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Prediction of Spatial Distribution of Plant Species Richness in the Valdarreh Rangelands, Mazandaran by Macroecological Modelling and Stacked Species Distribution Models

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ABSTRACT

Aims The information on species richness (SR) can be used to help establish conservation strategies or to predict future patterns of biodiversity under global change. The aim of the present study was the prediction of spatial distribution of plant species richness in the Valdarreh Rangelands, Mazandaran, Iran by Macroecological Modelling (MEM) and Stacked Species Distribution Models (S-SDM).

Materials & Methods This experimental study was carried out in the Valdarreh rangelands. In the present study compared the direct, macroecological approach for modeling species richness with the more recent approach of stacking predictions from individual species distributions. Both approaches performed in reproducing observed patterns of species richness along an elevation gradient were evaluated. MEM was implemented by relating the species counts to environmental predictors with statistical models, assuming a Poisson distribution. S-SDM was implemented by modelling each species distribution individually, assuming a binomial distribution.

Findings The direct MEM approach yielded nearly unbiased predictions centered around the observed mean values, but with a lower correlation between predictions and observations, than that achieved by The S-SDM approaches. This method also cannot provide any information on species identity and, thus community composition. Predicted SR by S-SDM was correlated by a Spearman p of 0.76 with the observed SR. The MEM-predicted SR achieved a Spearman rank correlation of 0.32 with S-SDM. The species richness along the elevational gradient for MEM and S-SDM were 0.21 and 0.82, respectively.

Conclusion MEM and S-SDM have complementary strengths and both can be used in combination to obtain better species richness predictions.of CO occurred in summer, and maximum concentration of PM10 was in autumn.

Keywords Biodiversity; Elevational Gradient; Macroecological Model; Valdarreh Rangeland

CITATION LINKS

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Introduction

Species richness is one of the most important and the most widely used biodiversity measure in basic and applied ecology [1]. Species richness (SR), the number of taxa occurring in a defined geographic unit, is widely used as a measure of biodiversity [2, 3]. Factors such as global warming, habitat destruction, biological invasion and pollution and human activities equally global changes have heavily affected the biodiversity [4]. Using these data could help to determine the biodiversity conservation strategies or predict the species richness patterns under global change. Two different approaches have been used to model SR: Direct modeling of species numbers, or stacking of individual species predictions [5].

A comparison approaches, “Macroecological Modelling” (MEM), statistically relates SR–the count of species within a geographic unit–to environmental variables characterizing the same unit. This approach has been used to better predict SR for numerous taxonomic groups at a wide variety of scales [5]. In this macroecological approach, the number of species at a given location is expected to depend on various control factors such as unit size, resources available, environmental heterogeneity and disturbance levels [1]. The second approach, stacked species distribution modelling, consists of predicting the distribution of each species independently using species distribution models and then stacking them to predict species assemblages, providing both SR and composition for each modelled unit. S-SDMs have already been used to predict current and future distributions of SR, community composition [6]. On the other hand, S-SDMs can predict the species composition but do not include a way to set a limit on the number of species that can possibly occupy a given habitat. S-SDMs thus ignore the environmental controls on SR that are hypothesized by MEMs, especially in saturated communities with productive habitats and intense competition for resources [1].

SDMs statistically relate species occurrences to a set of environmental variables, thus rely on the realized environmental niche concept, including biotic and dispersal limitations [4]. One could then assume that combining individual species predictions allows the prediction of SR at each modelled unit. From the theoretical perspective, MEM relies on the existence of macro ecological controls on community assembly, whereas S-SDM relies on a Gleason [7] an overlay of species and therefore inherits assumptions typically associated with SDM, such as equilibrium and niche stability [8, 9]. For instance, growing season temperature might mostly express the amount of energy that can be shared between species in MEM, but would rather express the limit to the growth period of single species in SDMs [10]. Many studies were carried out in the field of the stacked species distribution models and macroecological models [7, 11-15].

The results of Guisan and Rahbeck on prediction the spatial variation of species in New Zealand showed that there were no significant differences between species richness obtained by the sum of the predicted probability with the species distribution modelling (SDM) and prediction of species richness was not direct [1]. Lehmann *et al.* [16] created a new framework to predict the spatial and temporal patterns of species distribution models with a combination of aggregation and macroecological as applicable. Predicting spatial patterns of plant species richness were compared with direct macro-ecological and species stacking modelling approaches in two study areas in the Alps of Switzerland [1]. The results showed that the direct MEM approach yields nearly unbiased predictions centered around the observed mean values, but with a lower correlation between predictions and observations, than that achieved by the S-SDM approaches. This method also couldn't provide any information on species identity and, thus, community composition [10].

Zhang *et al.* [17] investigated changes of plant diversity patterns affected by spatial and environmental variables in Asia desert and showed that precipitation and topographic heterogeneity were more closely correlated to the diversity. Kargar-Chigani *et al.* [18] studied the effective factors on distribution species using multivariate analysis in semi-arid rangeland in Iran. Elevation was the most effective factor on plant groups. This approach has been used to better understand and predict SR for numerous taxonomic groups at a wide variety of scales. Because one of the criteria for measuring biodiversity is species richness, information on large-scale species richness is not complete. Richness empirical models are used to overcome this limitation by identifying areas of species richness.

With the increasing human impact on biodiversity the factors that determine the distributions of species and the communities they compose are of primary interest to the optimization of conservation actions. Also, the study area is a tourist area and has valuable species, these studies have helpful and the results of these approaches can be used in programs of conservation and improvement of the area.

The aim of the present study was the prediction of the spatial distribution of plant species richness in the Valdarreh Rangelands, Mazandaran by Macroecological Modelling (MEM) and Stacked Species Distribution Models (S-SDM).

Materials and Methods

Valdarreh rangeland is located in Mazandaran province, Iran at 52°5′-52°11′-N; and 35°46′-35°49′-E. It covers 5000ha and has an elevational gradient between 2500 to 3910m. The climate is semi-arid and cool. The annual temperatures in the summer and winter are 19.2°C and −0.03°C, respectively; mean annual precipitation is 418mm [19]. Also, the dominant plant species in the study area include *Festuca ovina* (L.), *Bromus tomentellus* (L.), Desv *Poa bulbosa* (L.), *Onobrychis cornuta* (L.), Desv *Acantholimon microcephalum* Boiss, *Dactylis glomerata* (L.), *Astragalus aegobromus* Boiss. & Hohen, *Onobrychis cornuta* (L.), Desv *Achillea millefolium* (L.), *Thymus pubescens* Boiss. & kotschy, *Astragalus brachystachys* Boiss. & Hohen, *Stachys lavandulifolia* Vahl (Figure 1).

In this experimental study, from mid-spring and summer of 2014, sampling was done in a 1×1m plot, using a random stratified sampling procedure. Elevation, slope, and aspect to stratify the area before sampling was used [20]. In each sampling unit, some plots were randomly established and the species occurrence was recorded as presence or absence. The only species with more than 20 occurrences throughout all sampling plots were kept for further analyses [21]. This approach resulted in 42 species in the study. Some climatic variables, including mean annual rainfall mean annual moisture, and the mean annual temperature was provided by the Meteorological Organization in Mazandaran province and with survey data using bar graphs [20]. Six topo-climatic predictors were extracted from Arc GIS 10.3 spatial analyst tool (ESRI) [1].

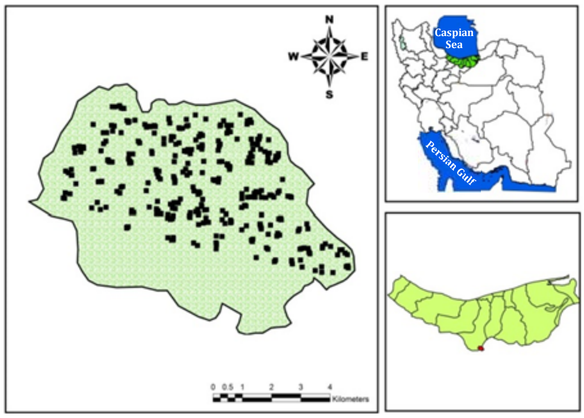

Figure 1) Location of the study area in the Mazandaran, North of Iran

In the present study, the direct, macroecological approach (MEM) for modelling species richness (SR) with the more recent approach of stacking predictions from individual species distributions (S-SDM) were compared and how both approaches performed in reproducing observed patterns of SR along an elevational gradient were evaluated.

In the direct approach, SR was set as the response variable in statistical models using Poisson distribution. Here, SR calculated as the count of all species was also modeled with SDMs (i.e., occurring in more than 20 plots; 350 in the Valdarreh). Two modelling techniques were used: Generalized Linear Models (GLM) [16, 22], Generalized Additive models (GAM; [23] R package "grasp"). In the S-SDM, each species was first modeled separately. The BIOMOD2 package in R, was used to implement GLM and GAM, assuming a binomial distribution and the same parameter options as for the MEM [3] but separately for each species (42 species in Valdarreh).

Again, a repeated (100 times) split-sample approach for evaluating the models was used. Each model was fitted using 70% of the plots and evaluated using the area under a curve (AUC) of a receiver-operating characteristics (ROC) plot calculated on the excluded 30%. In this approach, the maps were reclassified into presence and absence using a ROC-optimized

threshold, as has often been described previously in the literature, thus maximizing model sensitivity and specificity. These presence-absence layers were summed to obtain an SR map for every modelling technique [10] Model calibration and other statistical analyses were computed using the R software version 3.1.1 [24].
The study presents only results based on the ensemble predictions averaged across techniques.
To further evaluate the accuracy of predictions, the predicted richness by different modeling approaches was plotted against the observed richness, and a linear regression line was fitted to this plot [17, 25].
To assess how the modeling approaches performed in reproducing well-known patterns of species diversity, regressions to analyze the relationship between SR predictions and elevation was fitted, and these were again evaluated with Spearman correlations [1].

Findings

Predictions of species richness (SR) were consistent across the two modelling techniques (i.e., GLM and GAM).
The MEM-predicted SR achieved a Spearman rank correlation of 0.26 with observed SR. Plots with the lowest observed SR tended to be overestimated, whereas the plots with SR>30 tended to be underestimated. SR predicted by S-SDM was correlated with a Spearman p of 0.80 with the observed SR. The MEM-predicted SR achieved a Spearman rank correlation of 0.32 with S-SDM (Diagram 1).
Intercepts and slopes of their regression lines with the observed SR, the predictions from MEM and the three S-SDM approaches were strongly correlated with one another with values ranging from 0.76 for the correlation between S-SDM and MEM to 0.80 for the correlation between S-SDM and observed richness. Despite such high correlation, the S-SDM tended to predict greater SR than did the direct MEM. Along the elevational gradient, the observed SR showed a peak of richness at mid-elevation, a decrease in SR towards high elevations and, to a lesser extent, a decrease in SR towards low elevations. Also, the species richness (SR) along the elevational gradient for MEM and S-SDM were 0.21 and 0.82, respectively. It is noticeable that some level of overprediction was also observed with the S-SDM low elevations (Diagram 2).

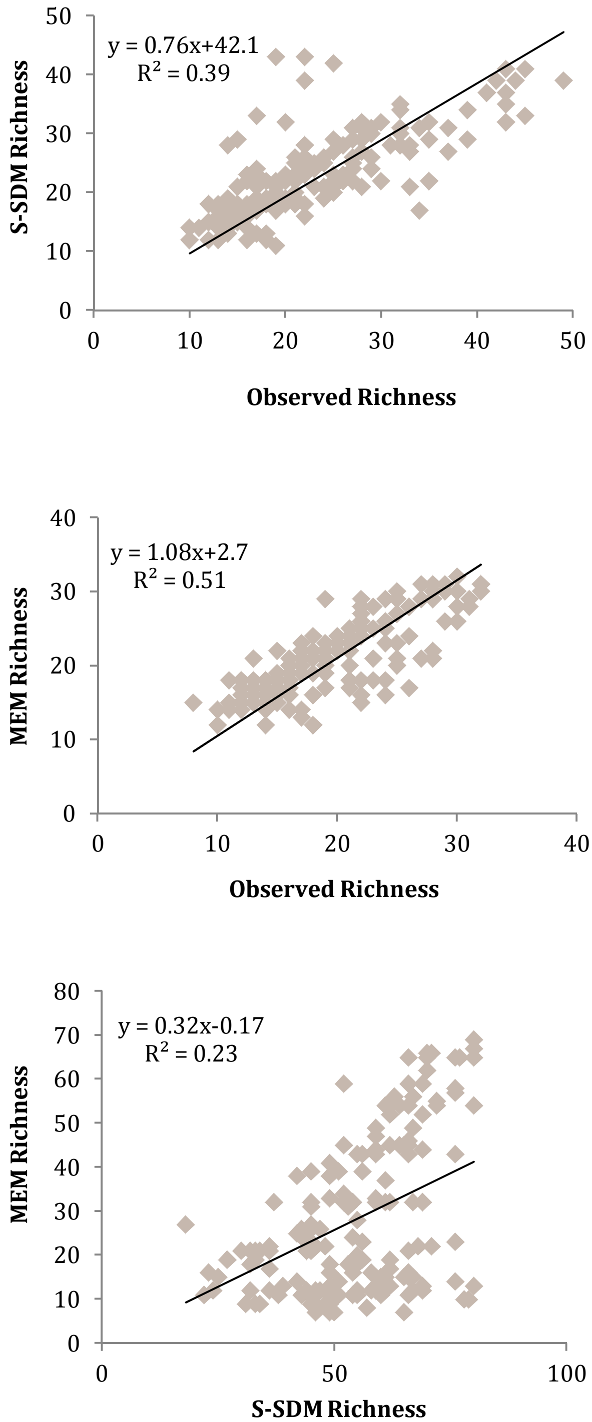

Diagram 1) Predicted Species Richness plotted against the observed data for (a) MEM, (b) S-SDM (The comparison between the two approaches show that despite the significantly different)

Along the elevational gradient, the observed SR showed a hump-shaped curve with a peak of richness at mid-elevation, a decrease in SR towards high elevations and, to a lesser extent, a decrease in SR towards low elevations (Figure 2).

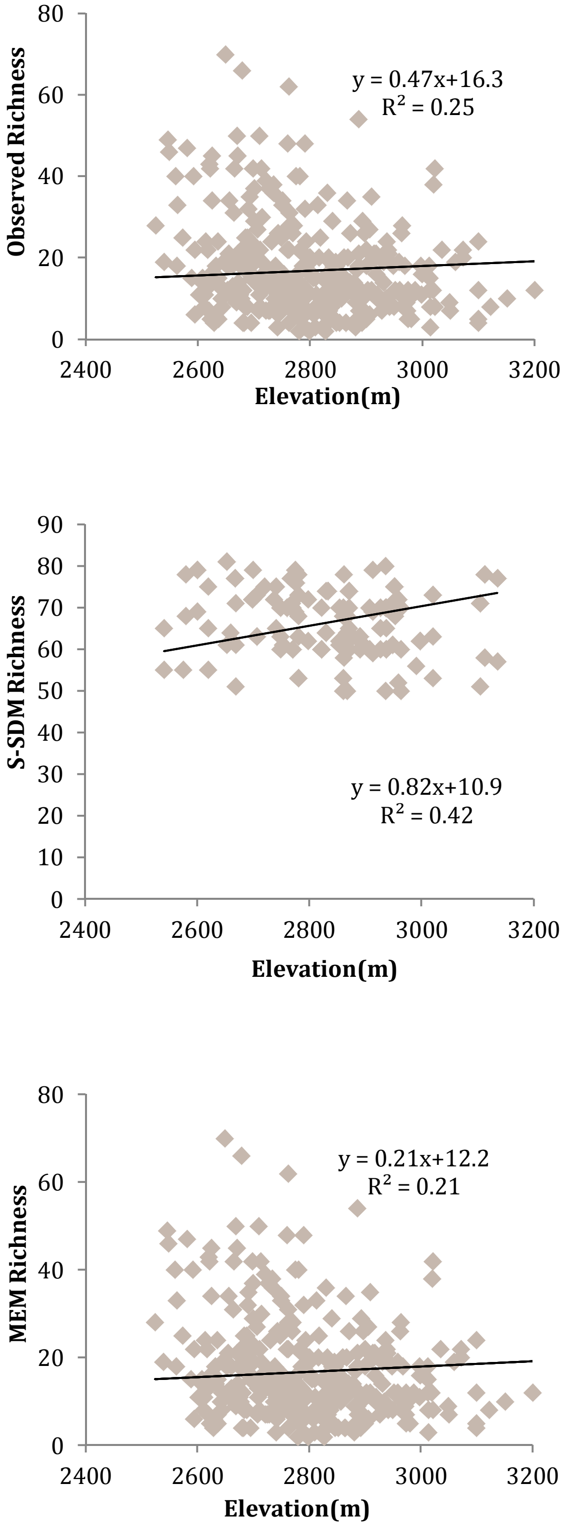

Diagram 2) Species Richness along the elevation gradient: observed, S-SDM, (c) MEM for the study area

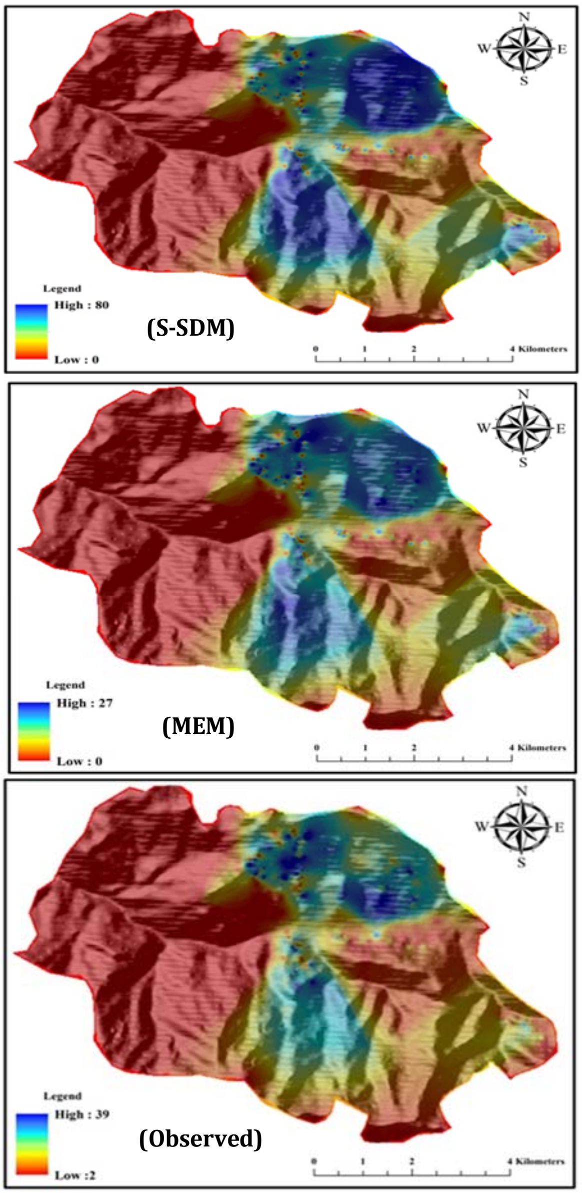

Figure 2) Model projections for predicted by S-SDM predicted by MEM, observed richness in the study area, Mazandaran, Iran

Discussion

The aim of the present study was the prediction of the spatial distribution of plant species richness in the Valdarreh Rangelands, Mazandaran by Macroecological Modelling (MEM) and Stacked Species Distribution Models (S-SDM).

The diversity and richness widely used in studies and assessments of vegetation management program as one of the important indicators of ecosystem status and the type of management. The results of the present study showed that the correlation between the various approaches for modelling species richness in the MEM is less than the S-SDM.

These results are consistent with findings correspond [10, 21]. MEM method is based on the actual number of species in the study area. Therefore, the prediction had a lower correlation with the observed species richness and our results correspond with the results of findings [26, 27]. Other factors were not taken into account in the model, such as human influences that are particularly important at lower elevations (e.g. Intensive land use) or natural disturbance regimes that are more intense at higher elevations. MEM is the appropriate method for Biogeography studies, because prediction is based on the actual number of observed species in the area and also prevents excessive estimation.

The MEM method can also detect information about the composition of plant communities and plant species in the area. The number of species that is predicted using MEM is the average number of species that can actually be present in a Macro ecological model. S-SDM is not a method which estimates richness near real value, but is the suitable method for prediction of individual species. S-SDM potential of all plant species that is present under different environmental conditions to the list. Research was conducted prediction of species richness butterflies by S-SDM. The results indicated that predicted by this method is estimated to be more than usual, which is consistent with the results of. Other studies [14, 28, 29]. Also the results indicated that the prediction by MEM is roughly equivalent to the observed average species richness, but the correlation is less than the S-SDM findings [7]. The results of this research showed that there is no difference between observed richness of species and MEM that our results correspond with these findings [16]. Among the factors topographic height due to the impact on climate and the plant species distribution plays an important role. This pattern is consistent with those reported in several other studies [15]. Some studied also predicted species richness along a altitudinal gradient. Species richness along an altitudinal gradient showed that the highest species richness in the central highlands that result in overlapping dominant species in the center and in the margin is less. These results are consistent with findings [1, 6, 30]. The reason is that the vast fertile land-use and habitat types are at lower elevations that it would lead to more intense competition between species out of the species in this elevation range. At higher elevations several studies have examined patterns of species richness along altitudinal gradient [14].

The limitations of this research include some environmental factors that might mostly express the amount of energy that can be shared between species in MEM, but would rather express the limit to the growth period of single species in SDMs. Also, the limitations of S-SDMs is that a sufficient number of occurrences must be available for each species to be modelled. Species that are too rare may need to be excluded from the analyses, whereas they can be implicitly included in the MEM.

For greater perspective, it would be interesting to assess in more detail the multiple assemblage compositions predicted by the binomial resampling trials, especially to investigate whether a processing of these could allow a single final prediction or if the competing alternative endpoints of assembly must be considered as the final prediction itself.

Conclusion

MEM and S-SDM have complementary strengths and both can be used in combination to obtain better species richness predictions. MEM predicts a realistic number of species on average and better reproduces the observed hump-shaped SR pattern along the elevation gradient, but its predictions are overall less correlated with observed SR. This approach seems, therefore more appropriate for testing biogeographic and studying general patterns of SR, because it avoids over prediction, but it does not provide any information on the identity of species and community composition.

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