Remote Sensing of Wetland Types: Subtropical Wetlands of Southern Hemisphere

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Contents

Keywords
Pantanal • Tropical wetland • Radar satellite • Mapping

Introduction

The Pantanal of South America, located in the center of South America, between Brazil, Bolivia, and Paraguay, represents one of the largest wetlands in the southern hemisphere subtropics. Estimates suggest that the inundated area of the Pantanal covers approximately 160,000 km^2 during maximum flooding, and with the entire Pantanal watershed occupying an area of approximately 362,000 km^2 (Junk et al. 2006). The upper Paraguay River and its three tributaries feed the Pantanal wetlands, promoting a strong annual unimodal flood that varies in duration, amplitude, and extent both yearly and spatially (Hamilton et al. 1996). Such characteristic

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flood dynamics require morphological, anatomical, physiological, and/or ethological adaptations from the local biota. As these seasonal water level variations are the driving force of ecological processes in floodplain systems, identifying the various permanent and semipermanent terrestrial and aquatic habitats in a seasonal flood-pulse ecosystem is critical for understanding the biogeochemical, hydrological, and ecological processes of the ecosystem (Hamilton et al. 1996). The dynamics of inundation in the Pantanal also promote a high diversity of vegetation (Alho 2008), expressed by a unique landscape characterized by different compositions of savanna vegetation, abundant species of aquatic vegetation, and different types of floodplain forests (Alho 2008). In addition to the floristic diversity, a large number of hydrochemically varied lakes, waterways, and other fluvial geomorphological patterns are observed, generating a complex mosaic of wetland habitats (Por 1995; Costa and Telmer 2006; Evans and Costa 2013; Evans et al. 2014).

The vast habitat diversity in the Pantanal is poorly understood, and currently threatened by human development occurring both in the floodplain and on the surrounding plateau. These developments threaten to alter the Pantanal ecosystem in a potentially irreversible manner, mostly through the modification of the natural hydrological cycles of the rivers, and the destruction of natural habitat (Alho 2008). Despite the ecological importance of the Pantanal, and potential consequences resulting from habitat alteration/loss, there is a lack of understanding about the spatiotemporal variability of the landscape units within this wetland ecosystem (Costa 2004). As such, quantification and monitoring of the landscape changes in the Pantanal are critically needed, so that sustainable management practices and effective conservation units can be established. Yet, given the size and relative inaccessibility of the Pantanal system, conventional methods of data gathering are difficult and expensive. Thus, remote sensing technology offers a cost-effective alternative for mapping the spatial variability of the landscape units within this highly heterogeneous wetland ecosystem. In this region, where capturing cloud-free imagery for a large region is difficult, synthetic aperture radar (SAR) imagery is the most viable alternative.

Mapping Wetland Landscape

Costa and Telmer (2006) utilized a combination of C-band (RADARSAT-1) and L-band (JERS-1) imagery to classify the geochemically varied lakes in the Nhecolândia region of the Pantanal, based on the specific types of aquatic vegetation associated with each geochemical condition. Evans et al. (2010) combined temporal coarse resolution SAR (ALOS/PALSAR ScanSAR) and RADARSAT-2 imagery, and more recently Evans et al. (2014) combined 50 m resolution SAR (ALOS/PALSAR, RADARSAT-2, and ENVISAT/ASAR imagery) to map the land cover for the entire Pantanal. Evans and Costa (2013) combine SAR data at improved spatial resolution (12.5 m) and produced a detailed landscape map of Nhecolândia, a sub region of the Pantanal.

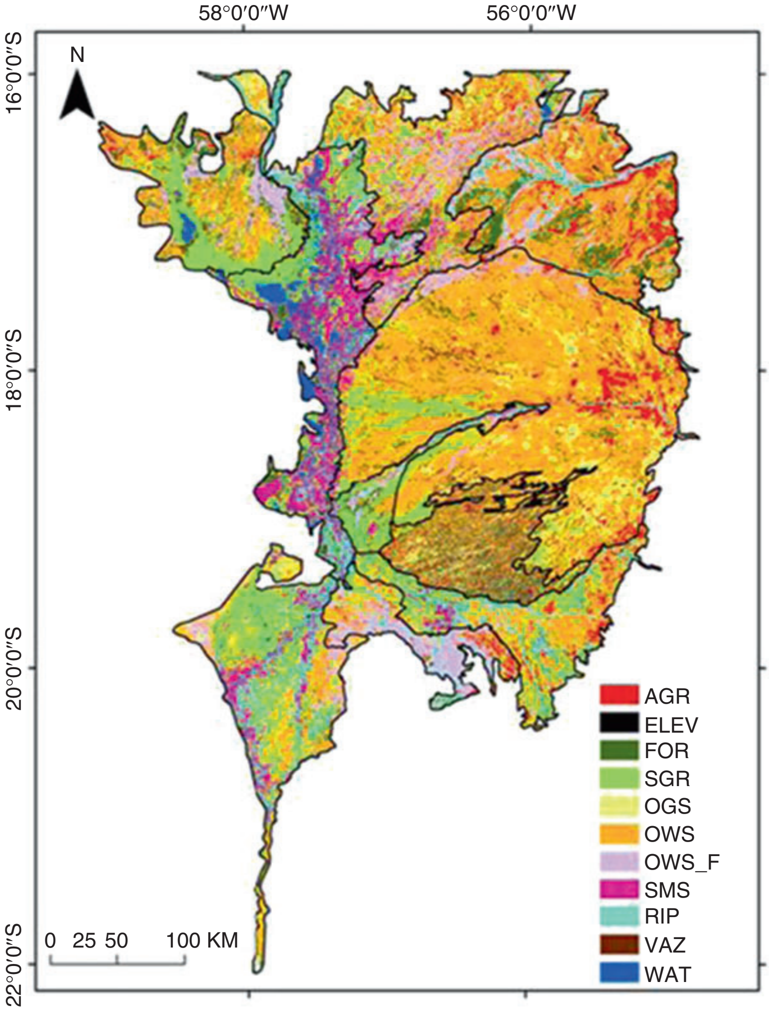

Fig. 1 Classification of land covers within the Pantanal generated using multitemporal ALOS PALSAR and RADARSAT-2 imagery. (*FOR*) forest/woodland, (*RIP*) riparian forest, (*OWS*) open wood savanna, (*OWS_F*) open wood savanna subject to prolonged flooding, (*OGS*) open grass savanna, (*AGR*) agriculture, (*SGR*) swampy grassland, (*SMS*) swampy mixed savanna, (*VAZ*) *Vazantes*, and (*WAT*) water (Evans et al. 2014)

SAR Medium Resolution

The first detailed landcover map for the entire Pantanal was generated by Evans et al. (2014) using these SAR imagery acquired over the same seasonal cycle (Fig. 1). The high frequency of SAR data acquisition was only achieved because of the systematic observation strategy associated with the ALOS PALSAR data. The classification uses 50 m spatial resolution, dual-season, HH and HV L-band ALOS/PALSAR, and HH and HV C-band RADARSAT-2 data, as well as a comprehensive set of ground reference points, to map nine classes of the hydrologically variant subregions of the Pantanal by using a hierarchical object-based image analysis approach. This classification was achieved with an overall accuracy of 80 % for the entire Pantanal. The relative coarseness of the image spatial resolution and the heterogeneity of landscapes within the region did, however, limit the features that could be resolved and also the accuracy of the classification. The produced habitat spatial distribution maps provide vital information for determining refuge zones for terrestrial species, and connectivity of aquatic habitats during the dry season, as well as providing crucial baseline data to aid in monitoring changes in the region, and to help define conservation strategies for habitat in this wetland.

SAR Fine Resolution

The first detailed landcover map for Nhecolândia, a subregion of the Pantanal, was generated by Evans and Costa (2013) using SAR imagery acquired over the same seasonal cycle and an object-oriented classification approach. L-band images from ALOS/PALSAR were acquired for January/February 2008 (12.5 m, HH polarization) coinciding with high water, and for August/September 2008 (12.5 m, HH and HV polarization) coinciding with low water. RADARSAT-2 images were acquired for August 2008 (25 m, HH and HV polarization) coinciding with low water and field campaign. Additional C-band imagery for high water was acquired in February/March 2010 from ENVISAT/ASAR (12.5 m, HH and HV polarization). The Level 1 classification defined four landscape units with an overall accuracy of 90 %. Defined habitats were as follows: (1) forest savanna, which includes deciduous and semideciduous forest, cerradão, cordilheiras, and capãos, and mixed vegetation with shrubs and short scattered trees on a grassy stratum; (2) open grass cover, which includes dominantly grassy/agriculture terrain with some scattered shrubs; (3) *vazantes*, defined as seasonal drainage channels; and (4) lakes, which includes all types (Fig. 2).

Within this region, numerous small lakes exist and these were classified by Costa and Telmer (2006) using a combination of high resolution RADARSAT-1 and JERS-1 SAR data and refined subsequently by Evans and Costa (2013) The general method to differentiate the lakes relies on the natural differences among these lakes: brackish lakes (locally known as *salinas*) are devoid of any emergent aquatic vegetation; fresh water lakes (locally known as *baías*) are populated by a variety of floating/emergent aquatic vegetation ranging in height from 2–100 cm (including *Cyperaceae*, *Pontederiaceae*, *Araceae*, *Salviniaceae*, and *Nymphaeaceae)* and *salobras* can also be colonized by floating and emergent aquatic vegetation, but are distinguished because of the large stands of *Typhaceae*, typically 200–300 cm in height. A relationship has been established between lake water geochemistry and associated vegetation (and therefore, radar backscattering signal), allowing for the

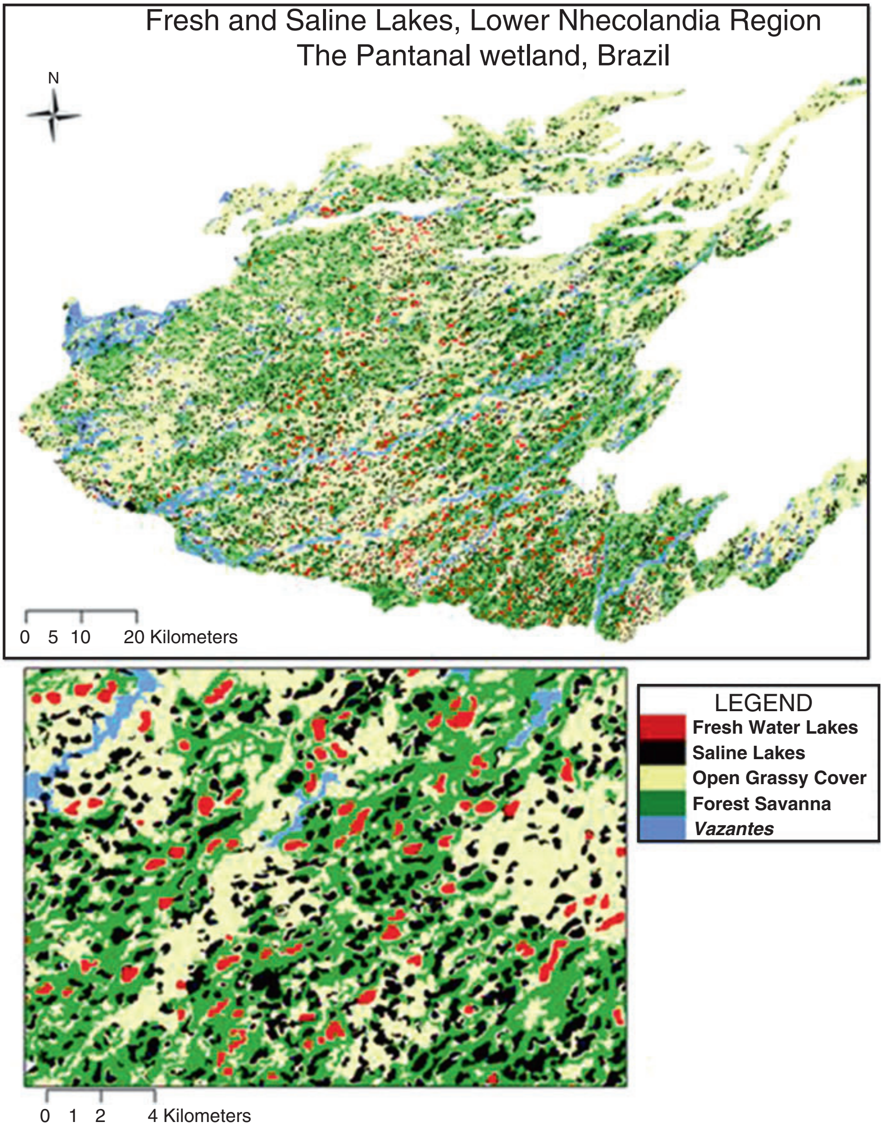

Fig. 2 Landscape classification (Modified from Evans and Costa 2013)

classification of lake geochemistry using radar imagery (Costa and Telmer 2006; Evans and Costa 2013). A Level 2 classification used only the "lakes" class from Level 1 and divided it into fresh lakes (*baías*) and saline lakes (*salinas*) with an accuracy of 98 % (Fig. 2).

As defined in Evans and Costa (2013), the lakes were classified with a combination of imagery from three SAR satellites and an object oriented classification approach. First, a multiresolution segmentation was performed on the imagery and training objects for the two lake types were defined based on field data and the segmented output. Next, radar backscattering mean and standard deviation values for these training objects were examined to determine separability between the lake types using the individual radar images. Finally, a combination of defined backscattering thresholds (class mean +/− 1SD), user-defined rules, and the utilization of the Feature Space Optimization (FSO) tool (in eCogniton) with a supervised nearest neighbor classification algorithm allowed for the classification of the two Pantanal lake types. The lakes classification map (Fig. 2) shows the broad distribution of fresh and brackish lakes in the region.

Cross-References

► Brazilian Wetlands: Classification
► Earth Observation Methods for Wetlands: Overview
► Electromagnetic Spectrum: Regions Relevant for Wetlands

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