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A transferability study of the kernel-based reclassification algorithm for habitat delineation

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ABSTRACT

Wetland mapping using Earth observation (EO) data has proved to be a challenging task for practitioners due to the complexity in the spatial structure and composition, the wide within-class spectral variability and the absence of easily distinguishable boundaries between habitat types. Furthermore, the inherent temporal water instability of these landscapes poses an obstacle to the integration of field data with remote sensing data, which also are not acquired simultaneously at all times.

To cope with these limitations we tested the applicability of the Kernel-based reclassification (KRC) algorithm on very high spatial resolution (VHR) satellite imagery over a wetland. A composite multi-temporal (i.e. dual-date) VHR WorldView-2 image consisting of spectral bands and indices derived from two images acquired during flooded and dry water conditions were employed. This dataset stresses the seasonal variations of the habitat in response to environmental changes (i.e. flooding) occurring between the two acquisition dates. Multi-temporal imagery is an important information source for fine mapping of wetlands such are river deltas. A multi-temporal approach could reveal even more specific information during the phenology of these habitats.

The methodology was applied firstly to Axios and then to Aliakmonas river deltas in Northern Greece. The results revealed an overall accuracy of 53% in the first and more complex site, and 86% in the second site.

Introduction

Wetlands are multiple-value systems covering approximately 4–6% of the world's terrestrial area with high ecosystem significance. Lately, they became of global concern because of the growing anthropogenic pressure and the sensitivity they demonstrate to climate change. The importance is further underpinned by the fact that the loss of wetlands, and the associated functions and values, through development is often irreversible (Mitsch and Gosselink, 2000). Furthermore, wetlands sequester and release large volumes of fixed carbon in the biosphere and therefore are potentially an important component in global climate change (Mitsch and Wu, 1995). On a global scale, the loss of biodiversity has initiated a scientific interest in species distribution, the associated environmental drivers and how they operate in different geospatial contexts (Turner et al., 2003), with most of the studies concentrating on temperate regions (Mace et al., 2005).

Efficient management and conservation of natural habitats is increasingly a topic for investigation and concern by several scientific groups during the last years (Spanhove et al., 2012). While the field is prevailed by biological and ecological oriented disciplines, Earth Observation (EO) data are progressively employed for mapping features of interest and indicators (Kerr and Ostrovsky, 2003). This has urged the need for developing methodologies based on remotely sensed data also tailored to wetland characteristics.

Nevertheless, mapping of wetlands based on EO data has proved to be a challenging task for practitioners due to the complexity in

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the habitat's spatial structure and composition, the broad within-class spectral variability and the absence of easily distinguishable boundaries between habitat types. Furthermore, the inherent spatio-temporal variability in the water content of these landscapes poses an obstacle to the integration of field data with EO data, which are not acquired simultaneously at all times. The need to investigate and establish advanced methodologies for mapping habitats based on remotely sensed data is prominent. Those application-specific methodologies combining multiple-source data are an active and vigorous topic of research. Klemas (2013) provides an overview of remote sensing of wetlands based on recent advances on sensor's resolutions, Rebelo et al. (2009) report on several recent initiatives using EO data to foster wetland inventorying and Ozesmi and Bauer (2002) summarize the literature on EO of wetlands.

With the advent of VHR sensors on-board satellites, the discrimination capacity in complex environments increases significantly. For example, WorldView-2 (WV-2), currently one of the satellite sensors with the highest spatial resolution (0.46 m and 1.85 m in panchromatic and multispectral bands respectively), is able to record electromagnetic radiation in 8 bands. WV-2 was launched in October 2009 as the successor of Quickbird and WorldView-1 satellites with the enhanced spectral capability of recording data in four additional bands designed for enriching multispectral analysis in vegetation studies. VHR has demonstrated to be a key factor in mapping natural habitats (Corbane et al., 2013) attaining to small wetlands mapping (e.g. Kuria et al., 2014) and small plant communities (e.g. Szantoi et al., 2013), providing information on species level (Turner et al., 2003), and identifying precisely ecosystem characteristics (Salari et al., 2014). However, the processing tools developed for medium resolution images might not provide the most accurate results, especially in cases of high land cover heterogeneity and small patch size (Smith et al., 2002), such as wetland habitats. In this mapping context, Keramitsoglou et al. (2006) applied three advanced pixel window (i.e. kernel) classifiers on VHR multispectral satellite images (IKONOS-2), namely Kernel based spatial Re-Classification (KRC), Radial Basis Function (RBF) Neural Networks (NN) and Support Vector Machines (SVM) and they report overall accuracies between 56% and 72% depending on the methodology and its parameterization (kernel size, number of fuzzy sets etc.). Furthermore and adding to the complexity of mapping evaluation, user's and producer's accuracy in wetland related studies can fluctuate significantly depending on the classes' spectral and textural characteristics. For instance Salari et al. (2014) reports accuracy between 60% and 97% when mapping land use/land cover in a tropical wetland with WorldView-2 imagery.

Along the development of purposeful algorithms, software tools with familiar interface and limited complexity are needed in order to be useful for ecologists not necessarily skilled in remote sensing science. ANAX (Advanced classification methods for inventorying and mapping protected areas using satellite imagery) is a software platform developed at the Institute for Astronomy, Astrophysics, Space Applications and Remote Sensing (IAASARS) of the National Observatory of Athens (NOA). The software has been specifically designed with the scope of creating a user-friendly interface digitizing polygon sets used for classification and validation purposes, performing unsupervised classification as well as the KRC algorithm. An informative description of ANAX is available at the MS.MONINA Tool Repository website (http://www.ms-monina.eu/tools-catalogue).

This paper focuses on the application of the KRC algorithm on ANAX platform on two neighbouring river deltas for mapping habitat types by evaluating the transferability of the methodology within a typical Mediterranean environment. The objective of this study is to demonstrate the applicability of a classifier which considers spectral and textural image characteristics from multi-temporal data with VHR. We concentrate on specific habitats (Table 1) of a wetland in Northern Greece covering Axios and Aliakmonas river deltas, and investigate the applicability of the KRC algorithm in mapping their extent.

Table 1
Habitats of interest that occur in the study areas.

Code	Description
Natural habitat types of Community Interest (Annex I)	
1310	Salicornia and other annuals colonizing mud and sand
1410	Mediterranean salt meadows (*Juncetalia maritimi*)
1420	Mediterranean and thermo-Atlantic halophilous scrubs (*Sarcocornetea fruticosi*)
6420	Mediterranean tall humid grasslands of the Molinio-Holoschoenion
92A0	*Salix alba* and *Populus alba* galleries
92D0	Southern riparian galleries and thickets (Nerio-Tamaricetea and *Securinegion tinctoriae*)
Other habitats	
72A0	Reed beds (habitat type of national interest, not included in Annex I to HabDir)
	Unvegetated muddy substrate

Study area

The Axios and Aliakmonas river deltas (Fig. 1) are specially protected areas and sites of conservation interest of the Natura 2000 network (site codes GR12200002 and GR1220010) as well as protected by the Ramsar Convention and included in Greece's national list of Sites of Community Importance (SCI). The river deltas are part of a larger complex National Park (GR1220002) covering 336.76 km^2 (source: Natura 2000 Viewer, EEA). Most of the habitats and species are protected under the Habitats Directives (HabDir, Council Directive 92/43/EEC). According to the Axios Loudias Aliakmonas Estuaries Management Authority (Axios – Loudias – Aliakmonas National Park, 2013) they encompass more than 370 species including rare and threatened ones as well as one of the most important mixed heron colonies in Greece living in the riparian forest of Axios. It is a valuable habitat for a numerous animals and home to the European ground squirrel (*Spermophilus citellus*), the European otter (*Lutra lutra*) and the Hermanns' tortoise (*Testudo hermanni*), all threatened to extinction. It is home for more than 500 plant species including the rare Sea daffodil (*Pancratium maritimum*).

Due to their vicinity, Axios and Aliakmonas deltas share common habitat characteristics and main species composition. They are forming a mosaic of brackish lagoons, saline soils, extensive mudflat, saltwater and freshwater, sand dunes, rich vegetation and extensive crops. The prevailing habitat in terms of coverage is the *Mediterranean and thermo-Atlantic halophilous scrubs* (*Sarcocornetea fruticosi*), Natura 2000 code 1420. Of specific interest is the habitat *Salicornia* and other annuals colonizing mud and sand 1310. The recommended strategic plan (Vareltzidou and Strixner, 2009) considers the surface of these two habitats amongst the indicators for monitoring and assessing the coastal ecosystem structure and its conservation status.

In this study we focus on the deltas as two separate areas of interest and classify the seven main detectable habitats (Table 1) based on two neighbouring satellite images. The nomenclature followed is according to the HabDir (European Council, 1992).

Materials and methods

In this study we employ dual-date VHR imagery, a habitat delineation map from the European Space Agency's GlobWetland I project and in situ observations.

Two acquisitions of WV-2 multispectral images for each river delta were employed synergistically. The first pair of images was