Global Environmental Change 23 (2013) 733–748

Contents lists available at SciVerse ScienceDirect

Global Environmental Change

journal homepage: www.elsevier.com/locate/gloenvcha

Land-cover change in the conterminous United States from 1973 to 2000

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ARTICLE INFO

Article history:
Received 29 August 2012
Received in revised form 18 March 2013
Accepted 23 March 2013

Keywords:
Land use
Land cover
Ecoregions
Landsat
Urbanization
Forestry
Agriculture

ABSTRACT

Land-cover change in the conterminous United States was quantified by interpreting change from satellite imagery for a sample stratified by 84 ecoregions. Gross and net changes between 11 land-cover classes were estimated for 5 dates of Landsat imagery (1973, 1980, 1986, 1992, and 2000). An estimated 673,000 km^2(8.6%) of the United States' land area experienced a change in land cover at least one time during the study period. Forest cover experienced the largest net decline of any class with 97,000 km^2 lost between 1973 and 2000. The large decline in forest cover was prominent in the two regions with the highest percent of overall change, the Marine West Coast Forests (24.5% of the region experienced a change in at least one time period) and the Eastern Temperate Forests (11.4% of the region with at least one change). Agriculture declined by approximately 90,000 km^2 with the largest annual net loss of 12,000 km^2 yr^{-1} occurring between 1986 and 1992. Developed area increased by 33% and with the rate of conversion to developed accelerating rate over time. The time interval with the highest annual rate of change of 47,000 km^2 yr^{-1} (0.6% per year) was 1986–1992. This national synthesis documents a spatially and temporally dynamic era of land change between 1973 and 2000. These results quantify land change based on a nationally consistent monitoring protocol and contribute fundamental estimates critical to developing understanding of the causes and consequences of land change in the conterminous United States.

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1. Introduction

Land-use and land-cover (LULC) change is a pervasive phenomenon impacting local-to global-scale processes and often involving the trade-off of meeting human needs and the preservation of ecosystem functions (Vitousek et al., 1997; DeFries et al., 2004). LULC change has emerged as a focus area in global change research (Committee on Global Change Research, 1999); in the U.S. it has been shown to directly impact weather and climate systems (Kalnay and Cai, 2003), surface radiative forcing (Sagan et al., 1979), and biogeochemical cycling (Houghton et al., 1999; Caspersen et al., 2000). While globally important, LULC change occurs locally, requiring integrative studies at finer geographic scales (Wilbanks and Kates, 1999). However, despite recent advances in terrestrial monitoring and observation, comprehensive mesoscale assessments spanning sufficiently long temporal periods, landscapes, and LULC classes are lacking.

The United States (U.S.) has several land-use or land-cover monitoring programs each of which contributes valuable information to our understanding of change but none of which individually offers a complete, nationally comprehensive assessment based on methods that are spatially and temporally consistent across the U.S. For example, statistical surveys such as the U.S. Department of Agriculture's (USDA) Forest Inventory and Analysis (Gillespie, 1999) and Natural Resources Inventory (NRI) (USDA, 2001) have been implemented, and the USDA Agricultural Census and the U.S. Census Bureau's decadal population census provide information on agricultural land use and population dynamics. However, these programs are limited to specific lands or land-use classes and therefore do not provide an adequate national synthesis of U.S. land change. Constructing a consistent and comprehensive land-cover change synthesis is also complicated by the fact that these survey and census programs use different spatial and temporal scales as well as different definitions of land-cover classes. For

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0959-3780/$ – see front matter. Published by Elsevier Ltd.
http://dx.doi.org/10.1016/j.gloenvcha.2013.03.006

example, forest use may include areas without tree cover, such as recent clear-cuts, while a forest cover classification is most often characterized by the biophysical presence of vegetation meeting certain criteria. The different definitions of "forest" have led to recognition of the usefulness of different data sources for characterizing trends in forest cover (Drummond and Loveland, 2010).

In contrast to statistical surveys and census approaches to quantify land change, remote sensing offers another platform for monitoring. The relative rarity of land-cover change – particularly over short time intervals and large spatial extents – has made accurate mapping and estimation of regional land-cover change difficult. Early national-scale efforts relied either on coarse resolution sensors, such as AVHRR (Advanced Very High Resolution Radiometer), and focused on characterizing land cover at a single point in time (e.g., Loveland et al., 1991), or using moderate resolution imagery for single class mapping (Skole and Tucker, 1993) or regional studies (Dobson et al., 1995). More recently, the U.S. Geological Survey has used remote sensing to produce the National Land Cover Database (NLCD) of land-cover products mapped at a 30-m x 30-m pixel resolution. NLCD is currently available for three dates, 1992 (Vogelmann et al., 2001), 2001 (Homer et al., 2007), and 2006 (Fry et al., 2011). NLCD offers a promising future monitoring framework; however, the current NLCD data are not available for a sufficiently long temporal period. As an alternative to wall-to-wall maps, probability-based sampling has been shown to be an effective method for quantifying land-cover change using remote sensing, particularly for forest cover loss (Achard et al., 2002; Hansen et al., 2010).

Because of the extensive temporal record and relatively consistent spatial and radiometric characteristics, the Landsat series of earth observation satellite data offer a unique opportunity to characterize changes between major land-cover classes across a wide range of ecosystems. The Landsat archive, consisting of data acquired by 6 satellites over a period of 40 years, offers a consistent source of appropriate resolution observational data that is critical to permit quantification of land change over sufficiently long time periods.

The objective of the U.S. Geological Survey Land Cover Trends project (Loveland et al., 2002) was to estimate the rates and types of recent historical land-cover change across ecoregions of the conterminous U.S. (Loveland et al., 2002; Stehman et al., 2003a) (hereafter, we will omit the modifier "conterminous" but all references to the U.S. should be understood as meaning the conterminous U.S.). The major land-cover changes captured in this study represent processes associated with forest harvest; urbanization; agricultural intensification, deintensification, and abandonment; and mining. In this article we report broad-scale patterns of land-cover change augmenting the national results with regional results presented for the following six regions: Eastern Temperate Forests, Great Plains, Western Cordillera, Marine West Coast Forests, North American Deserts, and Mediterranean California (Fig. 1). National estimates of overall change are first summarized by the land change footprint (or change footprint) of the U.S., defined as the total area of land that experienced a change in land cover in at least one of the four time intervals (1973–1980, 1980–1986, 1986–1992, and 1992–2000) partitioning the 1973–2000 study period. Regional estimates of

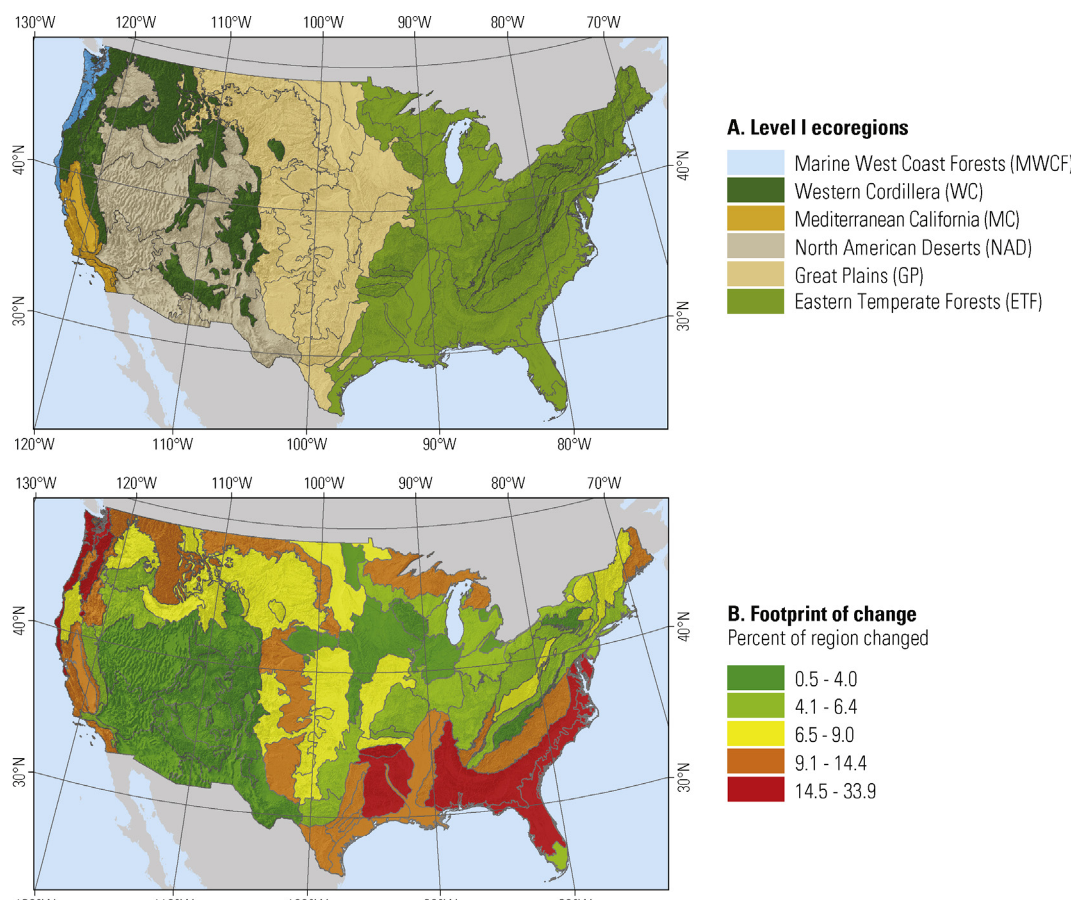

Fig. 1. (A) Six reporting regions partitioning the conterminous United States (MWCF is Marine West Coast Forests, MC is Mediterranean California, WC is Western Cordillera, NAD is North American Deserts, GP is Great Plains, and ETF is Eastern Temperate Forests), and (B) the estimated land change footprint, or the area that changed at least one time between 1973 and 2000 (% of ecoregion area).