Biological Conservation xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Biological Conservation

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

Priority areas for the conservation of perennial plants in China

Ming-Gang Zhang [a,b], J.W. Ferry Slik [c], Ke-Ping Ma [b,*]

[a] Institute of Loess Plateau, Shanxi University, Taiyuan 030006, China
[b] State Key Laboratory of Vegetation and Environmental Change, Institute of Botany, Chinese Academy of Sciences, Beijing 100093, China
[c] Faculty of Science, Universiti Brunei Darussalam, Jln Tungku Link, Gadong BE1410, Brunei Darussalam

ARTICLE INFO

Article history:
Received 29 November 2015
Received in revised form 8 June 2016
Accepted 12 June 2016
Available online xxxx

Keywords:
Plant diversity
Species distribution model
Collection bias
Systematic conservation planning
Priority areas for conservation
Land use planning

ABSTRACT

With over 35,000 higher plants recorded, China is among the countries with the highest plant diversity. However, due to increasing human population, land-use intensification, and economic development, the habitat of most species is under considerable threat. Here we develop conservation priority maps covering all of China based on plant species distribution models in combination with spatially explicit decision making tools for systematic conservation planning. Our aim was to find spatial scenarios that maximize the success of conservation goals while minimizing the required land area to achieve these goals, so that economic development can proceed with minimal damage to existing biodiversity resources. We built species distribution models for 7427 vascular plant species at a 10 × 10′ resolution covering whole China, using geo-referenced herbarium collections and detailed environmental data, corrected for spatial bias using a null model. Based on these models we mapped: (1) species richness centers for common species (3535), endemic species (1965) and Chinese red list species (1927); (2) priority areas for conservation, distinguishing between conservation targets for common species (15% of the predicted suitable habitat), endemic species (25% the predicted suitable habitat) and red list species (35% the predicted suitable habitat); and (3) downscaled land-use pattern in each priority area for conservation. Clear priorities for the development of a sustainable and feasible biodiversity conservation strategy can now be provided based on our maps at national and regional levels.

1. Introduction

Strong environmental gradients, complex topography and a long geological history have resulted in a diverse Chinese flora (Wang et al., 2012). Over 35,000 higher plants have been recorded in this region (Editorial Committee of *Flora Reipublicae Popularis Sinicae*, 1959–2004), and over half of them are endemic (Huang et al., 2012; Ying and Zhang, 1994). As a developing country famous for its extremely high biodiversity, solving the conflict between plant conservation and economic development is a major challenge for both scientists and the government (Corlett, 2015; Sang et al., 2011). Several efforts have been made to conserve the biodiversity of China over the past decades. According to the recent list provided by Ministry of Environmental Protection of China (MEP), over 2600 protected areas (national parks, natural parks, nature reserves, protected landscapes, etc.) have been established, the total area of which reaches ~15% of China's land surface (MEP, 2007). From 2008 onwards, using the red list categories and criteria developed by International Union for Conservation of Nature (IUCN), the Chinese Ministry of Environmental Protection and Chinese Academy of Sciences evaluated the threat status of over 35,000 higher plants of China (MEP and CAS, 2013). The results showed that over 6000 higher plants are threatened or near threatened (Qin and Zhao, 2014), meaning that over 18% of all higher plants in China need urgent conservation action.

A major problem with the current protected area system in China is that it lacks a sound spatial design at the macro-scale (Zhang et al., 2012, Wan et al., 2014). Furthermore, in the past decades the effectiveness of those reserves in protecting threatened species has been questioned (Zhang et al., 2015). Most protected areas were selected based on their inaccessibility or unsuitable nature for other purposes rather than their biodiversity value per se (Sang et al., 2011). This bias is especially problematic for species that specialize on productive or potentially productive landscapes because they may not be well represented in the current protection system. Therefore, there is a real and urgent need for more systematic spatial planning to identify priority areas for protection. Meanwhile, those areas should conserve most of China's biodiversity but leave enough room for economic development (Ardron et al., 2010; Huggins, 2005).

Once conservation priority areas have been identified, it is important to analyze current and planned future land use. China's forests are facing serious risk of being converted into economically more productive land-use types, such as tree plantations and agriculture (Zhang et al., 2014). Recent reviews give some sensible recommendations on land-use planning within protected and agricultural areas, which include: restoration towards natural forest, designating corridors that facilitate migration of

---

* Corresponding author.
E-mail address: kpma@ibcas.ac.cn (K.-P. Ma).

http://dx.doi.org/10.1016/j.biocon.2016.06.007
0006-3207/

Please cite this article as: Zhang, M.-G., et al., Priority areas for the conservation of perennial plants in China, Biological Conservation (2016), http://dx.doi.org/10.1016/j.biocon.2016.06.007

plants and animals, and maintenance of diverse landscape mosaics (Tambosi et al., 2014). Due to the large area of China and the wide distribution of priority areas, multiple land use planning strategies will be needed.

In this paper, we used species distribution modeling in combination with systematic conservation planning and decision making tools (Possingham et al., 2000) to: (1) map the botanical richness patterns of common species, endemic species and red list species across China; (2) identify priority areas for conservation based on the current distribution of species; and (3) explore current land use in the proposed priority areas to determine the threats to conservation faced by each priority conservation area.

2. Methods

2.1. Species data

We obtained collection information for *c.* 4.5 million specimens of Chinese vascular plants present in 42 major herbaria from the Chinese Virtual Herbarium (<http://www.cvh.org.cn/cms/en/>, accessed September 2012). As a first step, we selected the 1.1 million records for woody species (trees, shrubs and lianas) for further analysis. Most of these records had no latitude and longitude information, so they were georeferenced by mapping the label locations on a high resolution map of China. This resulted in 464,045 specimens with latitude and longitude information. Based on these georeferenced collections, species presences were scored in 10′ grid cells, avoiding duplicate species records in each grid cell. We used the 10′ spatial resolutions because it provided a good balance between geo-referencing accuracy and the spatial resolution of available species occurrence data. Species that were present in fewer than 5 grid cells were removed from the analysis because no statistically sound habitat association analyses could be performed with these. This meant that the final species distribution analyses made use of 371,712 records belonging to 157 plant families representing 6828 species. Furthermore, following the three steps above, 867 herbaceous plant species were also included in the analysis. These herb species were chosen because they were evaluated as threatened or near threatened in the China biodiversity red list (MEP and CAS, 2013). Finally, all of these species were re-classified into three categories according to the China biodiversity red list: common species, endemic species and red list species.

2.2. Environmental predictors

Initially, 35 environmental predictors were selected to model the species distribution patterns. These included 19 bioclimatic predictors (1950–2000) plus altitude of the WORLDCLIM dataset (<www.worldclim.org>) for China at 10′ resolution, and 15 soil variables selected from the FAO database for poverty and insecurity mapping (FAO, 2002). The FAO soil properties had a spatial resolution of 5′, so we resampled all soil layers into 10′ grid cells using ArcGIS 9.3. The whole mainland of China was thus covered by 34,230 grid cells.

Because multi-colinearity of variables can result in over-fitting in species distribution modeling (Graham, 2003; Pearson et al., 2006), we removed highly correlated environmental predictors. For both bioclimatic and soil predictors, we used spearman's rank correlation tests to select the least correlated variables (Spearman's rho < 0.75). From correlated variables with Spearman rho higher than 0.75 only the ecologically most meaningful factors were kept. This procedure eventually resulted in the following climatic variables being included for further analyses (Table S1): (1) Bio01: Annual Mean Temperature; (2) Bio03: Isothermality (P2/P7) × 100 (P2: Mean Diurnal Rang; P7: Temperature Annual Range); (3) Bio07: Temperature Annual Range; (4) Bio12: Annual Precipitation; (5) Bio15: Precipitation Seasonality; and (6) Elevation. Of the soil predictors the following variables were included in the analysis (Table S2): (1) BS-T: base saturation% topsoil; (2) CE-S: CEC clay subsoil (CEC = cation exchange capacity); (3) CN-T: C:N ratio class topsoil; (4) CP-T: organic carbon pool topsoil; (5) Depth: effective soil depth; (6) Drain: soil drainage class; (7) NN-T: nitrogen% topsoil; (8) Prod: soil production index; (9) Text.: textural class subsoil. In total 15 of the original 35 predictors were kept to model species distributions.

2.3. Species distribution model building and significance testing

In order to model species distributions we used the modeling application Maxent (ver. 3.3.3k; < www.cs.princeton.edu/~schapire/maxent/ >) (Phillips et al., 2006). Maxent was specifically developed to model species distributions with presence-only data. Of available species distribution modeling algorithms, Maxent has been shown to perform best when few presence records are available (Wisz et al., 2008), while it is also the least affected by location errors in occurrences (Graham et al., 2007). Maxent was run with the following modeling rules: (1) for species with 5–10 collection records linear features were applied, (2) for species with 10–14 records quadratic features were applied, while (3) for species with >15 records hinge features were applied (Raes and ter Steege, 2007).

As a measure of the accuracy of the SDMs, we used the threshold independent area under the curve (AUC) of the receiver operating characteristic (ROC) plot produced by Maxent. All measures of SDM accuracy require absences (Liu et al., 2011). When these are lacking, as is the case here, they are replaced by pseudo-absences or sites randomly selected at localities where no species presence was recorded (Phillips et al., 2006, Merow et al., 2013). However, when SDM accuracy measures are based on presence-only data and the background data, the standard measures of accuracy (e.g. the often used measure AUC > 0.7) do not apply (Raes et al., 2009; Raes and ter Steege, 2007). When building the presence-only models for these species with low prevalence, the AUC values tend to inflate (van Proosdij et al., 2015). Therefore, we applied the null-model developed by Raes and ter Steege (2007) to test the AUC value of an SDM developed with all presence records against the AUC values expected by chance. However, this assumes that collection localities represent a random subset of the study areas environmental space. In many cases this is not a valid assumption due to collecting biases (Kleidon and Mooney, 2000; Tsoar et al., 2007).

To check for collecting bias in our dataset we tested whether our 3068 collection localities formed a random subsample of China's environmental predictor space. To do this we divided each of the 15 environmental predictors into 10 equal-interval bins based on the ranges observed for whole China (34,230 grid cells) (Loiselle et al., 2008). We then tested whether the observed frequency distributions represented by the 3068 collection localities differed from those observed for whole China using a Chi-square test. This showed that for 14 of the 15 environmental predictors, our collection locations represented non-random subsamples of China's environmental predictor space. To correct for this we developed a bias corrected null model by testing each species model AUC value against 1000 AUC values that were generated by randomly sub-sampling from all the available collection localities. When the observed AUC value fell in the top 95% of randomly generated AUC values, it was considered to have a significant non-random distribution and was used in our further analyses. For all the 6828 available woody species of China, 6560 species showed a significantly non-random distribution (AUC value ≥ 95% C.I.), while all of the 867 herbs passed the null model test. Therefore, 7427 species were included in the final analyses.

2.4. Species richness pattern and priority areas for conservation of China

To define whether a species was present or absent in a grid cell, the following thresholds in Maxent were applied: ‘sensitivity specificity equality’ or the ‘sum maximization’ (for SDMs represented by 5–9

Please cite this article as: Zhang, M.-G., et al., Priority areas for the conservation of perennial plants in China, Biological Conservation (2016), http://dx.doi.org/10.1016/j.biocon.2016.06.007