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Satellite Image-Based Time Series Observations of Vegetation Response to Hurricane Irma in the Lower Florida Keys

Jan Svejkovsky[1] · Danielle E. Ogurcak[2] · Michael S. Ross[3] · Alex Arkowitz[1]

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Abstract

High-resolution satellite imaging represents a potentially effective technique to monitor cyclone-caused environmental damage and recovery over large areas at a high spatial scale. This study utilized a 10-m resolution Sentinel satellite image series to document vegetation changes in a portion of the Florida Keys, USA, over which the core of Category 4 Hurricane Irma passed on 10 September 2017. A previously assembled field survey was used to establish land-cover patterns in the satellite data, and concurrent field measurements verified post-hurricane changes. Normalized difference vegetation index (NDVI) was utilized as a tracer for pre-storm baseline patterns and through 19 post-storm months. NDVI patterns show that the severity of vegetation damage varied appreciably across the area, with the least damage on islands in the western sector of the hurricane's eye and around its center, and greatest damage on islands just east of the eye. The data reveal that for 2.5 months after the storm, multiple inland vegetation classes showed substantial early regrowth. However, mangrove forests were more negatively affected. The storm caused extensive mortality of black mangrove (*Avicennia germinans*) and red mangrove (*Rhizophora mangle*), corresponding to more than 40% of the total mangrove area on some islands. The full extent of mangrove die-off was not immediately evident, and increased progressively through the first few months after the storm. In addition to demonstrating the utility of high-resolution satellite image series for post-hurricane environmental assessment, this study reveals high-resolution links between vegetation types, their location within the cyclone, and the extent of post-storm recovery.

Keywords Hurricane Irma · Remote sensing · NDVI · Image series · Mangroves

Introduction

Tropical cyclones are large and intense disturbances known for their vast ecological and economic damage potential. Even within their core path, however, environmental damage tends to be quite variable. This is due to the storms' inherent spatial variability in wind speed and direction, the height and direction of their storm surge, and their interaction with abiotic and biotic features of the affected land areas. Damage to vegetative cover can be affected by the surrounding topography's influence on wind exposure (Boose et al. 2004) and storm surge (Smith et al. 2009), and soil characteristics, which will affect windthrow (Everham and Brokaw 1996). Biotic factors affecting damage severity include tree species, size (Walker et al. 1991), and stand attributes such as species composition (Craighead and Gilbert 1962; Zimmerman et al. 1994). Another factor—the severity of vegetation damage relative to its position within the hurricane—has not been frequently documented. Wadsworth and Englerth (1959) observed significant damage up to 43 km from the track of the eye of Hurricane Betsy in Puerto Rico and Thompson (1983) observed varying effects of Hurricane Allen in Jamaica up to 60 km from its eye. Hu and Smith (2018) noted a strong relationship with remotely sensed damage parameters for more than 70 km from Hurricane Maria's track in Puerto Rico. The timing of assessment is also important in characterizing hurricane impacts, as many short-term effects of a storm

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✉ Jan Svejkovsky
jan@oceani.com

[1] Ocean Imaging Corp., 13976 W, Bowles Ave, Suite 100, Littleton, CO 80127, USA

[2] Institute of Environment, Florida International University, 11200 SW 8th St, Miami, FL 33199, USA

[3] Southeast Environmental Research Center and Department of Earth & Environment Florida, International University, Miami, FL 33199, USA

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