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An accuracy assessment of forest disturbance mapping in the western Great Lakes

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ABSTRACT

The increasing availability of satellite imagery has spurred the production of thematic land cover maps based on satellite data. These maps are more valuable to the scientific community and land managers when the accuracy of their classifications has been assessed. Here, we assessed the accuracy of a map of forest disturbance in the watersheds of Lake Superior and Lake Michigan based on an improved version of the Vegetation Change Tracker algorithm (VCTw). We constructed a probability-based sampling design using two stages of sampling with stratification at each stage. Results are presented for the portion of the map within the U.S. as well as separately for the U.S. portion of Lake Superior's watershed and for Lake Michigan's watershed. We also present estimates and standard errors of the percent cover for each land cover class that incorporate both the map's data and our sample data. The overall accuracy for the U.S. portion of the map is estimated to be 91% with a standard error of 0.8%. We discuss the relative strengths of the VCTw algorithm as well as the dependence of such an algorithm's success on the characteristics of the landscape being mapped.

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1. Introduction

The Great Lakes Restoration Initiative (GLRI) is a multi-year and multi-agency investment in the improved health of the Great Lakes coordinated by the US Environmental Protection Agency (EPA). The Great Lakes watersheds are approximately 54% forested, and the wise management of forest in watersheds has long been identified as critical to the maintenance of high quality streamflow (Gregory et al., 1991; Karr & Schlosser, 1978; Naiman & Bilby, 1998; Peterjohn & Correll, 1984; Sweeney, 1992). The USDA Forest Service serves as a partner in the GLRI, with a particular focus on investigating the relationship between land management in watersheds and the health of the Great Lakes.

Recent publications provide information on forest land uses and land use change in Michigan (Pugh et al., 2009), Wisconsin (Perry et al., 2008), and Minnesota (Miles et al., 2011), focusing on states as analysis units, but actual management occurs on an owner-by-owner basis within states. Forest restoration and management activities will be more effective at achieving identified water quality objectives if implemented through a watershed perspective. Additionally, the existing data are not designed to provide insight on the watershed-level spatial patterns inherent in forest ecology and management.

As an alternative to state-level analysis, Landsat Time Series Stacks (LTSS) and the Vegetation Change Tracker (VCT) algorithm (Huang et al., 2010) can be used to map forest cover and disturbance at a spatial scale effective for informing watershed-level management. We have adapted the VCT process for the watersheds of Lake Superior and Lake Michigan using a surrogate source of winter images to reduce commission errors in the predictions of forest disturbance classes. The result is a product we call VCTw, which is used to map forest disturbance and described in detail by Stueve et al. (2011) (Fig. 1).

Basing land management decisions on a land-cover map will always be more defensible if a proper accuracy assessment has been performed. In fact, an accuracy assessment of land-cover classifications is considered to be a necessary part of the publication of any such map (Cihlar, 2000). References exist in the literature to help plan such accuracy assessments (Congalton & Green, 1999; Stehman, 2009a; Stehman & Czaplewski, 1998; Strahler et al., 2006), but tailoring an assessment to a particular map can still be challenging; what constitutes an effective assessment of one map may be a poor assessment of another. Some examples of specially-tailored assessments are those by Nusser and Klaas (2003) and Stehman et al. (2003). Here, we describe our assessment procedure and report results for the portion of the map within the U.S. of the forest disturbance map produced by VCTw.[1] Additionally, we present improved estimates of the percent cover of each disturbance class that take advantage of the sample data collected in the accuracy assessment.

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[1] Due to limited availability of data, the Canadian portion of the map was considered in a separate, later assessment.

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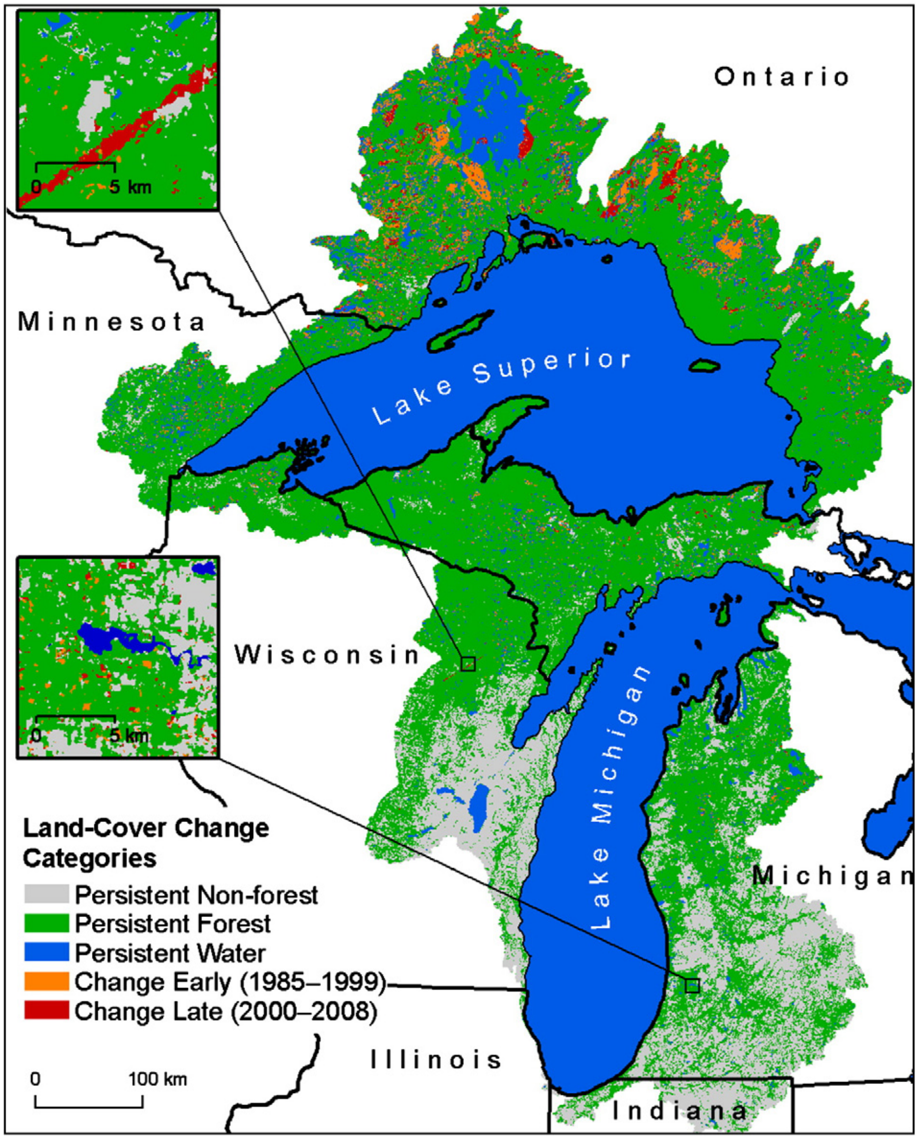

Fig. 1. Forest disturbance map produced by VCTw.

2. Methods

The accuracy assessment was conducted by comparing the forest disturbance map data to "reference data" for a sample of map pixels. By reference data, we mean disturbance classes that were assigned by photointerpreters after inspecting high-resolution imagery (i.e., a proxy for "ground truth"). In this section, we will briefly review the creation of the VCTw data, explain how the sample of map pixels was selected, and how the reference data were obtained for the sample.

2.1. Disturbance mapping

Although VCT has been described in several previous papers (Huang et al., 2009, 2010), it may be helpful to briefly describe the more recently developed VCTw. A detailed description is available in Stueve et al. (2011).

The standard VCT protocol was used to process 36 Landsat path/rows that intersect the Lake Superior and Lake Michigan basins, but the resulting forest disturbance map appeared to contain large areas of incorrectly classified persisting forest and forest disturbance. After reviewing some apparent mapping errors, it was hypothesized that the errors were due to the spectral inseparability between forest and both leafy cultivated crops and emergent herbaceous wetlands. Because cropland and wetlands are highly variable across time, they were also often classified as forest disturbance. This motivated the development of the winter Landsat Time Series Stack (LTSSw) false positive mitigation technique (Stueve et al., 2011). For each path/row, a LTSSw was constructed with roughly quadrennial imagery with the key requirement that the entire image was snow-covered. VCT's cloud masking model was then applied to identify all non-forested, snow-covered areas. Any pixel that was classified as a cloud or cloud edge throughout every mask in the LTSSw, and did not demonstrate a long-term recovery trend was included in a non-forest mask. This mask successfully eliminated a substantial portion of classification errors committed by the standard VCT operating procedure.

A minimum mapping unit (MMU) of 0.356 ha (4 contiguous pixels) was applied to all masked VCT disturbance year outputs. Afterward, the classes initially assigned by VCTw were collapsed into broader classes based on the temporal resolution of available reference data (see Section 2.3.1). Specifically, the typical biennial disturbance classes used by VCT (e.g., "disturbed between 1988 and 1989") were collapsed into an early (1985–1999) (D1) or late (2000–2008) (D2) class. Also, the pre-series disturbance class was collapsed into the persisting forest