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Applying time series Landsat data for vegetation change analysis in the Florida Everglades Water Conservation Area 2A during 1996–2016

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ABSTRACT

Mapping plant communities and documenting their changes is critical to the on-going Florida Everglades restoration project. In this study, a framework was designed to map dominant vegetation communities and inventory their changes in the Florida Everglades Water Conservation Area 2A (WCA-2A) using time series Landsat images spanning 1996–2016. The object-based change analysis technique was combined in the framework. A hybrid pixel/object-based change detection approach was developed to effectively collect training samples for historical images with sparse reference data. An object-based quantification approach was also developed to assess the expansion/reduction of a specific class such as cattail (an invasive species in the Everglades) from the object-based classifications of two dates of imagery. The study confirmed the results in the literature that cattail was largely expanded during 1996–2007. It also revealed that cattail expansion was constrained after 2007. Application of time series Landsat data is valuable to document vegetation changes for the WCA-2A impoundment. The digital techniques developed will benefit global wetland mapping and change analysis in general, and the Florida Everglades WCA-2A in particular.

1. Introduction

1.1. Significance of vegetation mapping and change analysis in the Florida Everglades Water Conservation Areas (WCAs)

The Florida Everglades is the largest subtropical wetland in the USA, supporting many threatened and endangered species. In the past century, human activities severely modified the Everglades ecosystem, resulting in many environmental issues in South Florida (e.g., McPherson and Halley, 1996). In 2000, the U.S. Congress authorized the Comprehensive Everglades Restoration Plan (CERP) to restore, preserve, and protect the Everglades while providing for other water related needs of the region (Everglades Restoration, 2016). CERP is the largest hydrologic restoration project in the USA with a cost of more than $10.5 billion and a 35+ year time-line. A range of projects have been conducted for the restoration, many of which require vegetation maps to document plant changes that can guide the restoration (Jones, 2011). Three Water Conservation Areas (WCAs) spanning 1322 square miles in the Everglades (Fig. 1) were established to provide flood control and water supply for South Florida. WCAs are representative areas in CERP and have been considered to be a principal beneficiary of the restoration. Monitoring the spatial and temporal changes of plant communities in WCAs is one critical component in CERP.

1.2. Past efforts of automated vegetation mapping and change analysis in WCAs

Land-cover vegetation maps in WCAs are mainly derived from manual interpretation of large-scale aerial photography using analytical stereo plotters (Rutchey et al., 2008). This procedure is time-consuming and labor-intensive. A few digital efforts have been made to automate the manual procedure using satellite imagery, including analysis of SPOT imagery for mapping vegetation in WCA-1 (Richardson et al., 1990) and in WCA-2A (Rutchey and Vilcheck, 1994, 1999), respectively, as well as the use of time series satellite imagery for vegetation change analysis in WCA-2A (Jensen et al., 1995). Jensen et al. (1995) are the first and only researchers who attempted to document vegetation changes by processing time series satellite images. In this work, a 1991 SPOT classified image created by Rutchey and Vilcheck (1994) was used as a base from which to analyze the historical trends of cattail coverage in WCA-2A. Landsat Multispectral Scanner (MSS) data (1973, 1976, and 1982) and SPOT data (1987) were normalized

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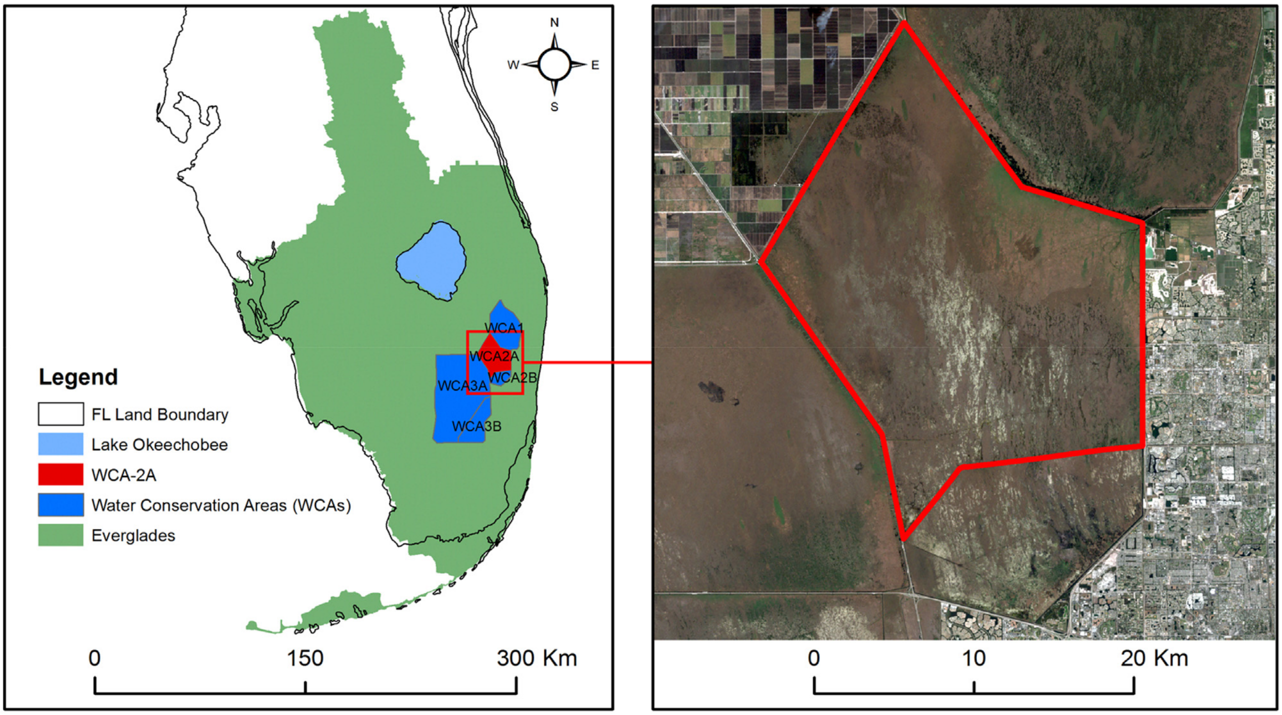

Fig. 1. Map of the Florida Everglades and the study site Water Conservation Area 2A (WCA-2A) shown in a nature color composite from a Landsat-7 ETM+ image collected on 13 February 2003 (bands 3, 2, and 1).

to the base year 1991 SPOT imagery. An unsupervised clustering approach was applied to generate the vegetation map for each individual year. A post-classification comparison change detection approach was used to reveal the trend of cattail coverage during 1973–1991. Cattail is an invasive species in the Everglades and its population growth is threatening to throw the ecosystem out of balance, which is why past efforts have focused on mapping and analysis of the cattail community. The above mentioned studies have demonstrated that application of medium spatial resolution satellite imagery (20–30 m) has a potential to map and inventory dominant plant communities in WCAs, even though this type of data might not be useful to map other regions with a high degree of heterogeneity in the Everglades.

1.3. Objectives

It has been more than 20 years since the work of Jensen et al. (1995). Few efforts have been made since then to document plant changes within WCAs using digital techniques, which have been largely advanced in the past decades. The latest vegetation map in the WCA-2A was produced by Rutchey et al. (2008) from manual interpretation of 2003 aerial photography. Recent vegetation maps are in urgent demand, but not available in the restoration. The temporal changes in the spatial extent, pattern, and proportion of plant communities within WCA-2A in the past two decades have not been released. High quality cloud-free Landsat data are available in WCA-2A, which makes them useful for documenting plant changes for this critical region.

Past digital efforts have focused on the traditional pixel-based image analysis which may lead to the "salt-and-pepper" effect in mapping heterogeneous landscapes. This issue can be overcome by object-based image analysis (OBIA) methods which first decompose an image scene into relatively homogeneous object areas and then analyze these object areas instead of pixels (Blaschke, 2010). OBIA has proven effective for vegetation mapping in the Everglades using either single-source remotely sensed data (e.g., Zhang and Xie, 2012, 2013), or a synergy of multi-source remotely sensed data (Zhang et al., 2013; Zhang and Xie, 2014; Zhang, 2014; Zhang et al., 2016); however, the application of OBIA for change detection has not been explored. A challenge in applying historical images for vegetation mapping and change detection is the training sample selection for images with either limited or no reference data. Visual interpretation of plant communities from imagery with such a spatial resolution (30 m) is difficult. The objectives of this study are 1) to design a framework to map plant communities and reveal their changes in WCA-2A using time series Landsat images and contemporary remote sensing data processing techniques; and 2) to develop a new training sample selection approach for historical images in the classification based upon the OBIA change detection techniques.

2. Study area and data

2.1. Study site

WCAs are vast tracts of remnant Everglades and are divided into WCA-1, WCA-2A & 2B, and WCA-3A & 3B by levees and canals (Fig. 1). WCA-2A was selected as the study site. WCA-2 is the smallest of the three WCAs and is located south of Lake Okeechobee, and below WCA-1. It is an extensive wetland covering 210 square miles. In 1961, WCA-2 was divided into two units, 2A (173 square miles) and 2B (37 square miles) by installing a partitioning levee to prevent excess water seepage losses to the south and to improve the water storage capacity. A few hydrologic projects were conducted within WCA-2A for water management purposes, which modified the original sawgrass-dominated communities due to the increased concentrations and loadings of phosphorus in this region. Field studies found a widespread encroachment of cattail into the natural sawgrass marsh within WCA-2A (Rutchey et al., 2008). This was further confirmed by the aerial photography captured in 1991 and 1995 (Rutchey and Vilcheck, 1999) and digital image analysis of satellite imagery captured during 1973–1991 (Jensen et al., 1995).