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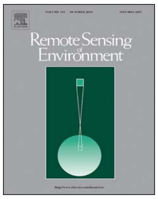

Enabling efficient, large-scale high-spatial resolution wetland mapping using satellites

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ABSTRACT

Global coastal and freshwater wetlands provide ecosystem services valued at over $200,000 USD per hectare per year. Despite their value, wetlands continue to be lost at alarming rates worldwide, with as much as 71% of global wetland extent being converted to other land-cover types since 1900. Targeted conservation and restoration efforts, however, have proven successful, particularly in Europe and North America. Such efforts require accurate protocols to identify, assess, and map wetlands repeatedly to enable detection of change. High-resolution (i.e. 2-meter pixel) satellite imagery has proven effective to map wetlands at higher accuracies than historical 30-meter or coarser satellite data. We describe a method to process and classify high volumes of multispectral high-resolution satellite data to update wetland maps. We show the results of a study conducted with 130 2-meter resolution WorldView-2 satellite images to map forested wetland, upland, water, bare land, and developed lands in a 6500 km^2 watershed. The processing of the map was completed in under 24 h and was more accurate at identifying forested wetland (78%) and upland (64%) than three previous, widely used maps of the same area (45–65%, and 49–53%, respectively). This method offers high potential for monitoring change in coastal areas and adjacent watersheds over large geographic scales.

1. Introduction

Wetlands provide a host of essential ecosystem services including nutrient removal, carbon sequestration, shoreline stabilization, flood prevention, and provision of habitat for numerous species of protected or commercially and recreationally important fish, birds, and invertebrates (Barbier, 2015; Barbier et al., 2011; Martin et al., 2016). De Groot et al. (2012) estimated the value of tidal and freshwater wetlands at $193,845 and $25,682 USD per hectare per year, respectively – second only to coral reefs in terms of global ecosystem value. Despite increasing recognition of the importance of their ecosystem services, wetlands continue to be lost at unprecedented rates worldwide. Globally, tidal wetland cover has declined at a rate of 0.7–3.0% per year, with freshwater wetlands disappearing at about 1% per year (Davidson, 2014; Mcleod et al., 2011). Local losses within smaller geographic areas, including individual watersheds and estuaries, may be significantly higher than the global average (Davidson, 2014). Prior to the 1850s, Florida is estimated to have contained 8.2 million hectares of wetlands (Dahl, 2005). Today, roughly half of these swamps and marshes have been lost to draining, flooding, and human development (Dahl, 2005). Coastal wetlands in Florida, which include mangrove, salt marsh, and salt barren habitats, have suffered extensive losses to human development in the early- and mid-1900's as a result of concentrated human development along the coast (Lewis et al., 1985; Sherwood and Greening, 2014). While restoration efforts have attempted to reverse this trend, Gulf of Mexico wetlands still experienced a net loss of over 1000 km^2 between 2004 and 2009, which amounted to a 1.6% loss (Dahl and Stedman, 2013).

Management of human activities to conserve and restore wetland resources and services requires accurate and up-to-date mapping of these critical ecosystems. Yet wetland cover has historically been difficult to evaluate synoptically. These areas are typically difficult to access, and mapping using field efforts is time-intensive, even for relatively small areas. Remote sensing has served as a valuable tool to evaluate land cover and wetland habitat extent since the 1960's (see references in Tiner et al., 2015). Common remote sensing tools to map wetlands include aerial photography and videography, hyperspectral imagery, radar and LiDAR data, and high- and medium-resolution multispectral satellite images (Klemas, 2009; Kuenzer et al., 2011; McCarthy et al., 2015). Aerial photographs are useful for location-specific projects as they provide excellent spatial resolution that can be used to create detailed maps at a relatively low cost (Tiner, 1997).

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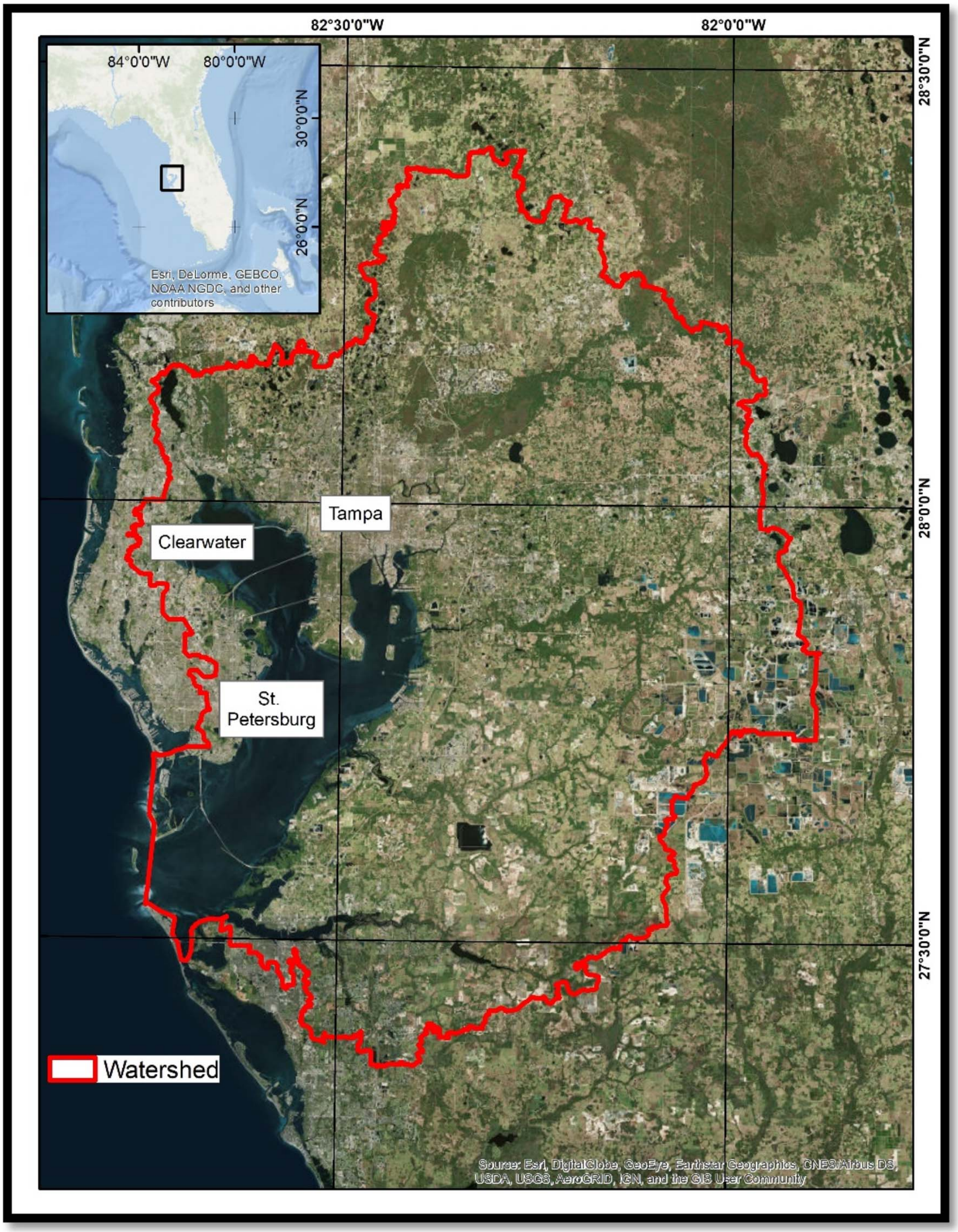

Fig. 1. Tampa Bay watershed study area. The watershed boundary, as defined by the U.S. Environmental Protection Agency's National Estuary Program, is outlined in red. Imagery is from ArcGIS "Imagery" basemap. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

However, the cost of aerial imagery increases with spatial coverage and repeated acquisitions.

Satellite data offer a cost-effective option for large-scale projects with spatially continuous coverage (Green et al., 1998; Kuenzer et al., 2011; Tiner et al., 2015). Additionally, digital data from satellite imagery enable efficient and rapid classifications through automated methods that have been shown to improve accuracy over aerial photo interpretations (Tiner et al., 2015). Medium-resolution imagery from the series of Landsat and SPOT satellite sensors have been used since the 1980's for the classification of land cover types and change detection over large scales, at a spatial resolution of 10–30 m pixels. Higher resolution satellite imagery (i.e., meter-scale pixels) enables study of details such as plant species, damage following severe weather, or fine-scale habitat mapping (Klemas, 2009; Kuenzer et al., 2011; McCarthy et al., 2015). The accuracy of habitat maps depends both upon the spatial and spectral resolutions of the data, the preprocessing methods applied, and the accuracy of the algorithm to discern the spectral signature of the target habitats (Hestir et al., 2015; Klemas, 2014; Klemas, 2013a, 2013b; Turpie, 2013).

Mapping mangroves and other forested wetlands is complicated by