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Thematic accuracy assessment of the 2011 National Land Cover Database (NLCD)

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ABSTRACT

Accuracy assessment is a standard protocol of National Land Cover Database (NLCD) mapping. Here we report agreement statistics between map and reference labels for NLCD 2011, which includes land cover for ca. 2001, ca. 2006, and ca. 2011. The two main objectives were assessment of agreement between map and reference labels for the three, single-date NLCD land cover products at Level II and Level I of the classification hierarchy, and agreement for 17 land cover change reporting themes based on Level I classes (e.g., forest loss; forest gain; forest, no change) for three change periods (2001–2006, 2006–2011, and 2001–2011). The single-date overall accuracies were 82%, 83%, and 83% at Level II and 88%, 89%, and 89% at Level I for 2011, 2006, and 2001, respectively. Many class-specific user's accuracies met or exceeded a previously established nominal accuracy benchmark of 85%. Overall accuracies for 2006 and 2001 land cover components of NLCD 2011 were approximately 4% higher (at Level II and Level I) than the overall accuracies for the same components of NLCD 2006. The high Level I overall, user's, and producer's accuracies for the single-date eras in NLCD 2011 did not translate into high class-specific user's and producer's accuracies for many of the 17 change reporting themes. User's accuracies were high for the no change reporting themes, commonly exceeding 85%, but were typically much lower for the reporting themes that represented change. Only forest loss, forest gain, and urban gain had user's accuracies that exceeded 70%. Lower user's accuracies for the other change reporting themes may be attributable to the difficulty in determining the context of grass (e.g., open urban, grassland, agriculture) and between the components of the forest-shrubland-grassland gradient at either the mapping phase, reference label assignment phase, or both. NLCD 2011 user's accuracies for forest loss, forest gain, and urban gain compare favorably with results from other land cover change accuracy assessments.

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1. Introduction

The National Land Cover Database (NLCD), sponsored by the MultiResolution Land Characteristics (MRLC) Consortium (http://www.mrlc.gov), is a well-established and widely used source of information on land cover (Wickham et al., 2014). The most recent release of the product, NLCD 2011 (Homer et al., 2015), includes 16 land cover classes (http://www.mrlc.gov/nlcd11_leg.php) and related information for three eras (2001, 2006, 2011) at the native 30 m × 30 m pixel size of Landsat Thematic Mapper. One objective of the NLCD project is to provide land cover monitoring data that can be used to assess land cover change and trends, and the release of NLCD 2011 is the first realization of the database that can be used to assess change over multiple time intervals (Homer et al., 2015).

Accuracy assessment is one of the protocols of the NLCD program. Continuing this protocol of documenting accuracy of NLCD products, the two main objectives of this assessment are: 1) assess the accuracy of the single-date land cover maps produced for each NLCD era (2001, 2006, 2011) at Level II and I classification hierarchies, and 2) assess the accuracy of land cover change across the three NLCD change periods (2001–2006, 2006–2011, 2001–2011). The focus on the accuracy of

change across the three NLCD time periods is consistent with the format used to report NLCD 2006 land cover thematic accuracy (Wickham et al., 2013). NLCD 2006 (Fry et al., 2011) was the first NLCD database to incorporate land cover change. This accuracy assessment was undertaken to document product quality, inform production of future NLCD products, and support monitoring, modeling, and assessments that use NLCD 2011 land cover data.

The continuing development of the NLCD database results in new versions of previously released land cover products. The NLCD 2011 database includes version 1 of the year 2011, version 2 of the year 2006 and version 3 of the year 2001. Thus, the NLCD 2011 accuracy assessment reported in this paper evaluates version 3 of year 2001, version 2 of year 2006 and version 1 of year 2011. Users of NLCD 2001 (Homer et al., 2007) and NLCD 2006 (Fry et al., 2011) products should refer to their associated accuracy assessments when using those products. The accuracy assessment of NLCD 2001, which includes version 1 of NLCD 2001, is reported in Wickham et al. (2010), and the accuracy assessment of NLCD 2006, which includes version 2 of year 2001 and version 1 of year 2006, is reported in Wickham et al. (2013). NLCD 1992 (Vogelmann et al., 2001) is not considered part of the NLCD time series because of substantial methodological differences from later NLCD versions (Homer et al., 2004). The NLCD 1992 accuracy assessments are reported in Stehman et al. (2003) and Wickham et al. (2004).

In addition to the three eras of land cover, the NLCD database also includes percentage urban impervious cover for 2001, 2006, and 2011 (Xian et al., 2011), and forest canopy density for 2001 and 2011 (Coulston et al., 2012; Homer et al., 2007). The number of accuracy assessment objectives increases with the continued growth and development of the NLCD database, and all of these objectives cannot be accommodated with the limited NLCD resources (Stehman et al., 2008). We focus here on accuracy of land cover and land cover change among the three NLCD eras because it was considered the highest priority among MRLC participants. Accuracy of urban impervious cover and forest canopy density are not addressed in this assessment.

2. Methods

2.1. Sampling design

Accuracy assessment methods were based on the sampling design, response design, and analysis components developed by Stehman and Czaplewski (1998). We implemented a stratified random sampling design to accommodate the dual objectives of individual era (i.e., single date) assessments at Level II and Level I (Table 1) and temporal change assessments at Level I for multiple change periods. The continental United States was first divided into east and west regions to create two geographic strata (Fig. 1). This regional stratification was used because previous NLCD accuracy assessments have shown geographic variations in accuracies in which class-specific accuracies tend to be higher when the class was dominant regionally (Stehman et al., 2003; Wickham et al., 2004, 2010, 2013). Thirty-eight (38) strata were sampled within each region, with 16 of these strata corresponding to mapped no change over all three dates for the 16 Level II classes. The other 22 strata were defined based on mapped change over the three dates (Table 2). The 22 change strata prioritized shifts among forest, shrubland, grassland and urban among the 504 possible change combinations of eight Level I classes for three dates (excluding Level I no change classes). The 38 strata accounted for all pixels in the NLCD 2011 map area thereby satisfying one condition of a probability sampling design which is that each pixel in the population must have a non-zero inclusion probability (Stehman, 2001). Accuracy estimates for the temporal component of NLCD 2011 were produced for 17 reporting themes that were based on the eight Level I classes (Table 3). These reporting themes are same as those used in the NLCD 2006 accuracy assessment (Wickham et al., 2013) facilitating comparison of accuracy of NLCD 2011 with NLCD 2006.

Table 1
National Land Cover Database (NLCD) land cover legend for Level II of the classification hierarchy and (class codes). Level I classes are based on the tens digit of the class code, e.g., classes 11 and 12 combine to form class = 10 (water). See http://www.mrlc.gov/nlcd11_leg.php for a complete description of NLCD classes.

Class (code)	Description
Water (11)	Open water, with generally < 25% vegetation or soil cover
Perennial ice/snow (12)	>25% permanent ice or snow
Developed, open space (21)	Dominated by vegetation; impervious cover (IC) ≤ 20%
Developed, low intensity (22)	Mixture of vegetation and IC (20% < IC ≤ 49%)
Developed, medium intensity (23)	Mixture of vegetation and IC (50% < IC ≤ 79%)
Developed, high intensity (24)	Mixture of vegetation and IC (IC ≥ 80%)
Barren (31)	Bedrock, desert pavement, etc.; vegetation <15 cover
Deciduous forest (41)	Trees >20% cover of which >75% shed foliage seasonally
Evergreen forest (42)	Trees >20% cover of which >75% maintain foliage year round
Mixed forest (43)	Trees >20% cover; neither deciduous or evergreen >75% cover
Shrubland (52)	Woody species <5 m and >20% cover
Grassland (71)	Herbaceous cover ≥80%; no management (e.g., tilling) evident
Pasture (81)	Herbaceous cover >20% for livestock, seed, or hay crops
Cultivated crops (82)	Herbaceous or woody cover ≥20% (e.g., corn, orchards)
Woody wetlands (90)	Woody cover >20% on periodically saturated soil
Herbaceous wetland (95)	Herbaceous cover >80% on periodically saturated soil

Previous NLCD accuracy assessments used 10 geographic strata (regions), but only two regions were defined for this assessment because limited resources reduced the total sample size to 8000 from 15,000 sample pixels used in the NLCD 2001 (Wickham et al., 2010) and NLCD 2006 (Wickham et al., 2013) accuracy assessments. The eastern U.S. region received 3900 sample pixels and the western U.S. region received 4100 sample pixels. There were no sample pixels of the NLCD perennial ice and snow class in the eastern region.

2.2. Response design

The main elements of the response design were: 1) blind interpretation; 2) reliance on Google Earth™ time series imagery to determine the reference labels; 3) reliance on the pixel as the spatial support unit of the assessment (Stehman and Wickham, 2011); 4) assignment of primary and alternate reference labels, and; 5) specific rules for coding
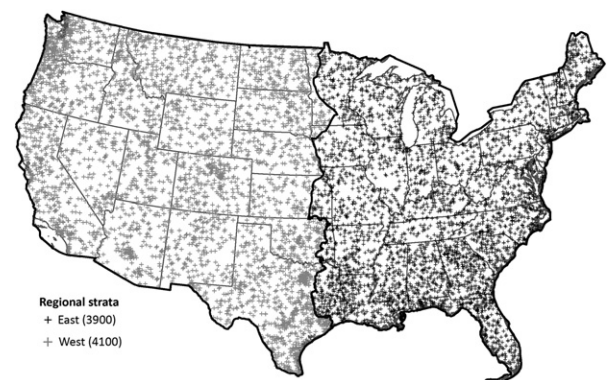

Fig. 1. NLCD 2011 accuracy assessment sample pixel locations and regional strata. The east-west regional strata were based on the mapping regions developed for NLCD 2001, version 1 (Homer and Gallant, 2001).