

A COMPARISON OF THE 1992 AND 2001 NATIONAL LAND COVER DATASETS IN THE LAMPREY RIVER WATERSHED, NH

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ABSTRACT

In 1992 and 2001, the Multi-Resolution Land Characteristics (MRLC) Consortium used Landsat imagery of the entire conterminous US to create two National Land Cover Datasets (NLCDs). Initially, the goal was to create the 2001 NLCD from a similar classification scheme as was implemented in 1992 to make the two datasets relatively compatible. However, to improve the accuracy of the 2001 NLCD, slightly different ancillary data and map class definitions were used, making a comparison problematic. Currently, the MRLC Consortium warns against trying to directly compare these datasets and have created a Land Cover Change Retrofit product, a land cover change map between the two years with Anderson I level map classes, as a possible solution. However, there are still many applications where the original 1992 and 2001 NLCDs could prove very useful for evaluating land cover change, if there was a way of correcting for the differences in classification schemes. To investigate this issue, we performed a land cover change analysis for the Lamprey River Watershed in southern New Hampshire. We found that the developed land class had the highest amount of error associated with the change in classification schemes for this region. Local sources report an estimated increase of 930 hectares of developed land per year during the 1992-2001 time frame, while the change analysis indicated that 56% of the developed land classified in 1992 changed to some other classification in 2001. Other classes, such as the forest category, do not appear to have been as affected by the change in classification schemes, since this category maintained similar definitions in both datasets. Therefore, the goal of our project was to evaluate the percent of the calculated "land cover change" that is actually due to change in land cover, and what is due to change in classification schemes.

Key words: National Land Cover Dataset, Land Cover Change Retrofit product

INTRODUCTION

In 1992 the Multi-Resolution Land Characteristics (MRLC) Consortium formed to gather Landsat TM imagery of the entire conterminous United States. These images were then used to create a land cover dataset called the 1992 National Land Cover Dataset (NLCD). Again in 1999, another MRLC Consortium was formed in order to purchase more Landsat TM imagery to be used to create a 2001 NLCD. These two National Land Cover Datasets can be used for a variety of applications, both independently and together. However, the use of these datasets for land cover change analysis was predicted to be one of the more valuable utilizations of this imagery.

After the creation of the 2001 NLCD and upon further investigation, the MRLC Consortium concluded that the improvements they had made in their mapping techniques for 2001 had made it nearly impossible to compare the 1992 and 2001 datasets (Fry et. al., 2009). Therefore, the use of these data for change detection is problematic. In 1992 an unsupervised classification system was used to create spectral classes for each of the Landsat TM images (Vogelmann et. al., 2000). These classes were then given labels using a hybrid classification system and classes approximately equivalent to the classes in the Anderson Level II system (Table 1a) (Anderson et. al., 1976). However, in the 2001 NLCD, advancements in classification systems prompted the MRLC Consortium to use a decision tree method for classifying the Landsat imagery, rather than the unsupervised and hybrid methods (Homer et. al., 2004). New technologies also allowed the MRLC Consortium to model imperviousness, or percent impervious surface cover, for each image prior to labeling the developed section. Therefore, because of the change in classification methods, the group also modified some of the class definitions to account for the different labeling techniques (Table 1b).

Table 1a and 1b. Table 1a expresses the different land classes and their numeric identifiers used in 1992 to create the 1992 NLCD. Table 1b expresses the land classes used to create the 2001 NLCD. Both groups are at the Anderson II level.

Table 1a.

1992 NLCD Classes	
11	Open Water
12	Perennial Ice/Snow
21	Low Intensity Residential
22	High Intensity Residential
23	Commercial/Industrial/Transportation
31	Bare Rock/Sand/Clay
32	Quarries/Strip Mines/Gravel Pits
33	Transitional
41	Deciduous Forest
42	Evergreen Forest
43	Mixed Forest
51	Shrubland
61	Orchards/Vineyards/Other
71	Grasslands/Herbaceous
81	Pasture/Hay
82	Row Crops
83	Small Grains
84	Fallow
85	Urban/Recreational Grasses
91	Woody Wetlands
92	Emergent Herbaceous Wetlands

Table 1b.

2001 NLCD Classes	
11	Open Water
12	Perennial Ice/Snow
21	Developed, Open Space
22	Developed, Low Intensity
23	Developed, Medium Intensity
24	Developed, High Intensity
31	Barren Land (Rock/Sand/Clay)
41	Deciduous Forest
42	Evergreen Forest
43	Mixed Forest
51	Dwarf Scrub
52	Shrub/Scrub
71	Grassland/Herbaceous
81	Pasture/Hay
82	Cultivated Crops
90	Woody Wetlands
95	Emergent Herbaceous Wetlands

Since the differences in the classification techniques and class definitions make it unwise to directly compare the 1992 and 2001 NLCDs, the group decided to create a Land Cover Change Retrofit (LCCR) product. To create this product, both the 1992 and the 2001 imagery were reclassified at a modified Anderson Level I using a decision tree method (Anderson et. al., 1976). The 1992 imagery was reclassified using the 2001 approach so that the two would be compatible for comparison. The reclassification resulted in two maps, one representing the land cover from 1992 and the other representing the land cover of 2001. Both of these maps were given classes from a modified Anderson Level I list, which is made up of fairly broad land cover classes (Table 2).

Table 2. The modified Anderson Level I classes used to create the LCCR product.

Change Product Classes	
1	Open Water
2	Urban
3	Barren
4	Forest
5	Grassland/Shrub
6	Agriculture
7	Wetlands
8	Ice/Snow

The objective of this study is to determine how well the LCCR product remedied the discrepancies between the 1992 and 2001 NLCDs and whether it is a usable source for land cover change in the Lamprey River Watershed, in seacoast New Hampshire.

METHODS AND RESULTS

In order to compare the Land Cover Change Retrofit (LCCR) product with the 1992 and 2001 NLCDs, the sets of NLCD maps of New Hampshire were added to a project in ArcMap 9.3 and trimmed to the Lamprey River Watershed. The original NLCDs, with classes at Anderson Level II, were then recoded and given new labels using the modified Anderson Level I class descriptions defined in the LCCR product (the LCCR product is only at Anderson Level I) (Fry et. al., 2009) (Table 3). Therefore, the recode ensured that both of the NLCDs had labels derived from the same Anderson Level I classes and definitions. Once both the 1992 and the 2001 datasets had the same labels, a change analysis was performed in order to find areas of change between the two years (Table 4). The change analysis is represented by a change matrix so that the major diagonal represents the area of no change between the two years while the off diagonal boxes represent the areas that changed classes between the two classification years.

Table 3. The Anderson Level I crosswalk with the original 1992 and 2001 NLCD classes.

1992 NLCD Class		2001 NLCD Class		Anderson Level I Class
11	Open Water	11	Open Water	1 Open Water
12	Perennial Ice/Snow	12	Perennial Ice/Snow	8 Ice/Snow
85	Urban/Recreational Grasses	21	Developed, Open Space	2 Urban
21	Low Intensity Residential	22	Developed, Low Intensity	2 Urban
22	High Intensity Residential	23	Developed, Medium Intensity	2 Urban
23	Commercial/Industrial/Transportation	24	Developed, High Intensity	2 Urban
31	Bare Rock/Sand/Clay	31	Barren Land (Rock/Sand/Clay)	3 Barren
32	Quarries/Strip Mines/Gravel Pits			3 Barren
33	Transitional			3 Barren
41	Deciduous Forest	41	Deciduous Forest	4 Forest
42	Evergreen Forest	42	Evergreen Forest	4 Forest
43	Mixed Forest	43	Mixed Forest	4 Forest
51	Shrubland	51	Dwarf Scrub	5 Grassland/Shrub
		52	Shrub/Scrub	5 Grassland/Shrub
61	Orchards/Vineyards/Other			6 Agriculture
71	Grasslands/Herbaceous	71	Grassland/Herbaceous	5 Grassland/Shrub
81	Pasture/Hay	81	Pasture/Hay	6 Agriculture
82	Row Crops	82	Cultivated Crops	6 Agriculture
83	Small Grains			6 Agriculture
84	Fallow			6 Agriculture
91	Woody Wetlands	90	Woody Wetlands	7 Wetlands
92	Emergent Herbaceous Wetlands	95	Emergent Herbaceous Wetlands	7 Wetlands

Table 4. A change matrix showing the differences between the 1992 NLCD and the 2001 NLCD. All boxes show total area in hectares. The boxed diagonal represents areas of no change between 1992 and 2001 while boxes in the off diagonal are areas of change.

		2001 NLCD Data (ha)							
		Open Water	Urban	Barren	Forest	Grassland/Shrub	Agriculture	Wetlands	Total
1992 NLCD Data (ha)	Open Water	698.70	22.52	4.96	316.71	30.09	22.01	278.66	1373.66
	Urban	13.47	1249.39	84.74	936.53	132.95	304.12	131.51	2852.71
	Barren	1.13	73.43	25.31	40.40	20.60	61.17	16.25	238.29
	Forest	155.59	2709.06	136.23	34936.03	986.96	1535.01	2281.30	42740.18
	Grassland/Shrub	0.00	0.57	0.49	3.45	2.79	1.64	0.15	9.08
	Agriculture	1.89	786.06	185.77	1006.44	110.32	1515.55	82.81	3688.84
	Wetlands	43.74	532.41	35.84	2346.69	206.68	264.76	1041.24	4471.37
	Totals	914.52	5373.44	473.35	39586.24	1490.41	3704.27	3831.92	55374.14

Unfortunately, because the classification process changed between the creation of the 1992 NLCD and the 2001 NLCD, there is no way of determining which differences are due to classification process changes and which are due to actual land cover changes. Comparison of the two land cover maps show very low agreement, with a KHAT statistic of 0.34 (Congalton et al., 1983). Therefore, it is likely that something more than land cover change is causing the large change in the datasets. An investigation of Figure 1 shows the largest discrepancies can be observed in the urban category, where over 56% of the area classified as Urban in 1992 was classified as something else in 2001. Although the total area of urban increased between 1992 and 2001, only around 44% of the original urban area remained the same between the two years. Other studies of the Lamprey River Watershed indicate that population in this area has increased 6.8% from 1990 to 1998 and number of housing units in the state has increased 55% from 1980 to 1998, without a substantial loss in developed land (Sundquist and Stevens, 1999). Therefore, the urban areas should have increased between 1992 and 2001, as shown, but without the significant loss of urban areas to other classes such as forest or agriculture. In total, around 28% of the total Lamprey River Watershed changed labels between 1992 and 2001, which for an area such as the Lamprey River Watershed, is far above the expected amount of land cover change (Figure 1).

Changed Areas as Observed by the Original NLCD Data in the Lamprey River Watershed

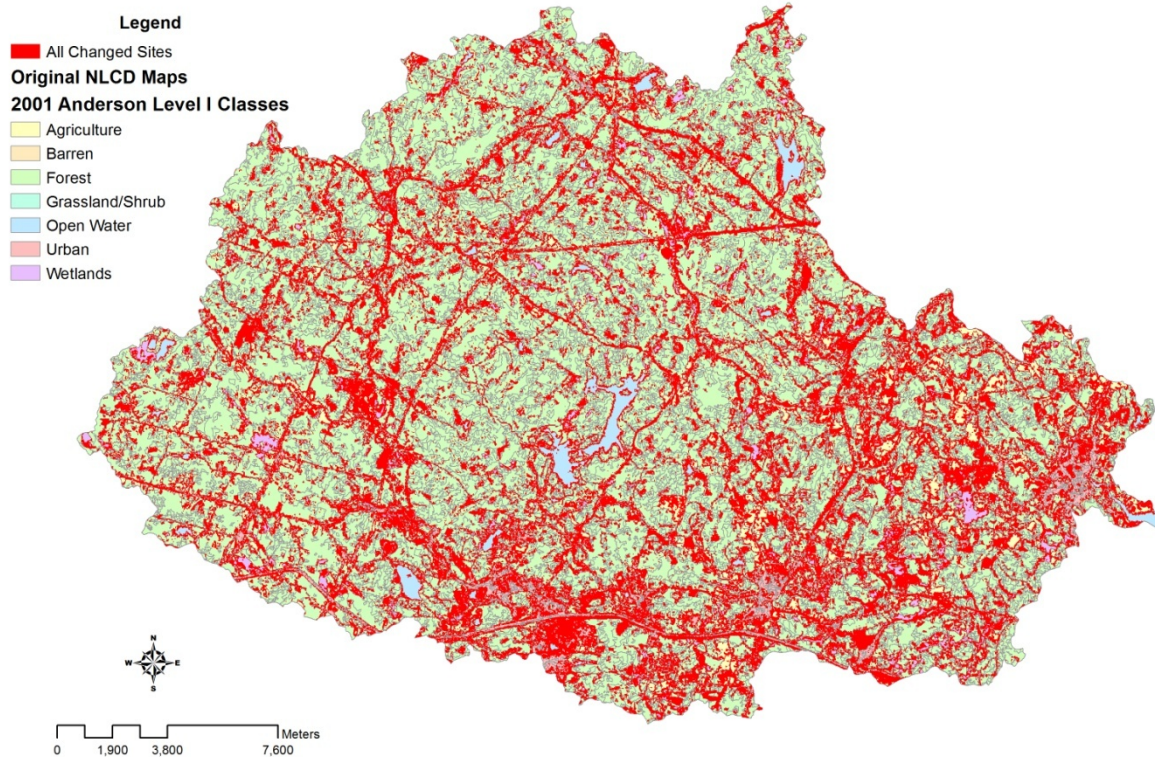


Figure 1. The areas of “land cover change” as determined by the 1992 and 2001 NLCDs. The red represents all of the area that was labeled one class in 1992 and another class in 2001.

To test whether the Land Cover Change Retrofit product adequately solved some of the classification issues observed between the 1992 and 2001, another change analysis was completed for the LCCR product. The modified Anderson I labels given in the 1992 reclassified map and the 2001 labels were again compared using a change matrix (Table 5). It is obvious from this table that far less of the habitat changed for the Lamprey River Watershed using this analysis. Using the change product to determine how much land cover changed, only around 2% of the total area changed classes between 1992 and 2001 (Figure 2). The 2001 and the 1992 LCCR products are in high agreement, or match very well, with a K_{HAT} statistic of 0.96 (Congalton et. al., 1983). The most notable change in the change analysis was the lack of change from urban to other categories from 1992 to 2001. Around 99% of the 1992 urban areas remained urban in 2001, which is more typical of urban development in New Hampshire.

Table 5. A change matrix showing the differences between the 1992 classes and the 2001 classes given in the LCCR product. All boxes show total area in hectares. The boxed diagonal represents areas of no change between 1992 and 2001 while boxes in the off diagonal are areas of change.

		2001 LCCR Product Data (ha)							
		Open Water	Urban	Barren	Forest	Grassland/Shrub	Agriculture	Wetlands	Total
1992 LCCR Product Data	Open Water	904.15	0.00	0.00	1.89	8.08	2.36	7.92	924.40
	Urban	0.00	5135.37	4.62	20.45	5.04	17.55	13.15	5196.18
	Barren	0.00	0.00	392.87	0.00	0.00	0.00	0.00	392.87
	Forest	5.36	296.32	82.23	39667.57	209.75	279.80	59.48	40600.52
	Grassland/Shrub	0.00	0.00	0.00	0.00	1218.63	0.00	0.00	1218.63
	Agriculture	0.00	0.00	0.00	0.00	0.00	3342.86	0.00	3342.86
	Wetlands	0.61	0.00	0.00	5.09	0.00	0.81	3692.17	3698.68
	Totals	910.12	5431.69	479.72	39695.00	1441.50	3643.38	3772.72	55374.14

Changed Areas as Observed by the LCCR Product in the Lamprey River Watershed

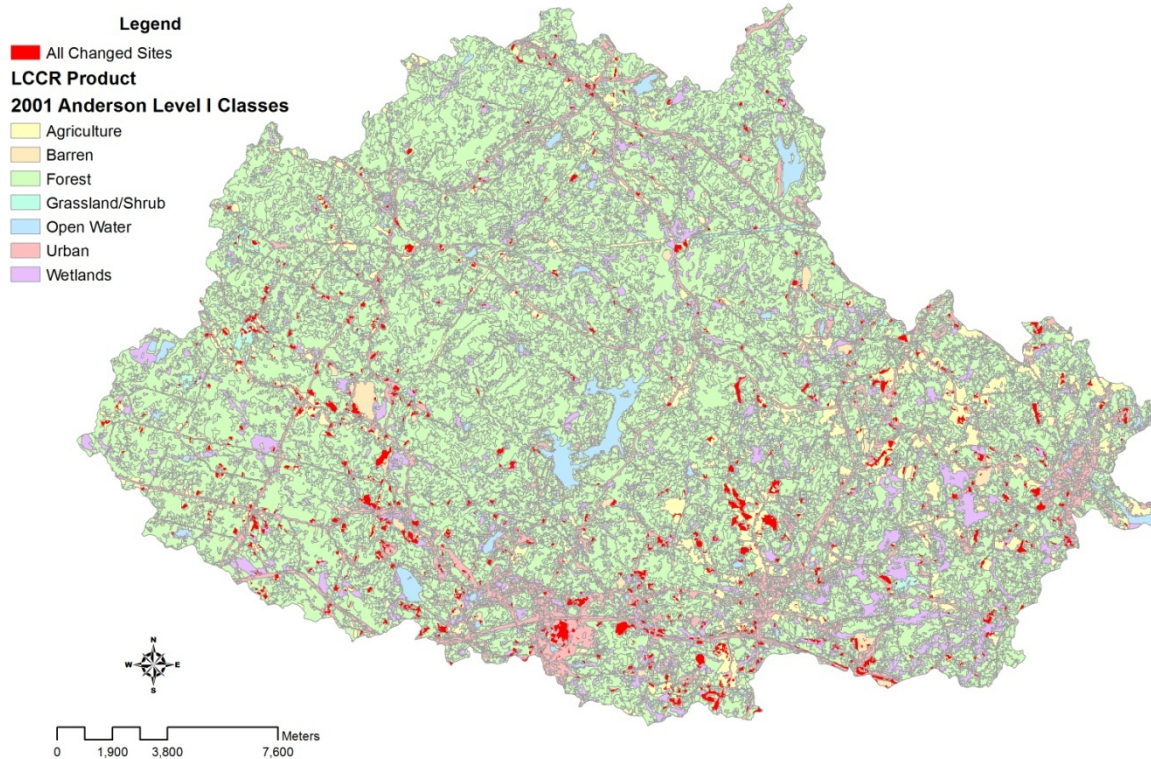


Figure 2. The areas of “land cover change” as determined by the LCCR product. The red represents all of the area that was labeled one class in 1992 and another class in 2001.

CONCLUSIONS

Although the Land Cover Change Retrofit product did give more reasonable estimates of land cover change between 1992 and 2001, the modified Anderson Level I classes are very broad and only useful for studies looking at general changes in the Lamprey River Watershed rather than specific changes in types of developed or forested land. The estimates of change provided by the LCCR product may have actually been low as compared with actual land cover change in the area. The low estimate of land cover change may be due to the very general definitions of the

land cover classes, or the actual mechanism for creating the LCCR maps. The 2001 land cover classes were used to create the 1992 land cover maps for the LCCR product by re-labeling the areas with definite spectral differences, rather than doing two completely separate reclassifications and then completing a change analysis. Also, the minimum mapping unit used for the LCCR product was 5 pixels, or around 150 m², so that the spectral reflectance being measured is averaged over a fairly large space, making small changes in land cover impossible to detect. This lead to a very low agreement between the 1992 NLCD and the 1992 LCCR product ($K_{HAT}=0.39$) and an average agreement between the two 2001 datasets ($K_{HAT}=0.61$).

Therefore, it seems unlikely that the LCCR product will be very useful for land cover change detection at the scale of the Lamprey River Watershed, however, for the conterminous United States, it is probably a very good general estimate for change. Further investigations should be completed to determine whether a comparison at the Anderson Level II classification system might be possible. For example, in the Lamprey River Watershed, only about 75% of the total area remained in the same in the two 1992 land cover classifications, while 82% remained the same between the two 2001 classifications (see Appendix A). Different classes had different likelihoods for remaining the same between classification types (either the NLCD or the LCCR classification), for instance the forest class increased only slightly (5%) between the two 1992 classifications and even less (0.2%) between the two 2001 classifications. On the contrary, the urban class increased by 82% in the 1992 reclassification and 1% between the 2001 classifications (see Appendix A). This shows that some of the classes, like the forest classes may be close enough to compare at Anderson Level II, while others, like the urban category need further investigation.

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APPENDIX A

Table 6. The matrix is a comparison of the 1992 NLCD and the 1992 LCCR product, both with Anderson Level I classes. Along the boxed diagonal are the areas (in hectares) that are the same for both datasets and the numbers in the off diagonal are the areas of observed differences between the two.

		1992 NLCD Data (ha)							
		Open Water	Urban	Barren	Forest	Grassland/Shrub	Agriculture	Wetlands	Total
1992 LCCR Change Data	Open Water	820.48	9.53	0.42	63.35	0.00	1.05	29.57	924.40
	Urban	16.91	1345.17	79.76	2395.25	0.59	822.64	535.84	5196.18
	Barren	5.33	80.57	26.73	57.70	0.25	196.46	25.83	392.87
	Forest	187.75	867.59	30.50	36285.09	3.41	842.77	2383.42	40600.52
	Grassland/Shrub	27.77	135.06	23.64	737.09	3.70	93.48	197.87	1218.63
	Agriculture	10.74	292.56	59.87	1123.41	0.74	1665.40	190.15	3342.86
	Wetlands	304.67	122.23	17.37	2078.29	0.38	67.05	1108.68	3698.68
	Totals	1373.66	2852.71	238.29	42740.18	9.08	3688.84	4471.37	55374.14

Table 7. The matrix is a comparison of the 2001 NLCD and the 2001 LCCR product, both with Anderson Level I classes. Along the boxed diagonal are the areas (in hectares) that are the same for both datasets and the numbers in the off diagonal are the areas of observed differences between the two.

		2001 NLCD Data (ha)							
		Open Water	Urban	Barren	Forest	Grassland/Shrub	Agriculture	Wetlands	Total
2001 LCCR Change Data	Open Water	709.21	11.13	0.93	126.27	2.30	6.74	53.54	910.12
	Urban	16.85	3411.52	22.38	1448.76	115.32	313.44	103.42	5431.69
	Barren	0.73	24.50	365.37	51.11	13.29	11.19	13.54	479.72
	Forest	140.83	1409.52	50.73	35435.11	623.27	771.83	1263.70	39695.00
	Grassland/Shrub	2.47	113.22	11.14	582.64	604.74	72.74	54.56	1441.50
	Agriculture	2.19	307.01	10.00	772.72	57.89	2452.81	40.77	3643.38
	Wetlands	42.24	96.55	12.81	1169.62	73.60	75.52	2302.39	3772.72
	Totals	914.52	5373.44	473.35	39586.24	1490.41	3704.27	3831.92	55374.14