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Transferability of species distribution models for the detection of an invasive alien bryophyte using imaging spectroscopy data

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ABSTRACT

Remote sensing is a promising tool for detecting invasive alien plant species. Mapping and monitoring those species requires accurate detection. So far, most studies relied on models that are locally calibrated and validated against available field data. Consequently, detecting invasive alien species at new study areas requires the acquisition of additional field data which can be expensive and time-consuming. Model transfer might thus provide a viable alternative. Here, we mapped the distribution of the invasive alien bryophyte *Campylopus introflexus* to i) assess the feasibility of spatially transferring locally calibrated models for species detection between four different heathland areas in Germany and Belgium and ii) test the potential of combining calibration data from different sites in one species distribution model (SDM). In a first step, four different SDMs were locally calibrated and validated by combining field data and airborne imaging spectroscopy data with a spatial resolution ranging from 1.8 m to 4 m and a spectral resolution of about 10 nm (244 bands). A one-class classifier, Maxent, which is based on the comparison of probability densities, was used to generate all SDMs. In a second step, each model was transferred to the three other study areas and the performance of the models for predicting *C. introflexus* occurrences was assessed. Finally, models combining calibration data from three study areas were built and tested on the remaining fourth site. In this step, different combinations of Maxent modelling parameters were tested. For the local models, the area under the curve for a test dataset (test AUC) was between 0.57–0.78, while the test AUC for the single transfer models ranged between 0.45–0.89. For the combined models the test AUC was between 0.54–0.9. The success of transferring models calibrated in one site to another site highly depended on the respective study site; the combined models provided higher test AUC values than the locally calibrated models for three out of four study sites. Furthermore, we also demonstrated the importance of optimizing the Maxent modelling parameters. Overall, our results indicate the potential of a combined model to map *C. introflexus* without the need for new calibration data.

1. Introduction

Remote sensing is a promising tool for the detection and monitoring of invasive alien plant species (Bradley, 2013). Invasive alien plants can be identified from different remote sensing platforms like unmanned aerial vehicles (UAVs) (e.g. Michez et al., 2016; Müllerová et al., 2017), airborne platforms (e.g. Cheng, 2007; Mirik et al., 2013; Skowronek et al., 2017a,b) or from satellites (e.g. Proctor et al., 2012; Somers and Asner, 2013). In particular, imaging spectroscopy data hold a high potential due to their high spectral resolution, which allows differentiating characteristic species from the surrounding vegetation (He et al., 2011; Huang and Asner, 2009).

The large majority of studies on mapping the distribution of invasive alien plant species have relied on models that are calibrated

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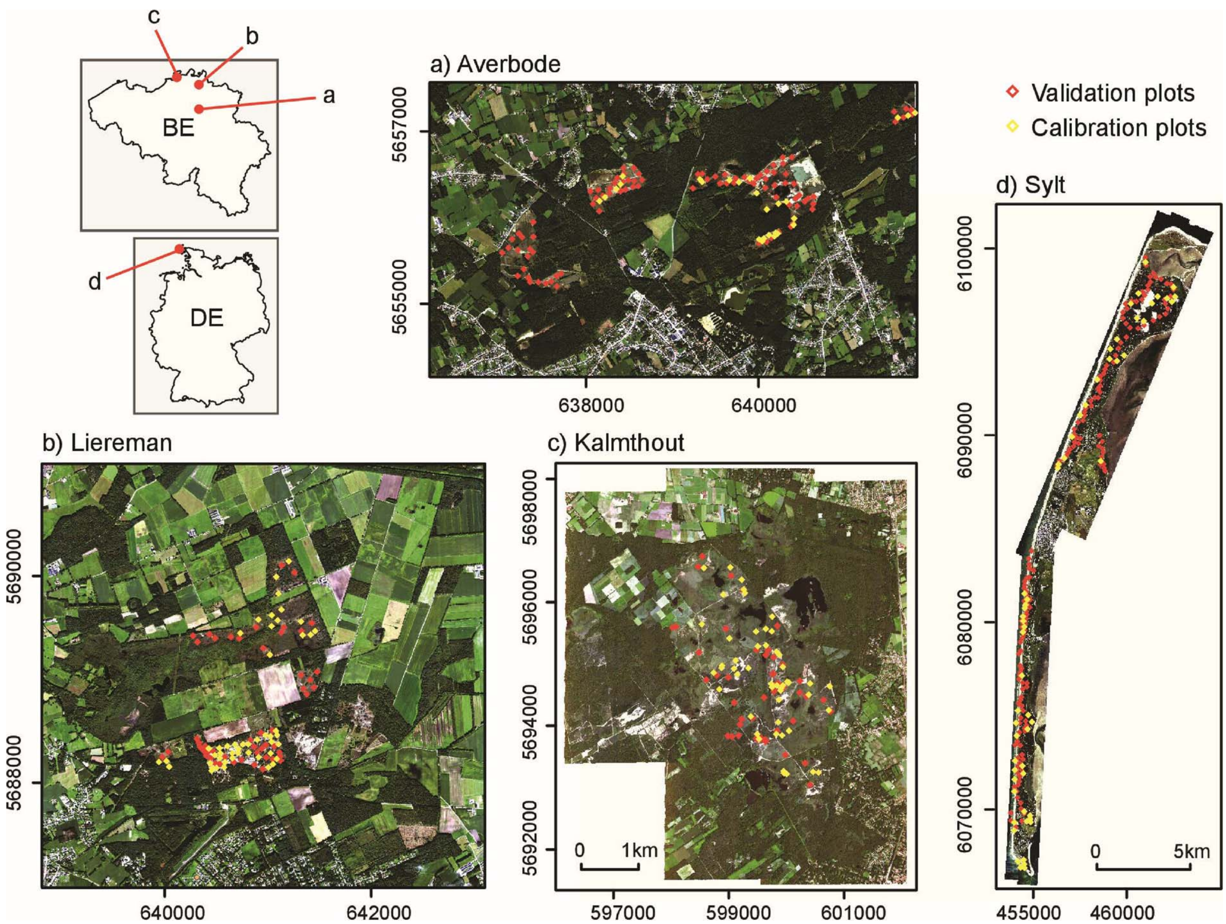

Fig. 1. Study areas (a) Averbode Bos & Heide (Av); (b) Landschap de Liereman (Li); (c) Kalmthoutse Heide (Ka) and (d) Sylt (Sy). A true colour composite derived from the APEX data is used as background.

(trained) and validated (tested) using field data specific to a particular location (referred to hereafter as site-specific models). The spatial transfer of species distribution models might be a useful tool for mapping the distribution of invasive alien species in the following two situations: when limited resources are available to carry out field work and remote sensing data are available for a larger area and when the detection of recently invaded sites is of interest, but manual search of the area to calibrate a site-specific model is not feasible. The transferability of species distribution models has been investigated in several recent studies which mainly evaluated the performance of different algorithms (Duque-Lazo et al., 2016; Heikkinen et al., 2012; Wenger and Olden, 2012), or focused on the tuning of model settings (e.g. Moreno-Amat et al., 2015; Muscarella et al., 2014). While most of these studies relied on climatic, topographic, soil, or similar data as predictor variables, few studies have examined the success of model transfer using spectral data (with the exception of Tuanmu et al., 2011, for example). However, He et al. (2015) highlighted the potential of airborne hyperspectral remote sensing data in species distribution modelling due to its high spectral and relatively high spatial resolution as well as a high spatial coverage.

One main challenge for model transferability is that individual models may be limited by site-specific information, causing the model to be overfit to a certain location (Anderson and Gonzalez, 2011; Moreno-Amat et al., 2015). Jiménez-Valverde et al. (2011) suggest combining data from several locations to calibrate an overall species distribution model for invasive alien species to predict on a new area. One of the most frequently used algorithms for species distribution modelling is Maxent (Merow et al., 2013). Two important parameters govern the functionality of Maxent: the regularization multiplier (*ß*), and the number of considered feature classes to construct the model (*fc*) (Elith et al., 2011; Merow et al., 2013; Radosavljevic and Anderson, 2014). To reduce over-fitting and to generate a simpler and potentially more transferable model, we can increase *ß* and limit *fc*. Elith et al. (2011) mention that Maxent is relatively stable when dealing with correlated input variables compared with other methods (for example stepwise regression). Consequently, there is less of a need for pre-selection of predictor variables when using Maxent. However, the selection of model metaparameters is important for Maxent to perform optimally. Warren and Seifert (2010) proposed to use information criteria for model selection in order to avoid selecting overly complex models.

In this study, we evaluated the transferability of Maxent models based on airborne imaging spectroscopy for detecting the invasive alien bryophyte *Campylopus introflexus*. This species was classified to be one of the 100 worst invaders in Europe (DAISIE, 2015). As a relatively small and inconspicuous species lacking characteristic features like colourful flowers, it was chosen to show whether remote sensing is a useful tool to detect such a species. Also, bryophytes constitute a largely understudied group of species among the invasive alien plants (Essl et al., 2014; Mateo et al., 2015).

We use four different study sites located in Germany and Belgium where we collected independent calibration and validation datasets. This study builds further on the work of (Skowronek et al., 2017b) which used Maxent modelling (using default settings) to map the distribution of *C. introflexus* based on airborne imaging spectroscopy on the island of Sylt, Germany. Our research questions are: (1) How well can we transfer models from one site to another? (2) Does combining data from multiple study sites improve the prediction? (3) How do parameter settings affect model performance?