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Improved coastal wetland mapping using very-high 2-meter spatial resolution imagery

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ABSTRACT

Accurate wetland maps are a fundamental requirement for land use management and for wetland restoration planning. Several wetland map products are available today; most of them based on remote sensing images, but their different data sources and mapping methods lead to substantially different estimations of wetland location and extent. We used two very high-resolution (2 m) WorldView-2 satellite images and one (30 m) Landsat 8 Operational Land Imager (OLI) image to assess wetland coverage in two coastal areas of Tampa Bay (Florida): Fort De Soto State Park and Weedon Island Preserve. An initial unsupervised classification derived from WorldView-2 was more accurate at identifying wetlands based on ground truth data collected in the field than the classification derived from Landsat 8 OLI (82% vs. 46% accuracy). The WorldView-2 data was then used to define the parameters of a simple and efficient decision tree with four nodes for a more exacting classification. The criteria for the decision tree were derived by extracting radiance spectra at 1500 separate pixels from the WorldView-2 data within field-validated regions. Results for both study areas showed high accuracy in both wetland (82% at Fort De Soto State Park, and 94% at Weedon Island Preserve) and non-wetland vegetation classes (90% and 83%, respectively). Historical, published land-use maps overestimate wetland surface cover by factors of 2–10 in the study areas. The proposed methods improve speed and efficiency of wetland map production, allow semi-annual monitoring through repeat satellite passes, and improve the accuracy and precision with which wetlands are identified.

1. Introduction

Wetlands are habitats located along the interface between land and either fresh- or saltwater environments, and are characterized by hydric soils that are flooded regularly (Cowardin et al., 1979; Lunetta and Balogh 1999). They are dominated by emergent, scrub, and forested vegetation. Wetlands are estimated to be worth billions of dollars to commercial and recreational fisheries by providing fish and wildlife habitat and nurseries (Dahl and Stedman, 2013; Ozesmi and Bauer 2002; Turner and Gannon 2014). They offer many other ecosystem services, including nutrient and suspended solid removal, flood protection, erosion control, recreation, aesthetics and other cultural values (Turner and Gannon 2014). The United States Environmental Protection Agency (US EPA) has estimated that the economic value of wetland services for even a single swamp is equivalent to up to $5 million in annual water pollution control costs, and up to $1.5 million in flood control costs (Turner and Gannon 2014). Wetlands provide habitat for wetland-dependent birds, which draw 50 million painters and photographers that contribute more than $10 billion per year to the U.S. economy. Nevertheless, the areal extent of wetlands declined rapidly in the 20th century, primarily as a result of development and pollution (Dahl and Stedman 2013; Raabe et al., 2012). This has led to important restoration efforts in the U.S. and elsewhere, which may conserve habitat biodiversity, and ecosystem services and goods (Nellemann and Corcoran 2010; Ozesmi and Bauer 2002; Rains et al., 2012). Because of their importance, wetlands are the only ecosystem covered by a global treaty, specifically the Ramsar Convention on Wetlands signed in 1971.

Wetland maps provide useful tools for wetland protection and management, including understanding impacts due to climate change or direct anthropogenic use (Rains et al., 2012). Wetland extent and change over time are typically evaluated with the help of synoptic mapping tools including aerial and satellite-derived

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photographs and digital imagery (Gianinetto et al., 2014; Raabe et al., 2012; Rains et al., 2012; Rundquist et al., 2001; Steffen et al., 2010; Zhang et al., 2011).

The primary objective of this study was to develop a simple and robust methodology for assessing the extent of wetlands using new, high spatial resolution satellite imagery (~2 m and ~30 m) in specific coastal environments of the Tampa Bay estuary, Florida (USA), and compare the results with existing historical wetlands assessments for these regions. The study area was chosen because of its extensive estuarine and palustrine wetlands, and because these are of high relevance to the ecological health and economic vitality of Tampa Bay. Dominant wetland vegetation in the Tampa Bay watershed (~6550 km^2) includes red, white and black mangroves, and buttonwood.

Several existing wetland maps for the region differ in their estimate of wetland extent and location. For example, the land area classified as wetland in the National Oceanic and Atmospheric Administration (NOAA) Coastal-Change Analysis Program (C-CAP) maps does not match contemporary results from either the National Wetland Inventory (NWI) or the Southwest Florida Water Management District (SWFWMD). C-CAP overestimates the wetland class surface area estimates by a factor of almost three relative to the other two for similar mapping years, with a proportional underestimation of upland forest. The complementarity in error between these classes is likely due to the spectral and spatial mixing of wetland and non-wetland vegetation in the Landsat Thematic Mapper-class images (30 m) used for the analyses. Nevertheless, at least one accuracy validation study estimated that C-CAP wetlands, uplands, and water are classified to an accuracy of 95% (C-CAP, 2013).

2. Methods

2.1. Imagery used

To evaluate the applicability of much higher (order of 2 m per pixel) spatial resolution satellite data now available commercially, we examined two images collected by Digital Globe's WorldView-2 satellite sensors. These data, and wetlands classifications derived from them were compared with wetlands extent estimated with data from the Landsat 8 Operational Land Imager (OLI). These two sensor platforms feature different spatial, spectral and radiometric resolutions. Moreover, imagery from the latter are freely available for download, whereas those of the former are commercially dis-

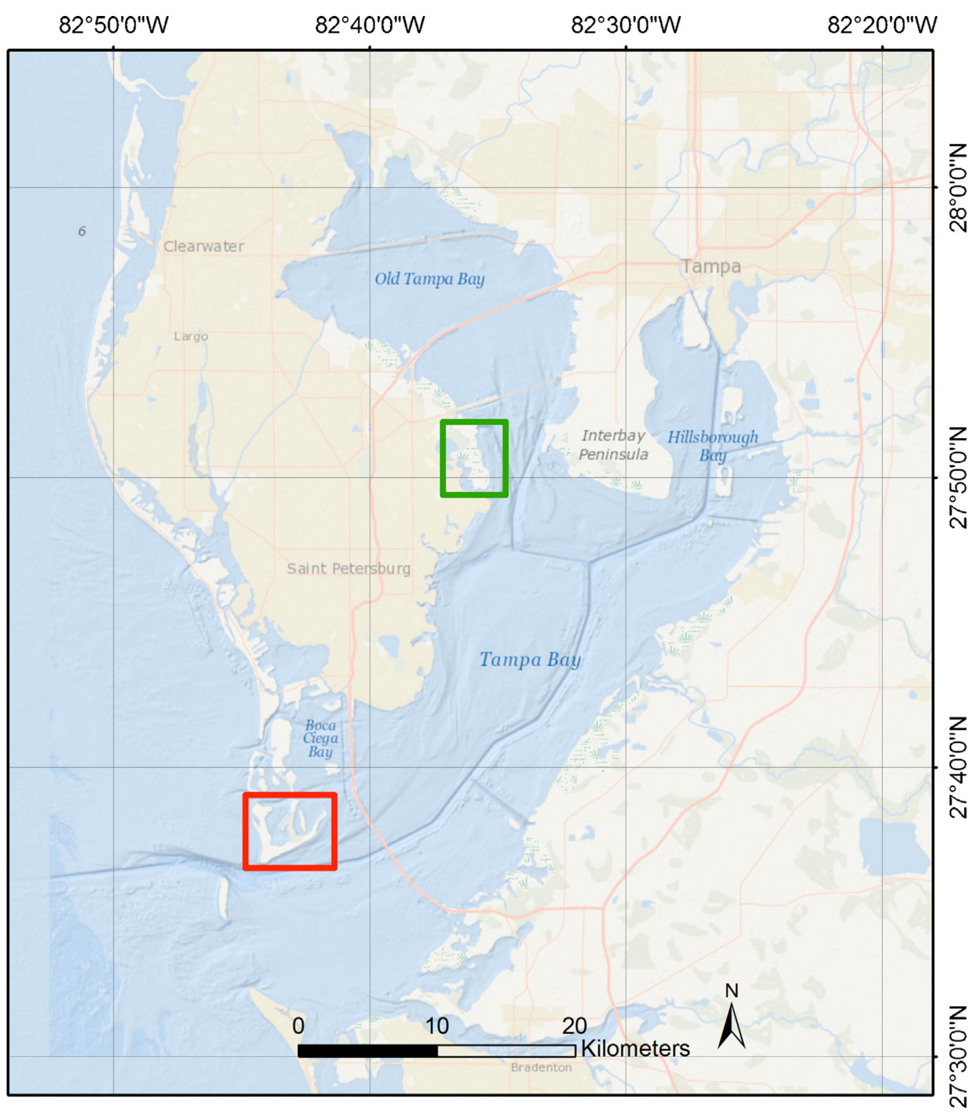

Fig. 1. Study areas in Tampa Bay: Weedon Island (Green box) and Fort De Soto (Red box). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)