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Land-Use/Land Cover Transitions in Delaware, 2002-2007

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Abstract:

This report quantifies land-use/land cover (LULC) changes in Delaware from 2002 to 2007. The analysis is presented in the same format as prior landscape change analyses dating back to Mackenzie (1989). Recent landscape change patterns are summarized in four tables: one for the entire state, and one for each of Delaware's three counties. The source data are GIS polygon shapefiles; change and no-change areas were calculated and summed by Anderson (1976) level II category. The complete analysis is available as an Excel spreadsheet downloadable from http://www.udel.edu/johnmack/research/datafiles/de_2002_07_lulc_change.xls.

Introduction:

Twenty years ago I quantified LULC transitions in Delaware by manually digitizing blueprint paper maps for each county on a primitive digitizing tablet and compiling the results in a simple spreadsheet. The source maps omitted mapping units less than 15 acres in size. Digitizer error caused biased area measures, but these biases were mostly consistent and correctable. The project took an entire summer to complete, but the resulting Agricultural Experiment Station bulletin was popular enough to get a second printing.

Since that report, Mike Mahaffie from the Office of Statewide Planning Coordination has published updated LULC transition summaries for the time intervals between successive statewide LULC mappings that were derived from digital orthophoto series recorded in 1992, 1997 and 2002. This paper presents the most recent update, summarizing LULC changes occurring in Delaware between 2002 and 2007. The source data were created from statewide orthophotos series recorded in the spring of 2002 and the spring of 2007. The statewide LULC maps are distributed as GIS shapefiles from the Office of Statewide Planning Coordination website at http://stateplanning.delaware.gov/info/lulcdata/2007_lulc.shtml. I split the two statewide shapefiles into separate shapefiles for each county to perform county-level change analyses.

Methods:

Consider two alternative LULC categories denoted i and j , where a_{ij} quantifies gross acreage converted from i in 2002 to j in 2007, and a_{ji} quantifies gross acreage converted from j to i over the same interval. a_{ii} and a_{jj} represent acreages in categories i and j that did not change. The net change is the difference between the gross changes $a_{ii} - a_{jj}$. The entire change process is conveniently summarized in matrix form:

$$A = \begin{bmatrix} a_{ii} & a_{ij} \\ a_{ji} & a_{jj} \end{bmatrix}$$

The off-diagonal elements quantify gross acreage transitions and the diagonal elements quantify acreages that did not change category. In the usual formulation, the row sums represent total starting acreages, and the column sums represent total ending acreages, in each category.

Land development typically follows a sequence of stages, e.g., forest is cleared for cropland; the cropland becomes low-density suburban housing; the low-density housing evolves into a higher-density mix of residential, commercial and other urban land uses. These transitions are not generally reversible, e.g., agriculture rarely displaces housing developments. If the LULC categories are sequenced by development stage, then unidirectional development where $a_{ij} > 0$ and $a_{ji} = 0$ implies a triangular LULC transition matrix.

I reconciled the slightly different classifications in the two mappings to the consistent 25-category scheme shown in Tables 1 through 4. I retained 2-digit Anderson codes for all urban, agriculture, brushland, forest and man-made pond/reservoir polygons, and consolidated other specific water, wetland and beach/barren categories into generalized categories.

After reconciling the classifications, I used ArcGIS to calculate area measures in acres for all polygons in the two shapefiles, and then tested three procedures for quantifying LULC changes.

- (1) Net aggregate changes can be obtained by an ArcGIS Summarize of the LULC code fields in the shapefile attribute tables, outputting the sums of the polygon areas. This procedure yielded the acreage totals reported in Tables 1 through 4. It does not quantify gross transitions into and out of each category.
- (2) A complete LULC transition matrix accounting for all gross changes can be obtained via the ArcGIS TabulateArea tool. This module executes a raster-based calculation of the area of each pairwise combination of 2002 and 2007 categories. Its accuracy depends on the user-defined analytic cellsize. Run on countywide shapefiles at 10-meter resolution, the procedure yielded 25x25 LULC change matrices with row and column sums that matched the area calculations from the Summarize method almost exactly.
- (3) A true LULC change map can be created via an Intersect of the two shapefiles. While this is computationally intensive, it yields precise intersection polygons and change area measures. I combined the 2002 and 2007 LULC codes into a composite change code in the intersection polygon attribute table, and then performed a Summarize of polygon areas by the composite code. I then imported the Summarize table into Excel, used Text-to-Columns to split the composite change code into separate 2002 and 2007 codes again, and created precise 25x25 LULC transition matrices as Excel pivot tables. These change matrices were virtually identical to the matrices created by the TabulateArea tool. The precision of this method exceeded the accuracy of the data.

Results

The 1974-84 change analysis showed that while development was displacing farmland in Delaware, farming was displacing forest land, so the annual net loss of forest land in Delaware was significantly larger than the net loss of farmland. Subsequent change analyses (Mackenzie and McCullough, 1994) showed this pattern continuing into the 1990's. The principal finding from this change analysis for 2002-2007 is that forest losses have slowed dramatically while net farmland losses have increased.

The net change data are presented by county and statewide in Tables 1 through 4. These tables, plus polygon counts and average polygon sizes (indicating landscape fragmentation) are included as worksheets in the downloadable Excel file. The corresponding LULC transition matrices extracted from the TabulateArea output tables are too wide to be presented here, but are also included in the Excel file.

References

Anderson, James R., Ernest E. Hardy, John T. Roach and Richard E. Witmer 1976. *A Land Use And Land Cover Classification System For Use With Remote Sensor Data*. US Geological Survey Professional Paper 964. Washington DC: US Government Printing Office.

Mackenzie, John. 1989. *Land Use Transitions in Delaware, 1974-1984*. Delaware Agricultural Experiment Station Bulletin No. 483 (August, 1989), Newark, DE: College of Agriculture & Natural Resources.

Mackenzie, John and Kevin McCullough. 1994. Delaware Land-Use/Land Cover Transitions 1984–1992. <http://www.udel.edu/FREC/spatlab/lulc/>

Table 1:

Land Cover by Category, New Castle County, Delaware, 2002 and 2007 (Acres)

CODE	CATEGORY	ACRES 2002	ACRES 2007	NET CHANGE	PCT CHANGE
11	Residential	67,728.5	71,767.1	4,038.6	6.0%
12	Commercial	9,883.0	10,222.3	339.4	3.4%
13	Industrial	6,095.9	5,651.8	(444.1)	-7.3%
14	Transportation	7,837.2	7,840.6	3.4	0.0%
15	Utilities	1,413.9	1,412.5	(1.3)	-0.1%
16	Mixed Urban	3,667.7	3,612.8	(54.9)	-1.5%
17	Other Urban	6,166.5	5,831.8	(334.7)	-5.4%
18	Inst/Govt	4,420.8	4,908.4	487.6	11.0%
19	Recreation	6,265.2	6,205.3	(59.9)	-1.0%
21	Cropland/Pasture	69,230.6	63,716.1	(5,514.5)	-8.0%
22	Orchard/Nursery	507.0	454.8	(52.3)	-10.3%
23	Confined Feeding	117.6	156.4	38.9	33.1%
24	Farmsteads	2,813.4	2,775.4	(38.0)	-1.4%
29	Other Agriculture	29.6	29.8	0.2	0.6%
31	Herbaceous Rangeland	634.3	556.4	(77.9)	-12.3%
32	Shrub/Brush Rangeland	3,094.2	3,179.7	85.5	2.8%
33	Mixed Rangeland	662.2	629.5	(32.8)	-4.9%
41	Deciduous Forest	38,425.3	38,113.4	(311.9)	-0.8%
42	Coniferous Forest	724.5	653.9	(70.5)	-9.7%
43	Mixed Forest	2,489.8	2,420.4	(69.3)	-2.8%
44	Clear-cut Forest	2.9	145.4	142.5	4908.1%
50	Open Water	41,547.2	42,495.6	948.3	2.3%
53	Man-Made Reservoirs	2,570.9	2,482.2	(88.7)	-3.4%
60	Wetland	33,331.1	32,751.1	(580.0)	-1.7%
70	Sand/Gravel	4,542.2	6,188.6	1,646.4	36.2%
	TOTALS	314,201.5	314,201.5	-	

Table 2:

Land Cover by Category, Kent County, Delaware, 2002 and 2007 (Acres)

CODE	CATEGORY	ACRES 2002	ACRES 2007	NET CHANGE	PCT CHANGE
11	Residential	35,304.9	41,737.7	6,432.8	18.2%
12	Commercial	3,818.7	4,255.4	436.7	11.4%
13	Industrial	966.6	988.7	22.1	2.3%
14	Transportation	4,076.7	4,282.3	205.7	5.0%
15	Utilities	260.7	281.8	21.0	8.1%
16	Mixed Urban	647.0	666.3	19.3	3.0%
17	Other Urban	1,984.9	1,548.2	(436.6)	-22.0%
18	Inst/Govt	2,168.7	2,281.4	112.7	5.2%
19	Recreation	1,821.0	1,906.3	85.3	4.7%
21	Cropland/Pasture	176,647.3	166,519.8	(10,127.6)	-5.7%
22	Orchard/Nursery	791.6	506.0	(285.6)	-36.1%
23	Confined Feeding	1,352.9	1,554.7	201.8	14.9%
24	Farmsteads	4,949.0	5,391.4	442.3	8.9%
29	Other Agriculture	122.8	111.8	(11.0)	-9.0%
31	Herbaceous Rangeland	1,018.6	969.3	(49.3)	-4.8%
32	Shrub/Brush Rangeland	2,071.6	2,327.3	255.7	12.3%
33	Mixed Rangeland	212.5	163.7	(48.7)	-22.9%
41	Deciduous Forest	16,706.2	16,008.1	(698.1)	-4.2%
42	Coniferous Forest	2,531.8	2,362.1	(169.7)	-6.7%
43	Mixed Forest	17,968.6	17,008.4	(960.2)	-5.3%
44	Clear-cut Forest	309.2	1,204.1	894.9	289.4%
50	Open Water	14,369.3	14,865.6	496.3	3.5%
53	Man-Made Reservoirs	2,808.8	3,030.8	222.0	7.9%
60	Wetland	95,791.1	94,957.4	(833.8)	-0.9%
70	Sand/Gravel	2,222.9	5,995.0	3,772.1	169.7%
	TOTALS	390,923.5	390,923.5	0.0	0.0%

Table 3:

Land Cover by Category, Sussex County, Delaware, 2002 and 2007 (Acres)

CODE	CATEGORY	ACRES 2002	ACRES 2007	NET CHANGE	PCT CHANGE
11	Residential	56,745.7	67,165.4	10,419.6	18.4%
12	Commercial	5,254.4	5,707.3	453.0	8.6%
13	Industrial	1,461.2	1,627.4	166.1	11.4%
14	Transportation	2,656.9	2,713.1	56.2	2.1%
15	Utilities	1,046.8	1,047.2	0.4	0.0%
16	Mixed Urban	3,427.7	3,430.9	3.2	0.1%
17	Other Urban	1,224.9	946.6	(278.2)	-22.7%
18	Inst/Govt	1,623.5	1,933.1	309.6	19.1%
19	Recreation	3,108.3	3,497.7	389.4	12.5%
21	Cropland/Pasture	256,721.7	243,583.8	(13,137.9)	-5.1%
22	Orchard/Nursery	444.5	464.5	20.0	4.5%
23	Confined Feeding	7,759.3	7,962.9	203.6	2.6%
24	Farmsteads	5,935.6	5,890.6	(44.9)	-0.8%
29	Other Agriculture	199.0	229.6	30.6	15.4%
31	Herbaceous Rangeland	2,151.7	1,907.3	(244.4)	-11.4%
32	Shrub/Brush Rangeland	15,454.2	15,801.4	347.2	2.2%
33	Mixed Rangeland	1,138.9	1,405.6	266.7	23.4%
41	Deciduous Forest	4,715.1	4,452.4	(262.7)	-5.6%
42	Coniferous Forest	26,278.4	26,177.7	(100.7)	-0.4%
43	Mixed Forest	73,949.0	70,457.8	(3,491.2)	-4.7%
44	Clear-cut Forest	6,443.5	8,506.1	2,062.6	32.0%
50	Open Water	44,699.0	45,817.5	1,118.6	2.5%
53	Man-Made Reservoir	3,386.2	3,805.2	418.9	12.4%
60	Wetland	113,288.4	109,157.9	(4,130.5)	-3.6%
70	Sand/Gravel	5,318.9	10,743.7	5,424.8	102.0%
	TOTALS	644,432.8	644,432.8	-	0.0%

Table 4:

Land Cover by Category, DELAWARE, 2002 and 2007 (Acres)

CODE	CATEGORY	ACRES 2002	ACRES 2007	NET CHANGE	PCT CHANGE
11	Residential	159,779.2	180,670.2	20,891.0	13.1%
12	Commercial	18,956.0	20,185.1	1,229.0	6.5%
13	Industrial	8,523.8	8,267.9	(255.9)	-3.0%
14	Transportation	14,570.8	14,836.1	265.2	1.8%
15	Utilities	2,721.4	2,741.5	20.1	0.7%
16	Mixed Urban	7,742.4	7,709.9	(32.5)	-0.4%
17	Other Urban	9,376.2	8,326.6	(1,049.6)	-11.2%
18	Inst/Govt	8,213.0	9,123.0	910.0	11.1%
19	Recreation	11,194.4	11,609.3	414.9	3.7%
21	Cropland/Pasture	502,599.6	473,819.7	(28,779.9)	-5.7%
22	Orchard/Nursery	1,743.1	1,425.3	(317.8)	-18.2%
23	Confined Feeding	9,229.8	9,674.0	444.3	4.8%
24	Farmsteads	13,698.0	14,057.4	359.4	2.6%
29	Other Agriculture	351.4	371.2	19.8	5.6%
31	Herbaceous Rangeland	3,804.6	3,433.0	(371.6)	-9.8%
32	Shrub/Brush Rangeland	20,620.1	21,308.4	688.3	3.3%
33	Mixed Rangeland	2,013.6	2,198.8	185.2	9.2%
41	Deciduous Forest	59,846.6	58,573.9	(1,272.7)	-2.1%
42	Coniferous Forest	29,534.6	29,193.7	(340.9)	-1.2%
43	Mixed Forest	94,407.4	89,886.6	(4,520.8)	-4.8%
44	Clear-cut Forest	6,755.6	9,855.7	3,100.0	45.9%
50	Open Water	100,615.5	103,178.7	2,563.2	2.5%
53	Man-Made Reservoir	8,765.9	9,318.1	552.2	6.3%
60	Wetland	242,410.7	236,866.4	(5,544.3)	-2.3%
70	Sand/Gravel	12,084.0	22,927.3	10,843.3	89.7%
	TOTALS	1,349,557.8	1,349,557.8	-	0.0%