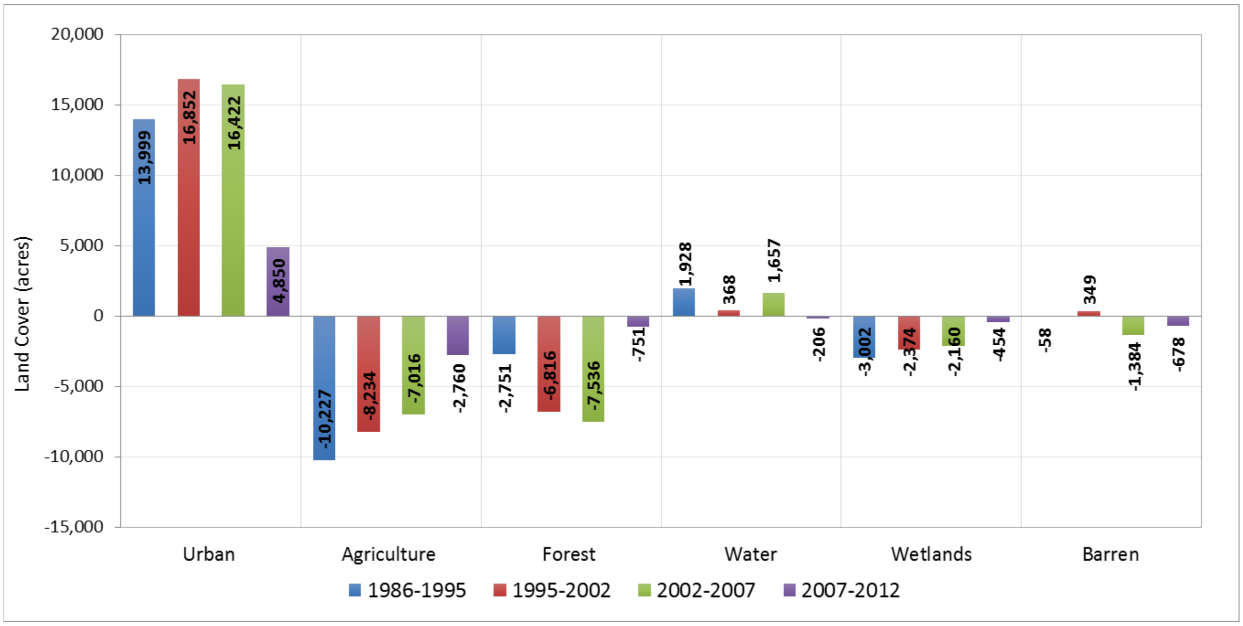


Figure 2.2 Annualized rates of land use change (acres per year).

3 Land Resource Impacts

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

Deforestation:

The open space land category that saw the conversion of the greatest number of acres, primarily to human altered land uses such as urban, barren or agriculture, was *upland forest* with 21,045 acres (32.9 sq. miles) converted statewide during T4 ('07 - '12). This represents a substantial decrease in the rate of forest conversion to 4,209 acres per year in T4 down from a peak of 7,536 acres per year in T3. The T4 rate is similar to the rate of deforestation when compared to T1 net rate of 4,300 acres forest loss per year. The data needs some clarification in that the conversion of forest in some locations has been partially offset by forest gain elsewhere. Thus in T4 the net change in forest was a decrease of only 3,756 acres due to the significant number of acres of agricultural, barren and urban land uses that changed back into forest during T4 (i.e., 21,045 acres lost vs. 17,289 acres gained for a net change of -3,756 acres). Overall, the conversion of forest land due to to urbanization slowed during the 2007 to 2012 (T4) time period at 12,329 acres or 2,466 acres per year as compared to 41,746 acres or 8,349 acres per year of forest urbanized in T3 ('02 – '07).

Looking across the entire 26 year study period, New Jersey lost a net of 113,907 acres (178 sq. mi) of upland forest between 1986 and 2012 representing a 7% loss. If you compare this amount with the prior 2008 report (for the time period 1986 to 2002), it looks like there has been a gain in forest. This difference is an artifact of the 2007 mapping redo where a not inconsiderable amount of what was once mapped as Urban or Agriculture area was remapped as Forest (in the 2012 data set). During the majority of New Jersey's history, upland forest was the predominant land category. However, the total amount of urban land in New Jersey surpassed the total amount of upland forest land by 2007. The conversion of upland forest to urban land uses is especially evident in the periphery of the Pinelands and across the central Highlands (Figure 3.1).

The net effect of landscape changes experience over the past two and half decades is that New Jersey's forested lands experienced significant losses including fragmentation and forest core loss which have significant ecological implications (Franklin 1993; Robinson et al., 1995). Habitat areas and movement corridors are diminished and disrupted when forest stands are broken into smaller and non-connecting sections. In recognition of the need to preserve, if not restore, forest connectivity, the NJ Division of Fish & Wildlife has initiated the "Connecting Habitat Across New Jersey (CHANJ)" project (NJDEP, 2015b). Many species that rely on large blocks of uninterrupted forest core for habitat

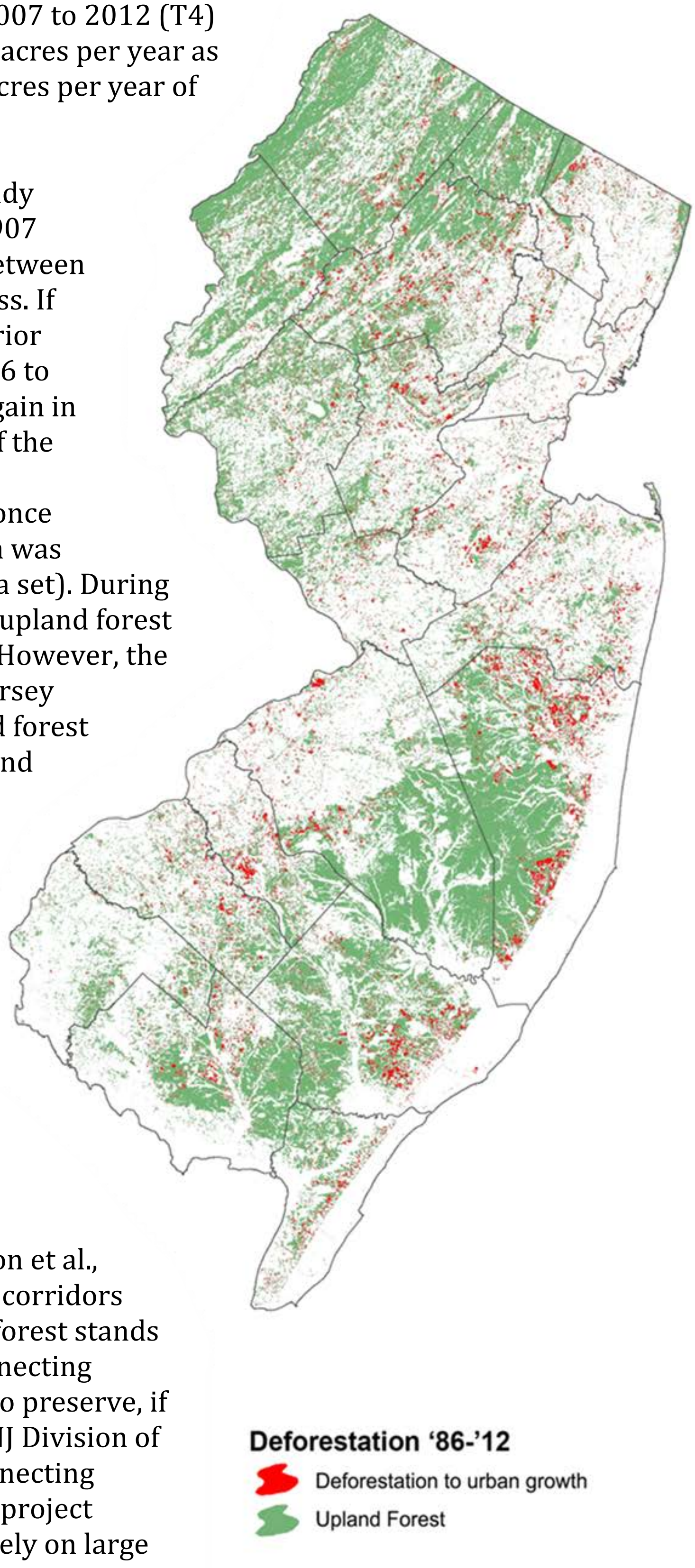


Figure 3.1 Upland Forest loss to urbanization 1986 through 2012

may be adversely affected by its reduction (NJDEP 2008). Forest core in NJ (measured 100 meters inward from forest edge including transitional forests and forested wetlands) also was diminished throughout the study period. During the 1986 to 2012 study period, the state lost an estimated 135,781 acres (212.2 sq. mi) of forest core habitat for an 11.2% loss. The impacts to forest lands revealed in the data suggest that addressing forest loss remains a critically important issue for the Garden State.

Farmland Conversion:

After Upland Forest, Agriculture showed the next highest conversion to other land uses human, primarily barren, forest and urban, with 19,438 acres (32.9 sq. miles) converted statewide during T4 ('07 - '12) (Figure 3.2). The net rate of *agricultural land* conversion has consistently declined over the same period from an annualized rate of 10,277 acres per year in T1 ('86-'95) to 8,234 acres per year in T2('95- '02) to 7,016 acres per year in T3('02 - '07) to the most recent 2,760 acres per year in T4 ('07-'12) (Figure 3.2). This trend is closely related to the declining amount of farmland consumed by urbanization with 6,114 acres per year in T1, 5,149 in T2, 5,124 acres per year in T3 vs. 1,444 acres per year in T4. Likewise, over this time period farmland preservation has made significant gains in protecting farmlands. In addition, to conversion of agricultural land to urban land uses, agricultural land continues to be abandoned and allowed to regenerate to forest, a process that has been going on in New Jersey since the peak of agricultural expansion in the mid to late 1800's. There was a slight downturn in this ongoing phenomena during the T4 mapping period at 1,986 acres per year in T4 vs. 2,435 acres per year in T3. However due to some of the differences in mapping of abandoned

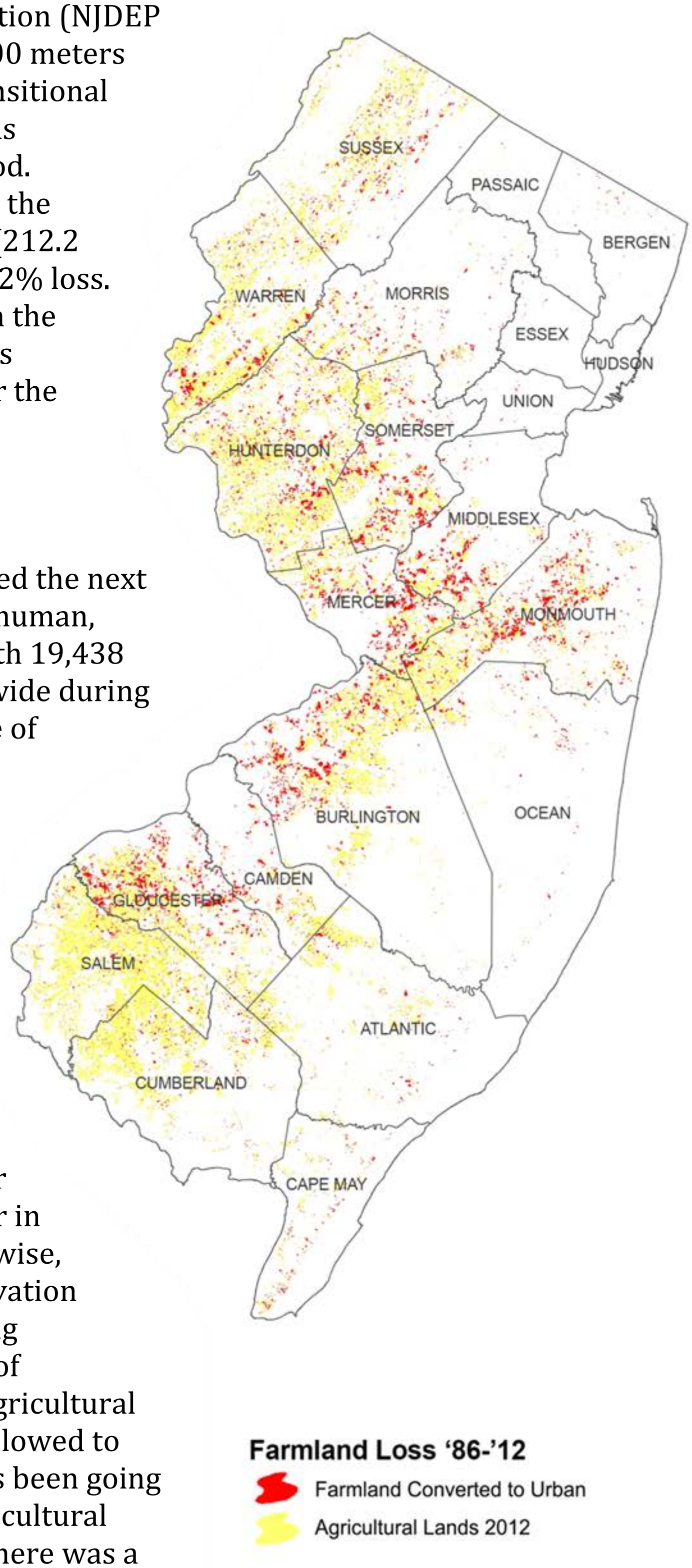


Figure 3.2 Farmland Loss to urbanization 1986 through 2012.

farmland (in T4) the net result is that more land that once was mapped as active cultivation was mapped as inactive (i.e. Old Field category) in 2012. Thus there may be a conflation of real and artifactual change that suggests caution in interpreting too much into this difference.

While the slowing of farmland loss is certainly a positive trend, it must be gauged against the bleak reality of the magnitude of 198,569 acres (310 square miles) or ¼ of the states total farmland that existed in 1986 was converted to other uses over the 26 year period of the study.

Wetlands Loss:

The overall NJDEP Level 1 annualized loss rate has demonstrated a steady decline over the past two and half decades with annualized rate of 3,002 acres per year in T1('86 - '95) to 454 acres per year in T4('07- '12) (Table 1). Examining the more detailed transition matrices (as defined by the H-L categorization, in Appendix B Table B.1 & B.2) reveals a lot of change within and between the various wetland categories. For example, 4,307 acres of emergent wetland converted to wetland forest, while 2,974 acres of wetlands forest converted to emergent wetland (Table B.1). Some of these changes might be real ecological transitions, while others might be due to artifacts of a change in the mapping approach.

New Jersey has a long history of wetlands protection. Coastal wetlands were first received protection under the Wetlands Act of 1970, which was supplemented later with the Coastal Area Facility Review Act of 1973 (CAFRA). The New Jersey legislature passed the Freshwater Wetlands Protection Act in 1987 to "preserve the purity and integrity of freshwater wetlands from unnecessary and undesirable disturbance" (ANJEC, 2004). Even with New Jersey's stringent regulations to protect wetlands, there was still a conversion of 1773 acres of wetlands to urban land use during T4 ('07- '12), with forested wetlands accounting for over half of the loss. However, the net numbers of wetlands conversion mask some of the positive trends that have occurred in wetlands change. Namely there has been a significant drop in rate of wetlands changing into urban classes, from 1,601 acres per year urbanized in T2 to 1,390 acres per year in T3 to 354 acres per year in T4, a 68% drop. So, while wetland losses continue, and are certainly of major concern, the fact that the conversion rates to urban land have dropped significantly is certainly a positive trend that shouldn't be overlooked.

Impervious Surface Gain:

One of the more significant landscape impacts attributable to urbanization is the creation of impervious surface. In nature water is continually moving between the atmosphere, ground water aquifers, lakes and rivers. When land becomes developed, a portion of the parcel is necessarily covered with impervious surface such as asphalt and concrete. The creation of impervious surface changes the natural hydrologic cycle by impeding precipitation infiltration to groundwater while increasing the amount of surface runoff. Storm peaks are amplified in velocity and magnitude changing the load carrying and erosion characteristics of stream channels. These changes have significant environmental consequences including impacts to ground water recharge, frequency and magnitude of flooding, elevated non-point source pollutant levels and degraded biological activity (Arnold and Gibbons, 1996; Kennen, 1998; Brabec et al., 2002). In recognition of the deleterious effects that impervious surface has on watersheds, considerable efforts has been expended to design new development in a way to minimize impervious surface and to retrofit existing development to slow and infiltrate stormwater runoff.

New Jersey's total impervious footprint as of 2012 was 515,106 acres or nearly 805 square miles of concrete and asphalt (Figure 3.3). During the T4 (2007-2012) period, New Jersey generated 6,425 acres (10.0 square miles) of additional impervious surface representing an annual rate of 1,285 acres of impervious surface increase per year or nearly 3 football American fields per day (including end zones). This a decline from an annual rate of 4,270 acres of impervious surface increase (or nearly 9 football fields per day) during time period T3 ('02 – '07).

Growth trends of over the 2007- 2012 time period added one acre of impervious surface for every 3.8 acres of development. In other words, newly developed land is, on average, 26.5% impervious surface as compared to the 23.8% average impervious surface for the prior 21 years. From a low impact development perspective, this can be looked at as a positive sign reflective of a trend towards higher density

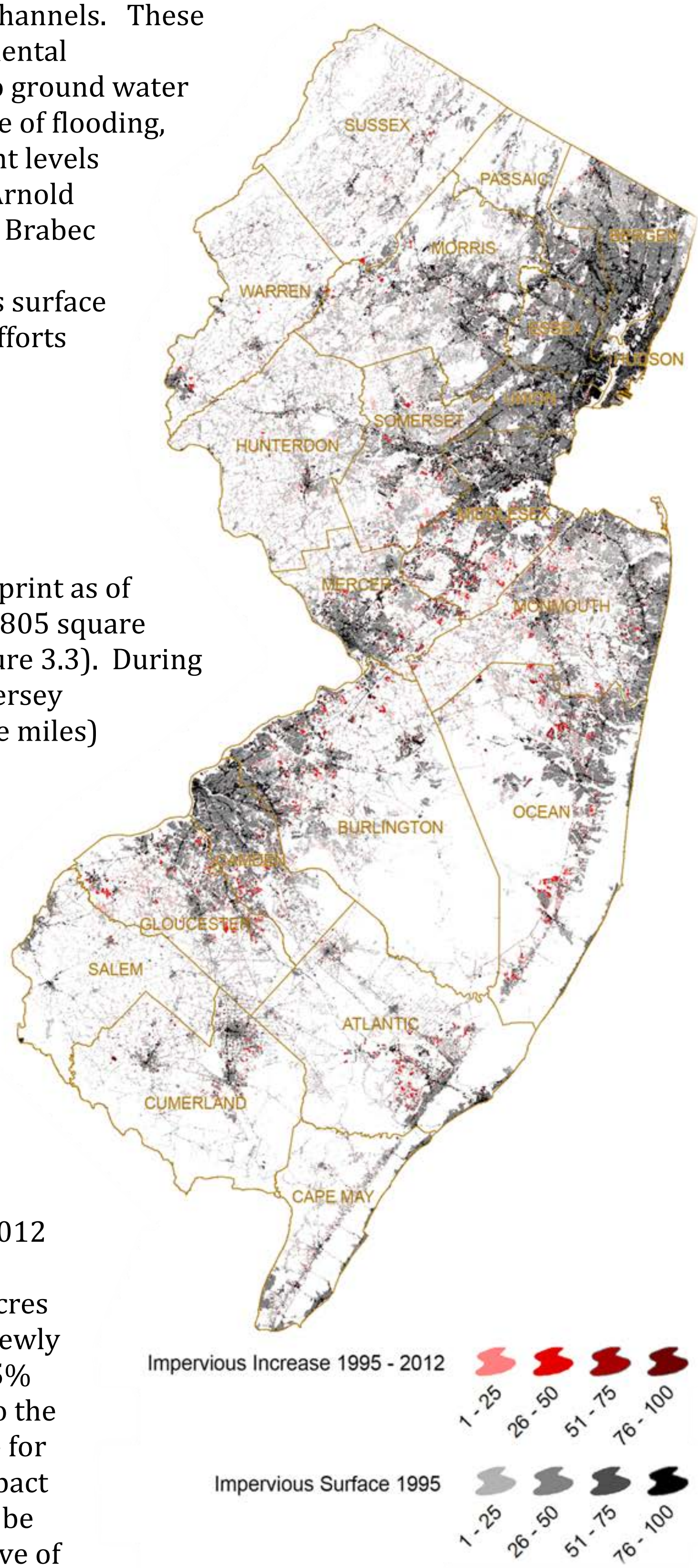


Figure 3.3 Percentage impervious surface cover 1995 through 2012.

development with higher % impervious surface vs. sprawling development with low % impervious surface that consumes more land. It is interesting to note, that during the T4 period, New Jersey added approximately 1,783 acres of stormwater basins (for a total of 15,209 acres). Regulation of impervious surface and improving our management of stormwater runoff may be the key to reining in some of the most deleterious effects of urban development on our water resources.

4 Coastal Resiliency?

New Jersey prides itself on being a coastal state with the 'Shore' an integral part of the Jersey psyche. As elsewhere in the United States and the world, there has been an increasing concentration of population and development in New Jersey's coastal zone. New Jersey's coastal municipalities (as designated by the NJDEP), have grown over 8% between 2002 and 2012 (Table 4.1). The increasing urbanization of the coast has raised red flags over water pollution, coastal habitat loss, restricted public access and increasing vulnerability to severe storms such as hurricanes and nor'easters. In response to the perceived "overdevelopment" in the state's coastal region, the Coastal Area Facilities Review Act (CAFRA) was enacted in 1973. CAFRA empowered the New Jersey Department of Environmental Protection to regulate residential, commercial, industrial, and public development in a specified CAFRA zone that stretches from Delaware Bay up along the Atlantic coast to Raritan Bay. How effective has CAFRA been in slowing coastal development? Looking at the NJLUCCC data alone, one would have to conclude that CAFRA has been only marginally effective. The urban growth In the CAFRA zone increased 6.8 % between 2002 and 2012, which is only slightly less than the NJ statewide average of 7.3% (Table 4.2). While annual development in coastal municipalities was at a slightly higher rate than the statewide average (1.23% vs. 1.13% in T3 and 0.39% vs. 0.32% in T4), development in the CAFRA zone was slightly lower than the statewide average (1.06% vs. 1.13% in T3 and 0.30% vs. 0.32% in T4).

Since the early 1970's, the Federal Emergency Management Agency (FEMA) has defined and mapped flood hazard areas, both interior watersheds and coastal areas, as part of the National Flood Insurance Program (NFIP). The NFIP distinguish different zones based on the probability of occurrence and/or or the severity of impact. For example, the 100 year flood has a 1% probability of occurring in any given year, with the floodplain inundated by such as event mapped as Zone A. The 500 year flood which has a 0.2% chance in any given year is mapped as Zones B or X. The resulting floodplain maps have also been incorporated into state and local development zoning and land use regulations. FEMA has recently replaced the earlier Q3 versions of their floodplains maps with new maps based on higher resolution topographic mapping and improved modeling of potential coastal flooding events. These new Federal Insurance Rate Maps (FIRM) are still considered preliminary and are thus abbreviated as PFIRMs.

While the new PFIRMS were only released subsequent to 2014, they still are instructive in examining the amount of development in coastal flood hazard areas. As of 2012 there were over 41,850 acres of urban land use located in FEMA PFIRM 100 year floodplains (within CAFRA zone) with another 9,935 acres in the mapped 500 year floodplain for a combined total of nearly 51, 800 acres (Table 4.3). Much of this development was already in place before the imposition of increasingly strict floodplain regulations, starting in the mid 1960's through the mid 1980's (i.e., 47,920 acres within the combined 100 and 500 year floodplains was developed before 1986). While still increasing, development was an order of magnitude lower than either the statewide or CAFRA averages, at an annual rate of 0.14% in T3 ('02-'07) and 0.02% in T4 ('07–'12) (Table 4.3).

As revealed by the devastation accompanying Superstorm Sandy in the fall of 2012, prior concern about the vulnerability of New Jersey's coastal development to severe coastal storms was well founded. The storm surge associated with SuperStorm Sandy (referred to as the Sandy Surge zone, as mapped by FEMA) inundated over 400,000 acres (625 sq. mi) of uplands and wetlands across the state of New Jersey. Based on our analysis, over 74,000 acres of urban lands were inundated. While there was little that coastal residents, federal, state and local agencies could do to halt the flooding and associated destruction once Sandy hit the Jersey Shore, it should be noted that the FEMA's floodplain mapping clearly delineated a vast majority of the areas at risk ahead of time. Over 93% of the Sandy surge zone (excluding the Delaware River portion of the state which was not analyzed) falls within mapped 100 and 500 year floodplains of the FEMA Q3 data (357,169 acres in Q3 100 year, 19,059 acres in Q3 500 year and 26,839 aces outside Q3). The PFIRMs cover an even larger percentage at 99% of the Sandy surge zone. Thus it should have come as no surprise that the Jersey shore had a high degree of exposure to a big coastal storm. We had just been lucky up to this point.

One notable success story has been the near complete halting of coastal wetlands destruction. Coastal wetlands – those wetlands along the tidal coastline where dominant vegetation is tolerant of saline conditions – were protected under the Wetlands Act of 1970, as well as the Coastal Area Facility Review Act of 1973 (CAFRA), and the Waterfront Development Law of 1914 (ANJEC, 2004). Prior to the 1970's, thousands of acres of New Jersey salt marshes were dredged and filled for lagoonal-style development (Lathrop and Bognar, 2001). The NJLULCC data set shows a steady decline in the rate of coastal wetland conversion to urban land uses. During the two and half decades between 1986 and 2012, 1020 acres of coastal salt marsh were mapped as converting to urban uses with 30 acres of that change occurring between 2007 and 2012, equating to a percentage loss of less than one half of one percent (or - 0.48%).

Table 4.1. Urban land use change within the NJDEP designated Coastal Municipalities.

2002_ACRES	**2007_ACRES**	**2012_ACRES**	**PCTCH_02_07**	**PCTCH_07_12**	PCTCH_02_12
338,992.00	359,799.39	366,811.49	6.14	1.95	8.21

2002_ACRES	2007_ACRES	2012_ACRES	PCTCH_02_07	PCTCH_07_12	PCTCH_02_12
73,211.71	73,997.64	74,142.72	1.07	0.20	1.27

Table 4.2. Urban land use change within the CAFRA Zone.

2002_ACRES	2007_ACRES	2012_ACRES	PCTCH_02_07	PCTCH_07_12	PCTCH_02_12
164,224.40	172,890.65	175,444.03	5.28	1.48	6.83

Table 4.3. Urban land use change within the FEMA PFIRM 100 and 500 year flood zones.

2002_ACRES	2007_ACRES	2012_ACRES	PCTCH_02_07	PCTCH_07_12	PCTCH_02_12
41,433.48	41,784.47	41,851.23	0.85	0.16	1.01

5 Conclusions

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 and the Department of Geography at Rowan 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. The NJDEP 2012 Update represents the fourth installment charting change in land use/land cover change across the state of New Jersey between 1986-1995, 1995-2002, 200-2007 and now 2007-2012.

Our analysis of the NJDEP 2012 Update land use/land cover data shows a dramatic leveling off of the rapid and extensive land use changes during the last two decades of the 20th century and the beginning of the 21st century. Given, the widespread effects of the Recession on the state's economy, job growth and housing market, it is not unexpected that the rate of new urban development slowed during the T4 ('07- '12) time period. While state's economy took a big hit, the Recession took some of the pressure off the "Race for Open Space" with the annual rate of conversion of agricultural land, upland forest and wetlands significantly slowing during this time period. For the first time, we also saw the % rate of population growth exceed the % rate in the growth of urban land. Other positive signs from a smart growth perspective include an increase in the ratio of new impervious surface vs. newly developed land with 26.5% impervious surface (during T4) as compared to the 23.8% average impervious surface during T1 to T3. While our results support the notion that New Jersey may be entering a new "post-suburban" phase that reflects a stronger push towards smart growth and a focus on urban redevelopment (Hughes and Seneca 2014), it is too soon to tell whether New Jersey has completely kicked the suburban sprawl habit.

In the aftermath of Sandy, there has been an intense focus on issues related to coastal development and infrastructure and questions on how to rebuild in a way that decreases future vulnerability. Present land use policies meant to discourage development in New Jersey's coastal zone have been a mixed bag: CAFRA slowed the pace but did not eliminate "overdevelopment"; likewise FEMA's NFIP discouraged but did not completely eliminate new development in coastal flooding hazard zones. One notable success story has been the near complete halting of coastal wetlands destruction as a result of state and federal government regulation through New Jersey's Wetlands Act of 1970 and later legislation. The exposure of New Jersey's coastal zone, its population and critical infrastructure to coastal flooding hazards is expected to increase under future sea level rise (Lathrop et al., 2014). While this 2012 NJLUCC update assesses only pre-Sandy data, the trend of increased conversion of open space lands to urban land uses in New Jersey's coastal zone, further illuminates why increasing resiliency in our coastal communities will be such a challenge. In other words, if you are in a hole, stop digging.

References

ANJEC. 2004. Freshwater Wetlands Protection in New Jersey: A Manual for Local Officials. Morristown, NJ. 52 pp. http://www.anjec.org/WaterFreshwaterWetlands.htm#manual

Arnold, C. L. Jr. & Gibbons, J.C. (1996). Impervious Surface Coverage – The Emergence of a Key Environmental Indicator. *Journal of the American Planning Association*. 62(2):243-258.

Brabec, E., Schulte, S., & Richards, P. L. (2002). Impervious Surface and Water Quality: A Review of Current Literature and Its Implications for Watershed Planning. *Journal of Planning Literature*. 16(4):499-514.

Franklin, J.F. (1993). Preserving Biodiversity: Species, Ecosystems, or Landscapes? *Ecological Applications*. 3:202-205.

Hasse, J. & Lathrop, R.G. (2008). Tracking New Jersey's Dynamic Landscape: Urban Growth and Open Space Loss 1986-1995-2002. Center for Remote Sensing & Spatial Analysis, Rutgers University, New Brunswick, NJ. pgs, 66. http://www.crssa.rutgers.edu/projects/lc/urbangrowth/index.html.

Hasse, J. & Lathrop, R.G. (2001). Measuring Urban Growth in New Jersey. Center for Remote Sensing & Spatial Analysis, Rutgers University, New Brunswick, NJ. pgs, 41. http://www.crssa.rutgers.edu/projects/lc/urbangrowth/index.html.

Hughes, J.W. and J.J. Seneca. (2014). New Jersey's Postsuburban Economy. Rutgers University Press. New Brunswick, NJ. 152 p.

Kaplan, M.B. and L.J. McGeorge. (2001). Guest Perspectives: The Utility of Environmental Indicators for Policymaking and Evaluation From a State Perspective: The New Jersey Experience. Inside EPA's Risk Policy Report 8(5):39-41.

Kennen, J.G., (1998). Relation of benthic macroinvertebrate community impairment to basin characteristics in New Jersey streams: U.S. Geological Survey Fact Sheet FS-057-98. West Trenton, NJ. pgs, 6.

Lathrop, R.G. and J.A. Bognar. 2001. Habitat Loss and Alteration in the Barnegat Bay Region. Journal of Coastal Research SI 32:212-228.

Lathrop, R.G., J. Bognar, E. Buenaventura, J. Rovito and J. Trimble. 2014. New Jersey Coastal Flood Exposure. http://nebula.wsimg.com/371031cafb163d05b7f380c712c8ed54?AccessKeyId=ACB457 C88AE224CE0A00&disposition=0&alloworigin=1

New Jersey Department of Agriculture: State Agriculture Development Committee (NJSADC). Trenton, NJ. Accessed June 2010. http://www.state.nj.us/agriculture/sadc/.

New Jersey Department of Environmental Protection (NJDEP). (2008). New Jersey Wildlife Action Plan. Division of Fish & Wildlife, Endangered & Nongame Species, Trenton, NJ. http://www.state.nj.us/dep/fgw/ensp/waphome.htm

New Jersey Department of Environmental Protection (NJDEP). (2015a). New Jersey Land Use/Land Cover (LU/LC). Trenton, NJ. Accessed April 2015.
2012 LULC, 2007 LULC (updated) http://www.state.nj.us/dep/gis/lulc12.html
2002 LULC data, 1995 LULC (updated) http://www.nj.gov/dep/gis/lulc02shp.html
1986 LULC data http://www.nj.gov/dep/gis/lulcshp.html

New Jersey Department of Environmental Protection (NJDEPb). (2015). Connecting Habitat Across New Jersey (CHANJ). Division of Fish & Wildlife, Endangered & Nongame Species, Trenton, NJ. http://www.njfishandwildlife.com/ensp/chanj.htm

Robinson, S.K., Thompson, F.R., Donovan, T.M., Whitehead, D.R. & Faaborg, J. (1995). Regional Forest Fragmentation and the Nesting Success of Migratory Birds. *Science.* 267:1987-1990.

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

The 2012 NJDEP Land Use/Land Cover (LULC) data set was produced by the visual interpretation of leaf off color infrared digital ortho-imagery with a spatial resolution of approximately 1 foot. Detailed metadata is available from the NJ DEP which documents the creation of each dataset (www.state.nj.us/dep/gis). Using the 2012 imagery along with the polygonal boundaries of the 2007 NJDEP, LULC changes that took place between 2007 and 2012 were interpreted and polygonal boundaries digitized. In the process, some earlier (i.e., 2007 –era) interpretations and boundaries were refined with the higher resolution imagery and a slight change in interpretation/mapping protocols, leading to two sets of 2007 LULC boundaries, one from the T3 data set and one from the T4 data set. Thus there are discrepancies if one compares the area totals for the year 2007 from the T3 and T4 data sets. For example, the 'old' T3 2007 total for Agriculture = 566,043 while the 'new' T4 2007 total is 559,615 acres, a difference of 6,423 acres or approximately 1.1% (Table A.1 below). Thus to help control for these discrepancies, for the T4 analysis we are only comparing the "new" 2007 LULC boundaries with the 2012 data. Similar differences occur in comparing the 2002, 1995 and 1986 data sets and similar methods are used to control for these differences. While it can be assumed that the 'new' T4 2007 dataset is more accurate than the 'old' 2007 dataset, errors and inconsistencies are inherent in all datasets and must be properly understood by the user.

Table A.1 Differences between the updated and the original 2007 Level I data.

	Quantify Previous 2007 data to Revised 2007	
Lev1_Cat	**Acres_Prev07_to_07**	**% ch_Prev07_to_07**
Urban	1,807.66	0.12
Agriculture	-6,427.82	-1.14
Forest	4,772.97	0.31
Water	1,398.61	0.17
Wetlands	-2,152.08	-0.22
Barren Land	537.65	1.04

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

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

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

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

Table A.2 H-L wetlands categories.

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

Appendix B. Land Use Change Matrix

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

The following tables (Tables B.1 and B.2) provide the net and annualized land use change matrix for changes that occurred in the 2007 – 2012 dataset. These tables allow for the examination of all possible transitions between different land classes. Not only can the total acreage of a particular class be read at the final columns and bottom rows of the tables, the number of acres of change for each possible transition can also be traced. These tables can be studied and compared with the land use change matrix tables for the T1, T2, and T3 datasets, see Hasse and Lathrop 2008 p. 9-14.

Table B.1 H-L class land use/land cover total acres change matrix for T3 vs. T4('07-'12).

(in acres)	**2012**						
2007	**AGRICULTURE**	**BARREN_LAND**	**FOREST**	**URBAN**	**WATER**	**WETAGR**	**WETCOAST**
AGRICULTURE	540,177	2,170	9,931	7,220	84	4	5
BARREN LAND	568	34,428	2,076	13,701	883	4	507
FOREST	3,390	4,970	1,510,083	12,329	200	1	24
URBAN	1,577	4,004	5,130	1,523,726	127	26	9
WATER	13	1,792	39	113	807,132	21	1,138
WETAGR	50	95	11	286	23	71,685	1
WETCOAST	0	542	4	30	1,475	0	196,928
WETDIST	7	173	54	261	102	223	1,351
WETEMERG	10	284	16	174	320	246	45
WETFOREST	20	336	15	895	86	174	4
WETURB	1	31	13	127	4	33	3
Total 2012	***545,813***	***48,826***	***1,527,372***	***1,558,862***	***810,437***	***72,418***	***200,015***

WETDIST	WETEMERG	WETFOREST	WETURB	Total 2007	Loss Ac. 2007-2012	Gain AC: 2007-2012	Net Change
1	4	1	19	**559,615**	19,438	5,636	-13,802
2	36	1	11	**52,216**	17,788	14,398	-3,390
10	76	36	9	**1,531,128**	21,045	17,289	-3,756
2	3	2	4	**1,534,612**	10,886	35,136	24,250
106	1,067	35	11	**811,468**	4,336	3,304	-1,031
277	2,299	42	156	**74,925**	3,240	732	-2,507
291	14	1	1	**199,287**	2,359	3,088	729
4,008	2,911	402	159	**9,653**	5,645	2,288	-3,357
697	98,869	4,307	93	**105,062**	6,193	9,567	3,375
857	2,974	585,866	165	**591,392**	5,526	4,838	-689
44	182	10	14,070	**14,518**	448	627	179
6,296	***108,437***	***590,704***	***14,697***	**5,483,876**			
-3,357	3,375	-689	179	**0**			

Table B.2 H-L class land use/land cover annualized acres change matrix for T3 vs. T4('07-'12).

(in acres) 2007	2012 AGRICULTURE	BARREN_LAND	FOREST	URBAN	WATER	WETAGR	WETCOAST
AGRICULTURE		434	1,986	1,444	17	1	1
BARREN LAND	114		415	2,740	177	1	101
FOREST	678	994		2,466	40	0	5
URBAN	315	801	1,026		25	5	2
WATER	3	358	8	23		4	228
WETAGR	10	19	2	57	5		0
WETCOAST	0	108	1	6	295	0	
WETDIST	1	35	11	52	20	45	270
WETEMERG	2	57	3	35	64	49	9
WETFOREST	4	67	3	179	17	35	1
WETURB	0	6	3	25	1	7	1
Annual Gain	***1,127***	***2,880***	***3,458***	***7,027***	***661***	***146***	***618***
Net Change Annualized	-2,760	-678	-751	4,850	-206	-501	146

WETDIST	WETEMERG	WETFOREST	WETURB	Annual loss	Loss Ac. 2007-2012	Gain AC: 2007-2012	Net An. Change
0	1	0	4	**3,888**	3,888	1,127	-2,760
0	7	0	2	**3,558**	3,558	2,880	-678
2	15	7	2	**4,209**	4,209	3,458	-751
0	1	0	1	**2,177**	2,177	7,027	4,850
21	213	7	2	**867**	867	661	-206
55	460	8	31	**648**	648	146	-501
58	3	0	0	**472**	472	618	146
	582	80	32	**1,129**	1,129	458	-671
139		861	19	**1,239**	1,239	1,913	675
171	595		33	**1,105**	1,105	968	-138
9	36	2		**90**	90	125	36
458	***1,913***	***968***	***125***	**19,381**			
-671	675	-138	36	**0**			