International Journal of Applied Earth Observation and Geoinformation 26 (2014) 193–204

Contents lists available at ScienceDirect

International Journal of Applied Earth Observation and Geoinformation

journal homepage: www.elsevier.com/locate/jag

Remote sensing of plant communities as a tool for assessing the condition of semiarid Mediterranean saline wetlands in agricultural catchments

J. Martínez-López*, M.F. Carreño, J.A. Palazón-Ferrando, J. Martínez-Fernández, M.A. Esteve

Ecology and Hydrology Department, Faculty of Biology, Campus de Espinardo, E-30100 Murcia, Spain

ARTICLE INFO

Article history:
Received 14 March 2013
Accepted 5 July 2013

Keywords:
Semiarid wetlands
Remote sensing
Irrigated agriculture
Plant communities
Watershed hydrological condition
Airborne multispectral sensors

ABSTRACT

Semiarid Mediterranean saline wetlands are unique ecosystems sheltering high biodiversity. In the last decades, the expansion of irrigated lands has led to hydrological imbalances in Mediterranean catchments, causing wetland degradation. Vegetation composition assessment is considered an important tool for evaluating wetland ecological condition and can be mapped using remote sensing. This study aims to develop a condition index based on plant community composition suitable for semiarid Mediterranean saline wetlands, as well as to test the applicability of airborne multispectral remote sensors for discriminating plant communities. Characteristic plant communities of 12 wetlands were identified by means of ordination and classification analysis of plant taxa cover percentages obtained through fieldwork sampling. An index for assessing wetland ecological condition was developed based on the relationship between wetland plant community composition and watershed hydrological condition. Selected wetland plant communities were then mapped by means of remote sensing techniques using random forest algorithm for supervised classification of airborne images. Following this methodology, remote sensing served as a tool for wetland condition assessment at a regional scale.

1. Introduction

Semiarid Mediterranean saline wetlands are semi-terrestrial ecosystems, which yearly undergo dry periods of several months, and shelter a rich, endemic and sensitive biota (Brinson and Malvárez, 2002; Vidal-Abarca et al., 2003). They are sinks of irrigation flows, which makes catchment scale management of vital importance for their conservation (Dudgeon et al., 2006). In the last decades, the expansion of irrigated areas in semiarid Mediterranean catchments has led to altered inputs of water and nutrients to lowland wetlands (Hollis, 1990; Carre no et al., 2008; Martín-Queller et al., 2010), which particularly affect soil salinity, water table level and regime and soil moisture conditions (Álvarez-Rogel et al., 2007b). Although much effort has been applied towards protection of wetlands, the preservation of their watershed areas has been largely ignored (Houlahan and Findlay, 2004). Moreover, the lack of systematic monitoring and management procedures for this type of saline aquatic ecosystems is ultimately leading to extensive wetland degradation, and therefore practical tools for assessing ecosystem state and functioning are required in order to orient decision making (Williams, 2002).

Vegetation composition assessment is considered an important aspect for evaluating wetland ecological condition (López and Fennessy, 2002; Miller et al., 2006; García et al., 2009; Caçador et al., 2013). Anthropic or climatic factors that affect wetland plant communities also affect wetland birds and invertebrates communities (Hughes, 2004; Pardo et al., 2008; Robledano et al., 2010). The European Habitats Directive considers salt marsh and salt steppe habitats as important and endangered ones and promotes their preservation (Council of Europe, 1992). Moreover, the European Water Framework Directive also impels to monitor the ecological status of transitional waters ecosystems including wetlands (European Commission, 2003; Ferreira et al., 2007). Plant species and communities can be used as a proxy to assess wetland hydrological perturbations if their ecological tolerances to environmental factors such as salinity and water table level are known (Cronk and Fennessy, 2001). Previous studies in similar wetlands have focused on individual taxa rather than on plant communities (Álvarez-Rogel et al., 2007b; Martínez-López et al., 2012). However, plant communities contain more information than single species and are easier to map by means of remote sensors (O'Connell, 2003; Johnston et al., 2009).

* Corresponding author. Tel.: +34 868884653; fax: +34 868883963.
E-mail addresses: javier.martinez@um.es, javi.martinez.lopez@gmail.com (J. Martínez-López), juliamf@um.es (J. Martínez-Fernández).

0303-2434/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.jag.2013.07.005

Given that wetlands are often located in remote areas and are difficult to survey, fieldwork sampling methods are labour intensive, specially for large wetland sites and for regional scale assessment. Therefore, most of these ecosystems receive no systematic monitoring (Buchanan et al., 2009). In this regard, remote sensing offers a rapid and cost-effective approach for generating ecologically relevant wetland vegetation maps (Jones et al., 2009; Lee and Yeh, 2009; Poulin et al., 2010). Remote sensing techniques are able to cover large areas, are prone to rapid technical improvements, and can help discriminate different wetland plant communities in order to systematically assess wetland conservation status (Belluco et al., 2006; Wang et al., 2007). Due to pixel size, specific plant species are usually more difficult to discriminate, unless they form dense monospecific stands (*e.g.* reed beds). However, plant communities are composed by similar relative proportions of specific plant species across wetland sites and therefore they tend to show characteristic spectral responses at large patches. Therefore, the establishment of plant communities that can be related to wetland hydrological pressures combined with remote sensing techniques can serve as a tool for wetland management and monitoring at a regional scale (Ozesmi and Bauer, 2002; Xie et al., 2008).

Different methods have been developed for wetland vegetation delimitation from remote sensing imagery (Horning et al., 2010; Friess et al., 2012; Szantoi et al., 2013). Wetlands are very heterogeneous ecosystems containing small vegetation patches with similar spectral responses that might generate spectral confusion (Ozesmi and Bauer, 2002; Baker et al., 2006). Enhanced classification methods like random forest algorithm or artificial neural networks have shown better performance for these Mediterranean ecosystems (Breiman, 2001; Černá and Chytrý, 2005; Sluiter, 2005). Medium-resolution satellite sensors such as Landsat TM are not suitable for detecting small wetlands or plant community patches (Xie et al., 2008; Adam et al., 2010). Therefore, airborne multispectral sensors are a good source of remotely sensed data for wetland vegetation mapping since they combine high spatial and spectral resolution with acquisition timing (Wang et al., 2007; Klemas, 2011).

The scarcity of available historical data on wetland vegetation due to inaccessibility and high economic cost calls for the use of remote sensing for present and future studies in order to provide a set of multi-temporal images to monitor wetland ecosystems (Klemas, 2001; Carre no et al., 2008; MacKay et al., 2009). Scientific studies bridging the gap between ecology and conservation biology are utmost important in order to influence conservation of aquatic ecosystems (Strayer and Dudgeon, 2010). This study proposes a procedure for a comprehensive study of wetlands and their drainage basins coupling fieldwork and advanced remote sensing techniques in order to evaluate wetland condition based on plant communities. The main objectives of this study were: (1) to characterize plant communities in several representative wetlands under a range of watershed hydrological conditions; (2) to explore the relationships between wetland plant community composition and watershed hydrological pressures; (3) to propose a wetland condition index based on plant community composition; and (4) to test the potential of remote sensing as a tool for assessing wetland condition.

2. Methods

2.1. Study wetlands

The study area was located in Murcia province, southeast of Spain (38°45′–37°23′ North and 0°41′–2°21′ West). The climate is semiarid Mediterranean, with a mean annual temperature of 16 °C and a mean annual precipitation of 339 mm (Esteve et al., 2006).

Table 1
Study wetlands and respective watershed areas (ha).

Wetland	Wetland area	Watershed area
Salinas del Rasall	26.3	236
Saladar de Cañada Brusca South	3.8	69.5
Saladar de Cañada Brusca North	17.4	360
La Alcanara	199	6508
Marina del Carmolí	314	16,923
Playa de la Hita	34.4	2052.8
Saladar de Matalentisco	10.4	907.6
Saladar de Boquera de Tabala	36.9	5819.2
Lopoyo	80	2783
Ajauque	100	7792
Derramadores	50	1963
Sombrerico	3	141

Twelve representative wetlands were selected, *i.e.* 8 coastal and 4 inland wetlands (Figs. 1 and 2; Table 1). Selected sites are included in the regional inventory of wetlands (Vidal-Abarca et al., 2003) and their protection status ranges from regional, national to international rules due to their high ecological values (Ramsar Site, Special Protection Area for Birds, Site of Community Importance and Special Protection Area for the Mediterranean), except for Matalentisco and Boquera de Tabala wetlands, which do not benefit from any protection status. Marina del Carmolí, Lo Poyo and Playa de la Hita wetlands are in a lowland coastal plain, called Campo de Cartagena, associated with the internal shore of the Mar Menor coastal lagoon, which comprises 12,700 ha (Conesa, 1990; Conesa and Jiménez-Cárceles, 2007). The lagoon and its associated wetlands are all RAMSAR sites, containing eighteen Habitats of Community Interest according to the European Habitat Directive (Council of Europe, 1992). Salinas del Rasall is a coastal wetland associated with a salt extraction pond embedded in the Calblanque Natural

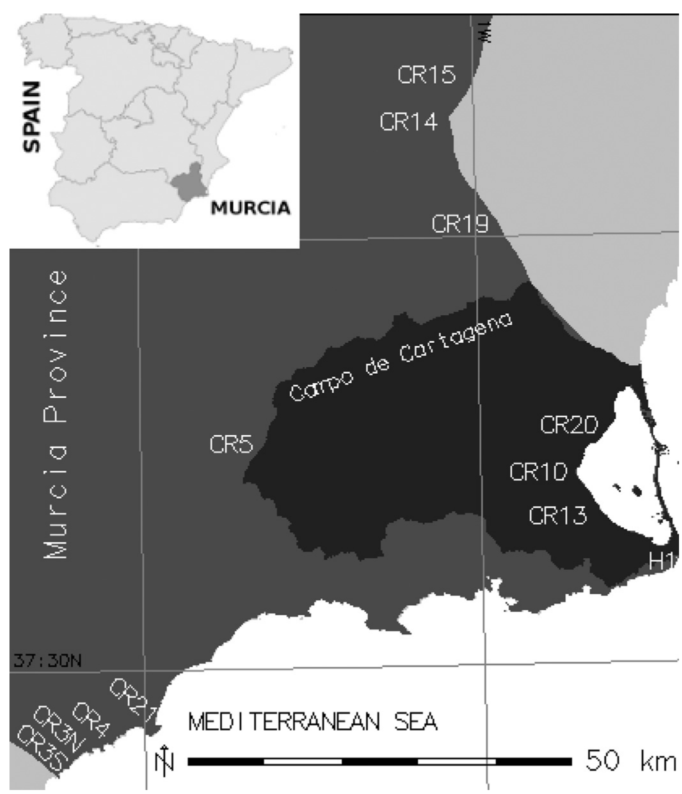

Fig. 1. Location of Murcia province in Spain and approximate location of the study wetlands. Wetland keys: H1: Rasall; CR3S: Cañada Brusca South; CR10: Carmoli; CR5: Alcanara; CR14: Ajauque; CR13: Lopoyo; CR15: Derramadores; CR19: Boquera de Tabala; CR20: Playa de la Hita; CR3N: Cañada Brusca North; CR4: Matalentisco; CR21: Sombrerico.