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An Endemic Vascular Plant Species for Türkiye, *Ferulago Humilis* Boiss., and Its Potential Distribution Areas

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Abstract

Turkey is expected to be affected considerably in future adverse climatic conditions. Plant species are one of the most vulnerable to these climatic changes. In this study, we aimed to investigate current and future potential distribution areas of *Ferulago humilis* Boiss., which is an endemic vascular plant species for Turkey, using CMIP5 projected to year 2070. For this purpose, we obtained occurence data (presence-only) from Global Biodiversity Information Facility (GBIF). Regarding bioclimatic data we used WorldClim dataset with 10 km^2 resolution. Using both plant occurrence and bioclimatic data, we performed species distribution modelling analysis. We used two methods namely Boosted Regression Trees (BRT) and Random Forest (RF). Additionally, we used bootstrapping method as partitioning resampling for all analysis. Our analysis has showed that potential distribution areas of the species has slightly changed for the future projection. The species movement is towards slightly upwards as higher latitudes. We believe that our study shows the importance and relevance of the endemic species in the scope of species distribution models for plant conservation topics.

Keywords: Biology, botany, vascular plant, species distribution models.

1. INTRODUCTION

Future climatic change projections show that considerable increase in average temperature of the world as well as changes of precipitation and extreme weather events [1]. Therefore, species are changing their distribution areas to the new climatic conditions and habitat conditions [2]. During this process, biodiversity loss or negative effects on species might occur by effecting ecosystem functions [3-6]. Likely, plant species will also be negatively affected in various ways [6-9]. Climatic projections show that Turkey will also be considerably affected by future conditions [10]. Projections for 2070 and 2100 predicts considerable temperature increase based on the various scenarios [10-12]. Therefore, species distribution models (SDMs) are useful and powerful tools for improving our understandings of the future potential areas for the species [13]. These models include various statistical methods and algorithms (e.g. Random Forest (RF), Artificial Neural

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Networks (ANN) by using species occurrence data.

Turkey is a well-known country in terms of having a high number of plant biodiversity. There are about 9996 species in Turkey and this number is increasing day by day. Moreover, about 30% of these species are endemic (more than 3000 species) [14]. The plant richness level known in Europe is about 12500 [15]. The reasons for this relatively high level of richness are: (1) Turkey has three Phytogeographic Regions as Europe-Siberia, Mediterranean and Iran-Turan; (2) the diversity of climate types, geomorphological features, altitude differences ranging from 0-5000 meters; (3) having different types of ecosystems; (4) less affected by the glacial period than European countries; (5) the existence of the Anatolian Diagonal [15-17]. Moreover, 3 of the 36 hot spots in the world are located in Turkey [18].

In this study, the genus of Ferulago W.D.J. Koch belongs to the Apiaceae family is represented by about 48 species in the world. [19-22]. Ferulago is a typical Mediterranean genus of Apiaceae, distributed from the Iberian Peninsula to Iran and Turkmenistan, with a concentration of maximum diversity in the eastern Mediterranean, especially in Turkey [23]. While the existence of 31 species was recorded in the Flora of Turkey and East Aegean Islands [24-25], since 2000, *F. idaea* Özhatay & Akalın [20], *F. trojana* Akalın & Pimenov [26], *F. glareosa* Kandemir & Hedge [27], *F. akpulatii* Akalın & Gürdal [21] as new species and *F. angulata* Boiss. subsp. *carduchorum* (Boiss. & Hausskn.) D.F.Chamb. [28] as a new record was described.

Therefore, the total number of species and subspecies taxa has been 36 [29], 20 of which are endemic to Turkey. *Ferulago humilis* Boiss. is one of endemic to Turkey and IUCN category is determined as LC (Least Concern) threatened category [30]. F. humilis is located in Manisa, İzmir, Çanakkale, Aydın, Muğla provinces and it prefers abandoned fields as well as macchie habitats [24]. Apart from our study, *F. humilis* is widely studied by scientist in the areas of chemotaxonomy, ethnopharmacology, phytochemistry, pharmacology, ethnobotanical fields [31-37]. In addition to this, studies have also been conducted on bioactivities of the obtained extracts, antifungal and antibacterial, fruit anatomy and enzyme inhibitory activity [38-42]. We believe that our study is a complementarity of all these studies across biological areas in which we aim to detect future potential distribution areas of vascular plant *Ferulago humilis* Boiss..

2. METHOD

We extracted plant occurence data from Global Biodiversity Information Facility (GBIF, https://www.gbif.org/). It resulted in 85 records including all possible record types. Among them we further extracted only geolocated occurences, which resulted in 40 observations. We performed further analysis using this occurrence data. Regarding bioclimatic data, we obtained 19 bioclimatic variables from WorldClim database [43-44]. with 10 km2 spatial resolution.

These variables were: bio1, Annual Mean Temperature; bio2, Mean Diurnal Range (Mean of monthly (max temp - min temp)); bio3, Isothermality (bio2/bio7) (×100); bio4, Temperature Seasonality (standard deviation ×100); bio5, Max Temperature of Warmest Month; bio6, Min Temperature of Coldest Month; bio7, Temperature Annual Range (bio5-bio6); bio8, Mean Temperature of Wettest Quarter; bio9, Mean Temperature of Driest Quarter; bio10, Mean Temperature of Warmest Quarter; bio11, Mean Temperature of Coldest Quarter; bio12, Annual Precipitation; bio13, Precipitation of Wettest Month; bio14, Precipitation of Driest Month; bio15, Precipitation Seasonality (Coefficient of Variation); bio16, Precipitation of Wettest Quarter; bio17, Precipitation of Driest Quarter; bio18, Precipitation of Warmest Quarter; bio19, Precipitation of Coldest Quarter.

Prior to the statistical modelling, we performed collinearity analysis using bioclimatic variables using Variance Inflation Factor [45] through correlation method. Variables greater than 0.8 correlation are considered collinear. After the procedure, 8 variables remained non-collinear, which used further analysis (bio 2, bio 8, bio 9, bio 13, bio 14, bio 15, bio 18, bio 19). In order to perform modelling, we created to pseudo-absences using 1000 geographically random selected pseudo-absences on the data. For the species distribution modelling, we fit two well-known methods namely Boosted Regression Trees (BRT) and Random Forest (RF). The models were assessed using two runs of bootstrapping replications obtaining 30 percent as a testing data for partitioning.

We fitted statistical modelling analysis for both current and future potential areas. We fitted potential distribution for current time using ensemble weighted averaging, which is based on TSS statistic. We set optimum threshold criterion as 2 optimizations for the thresholds. Regarding projection for future time, we used bioclimatic (CMIP5) data for the year of 2070 as a resolution of 10 km2. We ensembled this data as the same method with current data. In addition, we investigated distributional difference between current and future distribution based on probability of occurrence of the model.

We obtained mean values of variable importance for multiple models based on training dataset. Further, we assess the results of each fitted model using accuracy and thresholds. Therefore, we used the mean values of the thresholds to find out extinction and colonization as well as persistence. We performed species distribution modelling using *sdm* package [46], and performed all analysis in R program [47].

3. RESULTS

Both Boosted Regression Trees (BRT) and Random Forest (RF) models has resulted in high accuracy values (Table 1). The results showed that both models performed well and provided considerable model performances. Based on the model results, ROC-AUC curves using specificity and sensitivity values are presented in Figure 1.

RF model resulted in slightly higher mean AUC values than BRT for training data. Regarding testing data both models performed same degree. Potential distribution areas of *Ferulago humilis* Boiss. for the current time and for the future (projected as 2070) time are presented in Figure 2 and 3, respectively. These figures shows that distribution patterns are quite similar across the regions. However, the difference becomes slightly visible in the specific areas of Mediterranean region. Relative Variable Importances (RVI) of the variables are shown in Figure 4. Precipitation of warmest quarter was the best variable for both models, while precipitation of coldest quarter was also considerable for the RF model.

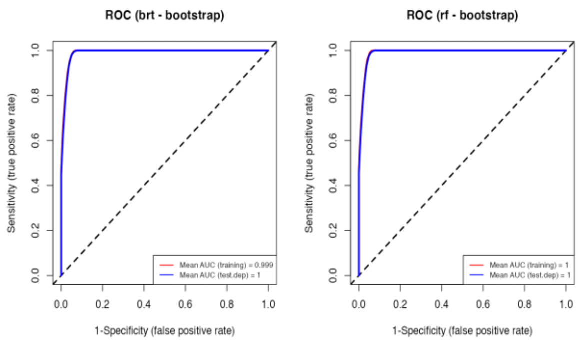

Figure 1 ROC-AUC curves of both models of Boosted regression trees (BRT) and Random Forest (RF)

Table 1 The model performances of both fitted models using bootstrap partitioning (Boosted Regression Trees (BRT) and Random Forest (RF)).

Methods	AUC	COR	TSS	Deviance
BRT	1	0.96	1	0.06
RF	1	0.96	1	0.02

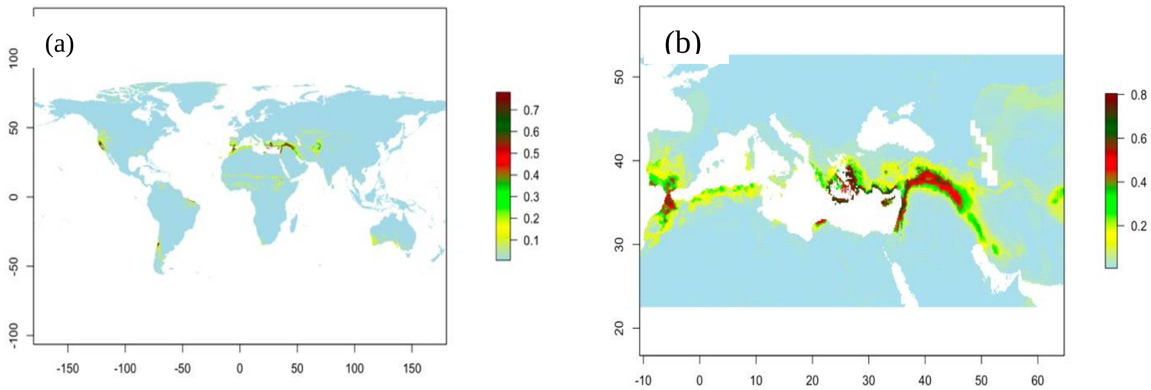

Figure 2 (a) Potential distribution areas of *Ferulago humilis* Boiss. for the current time across the World, (b) Potential distribution areas of *Ferulago humilis* Boiss. for the current time in Mediterranean region

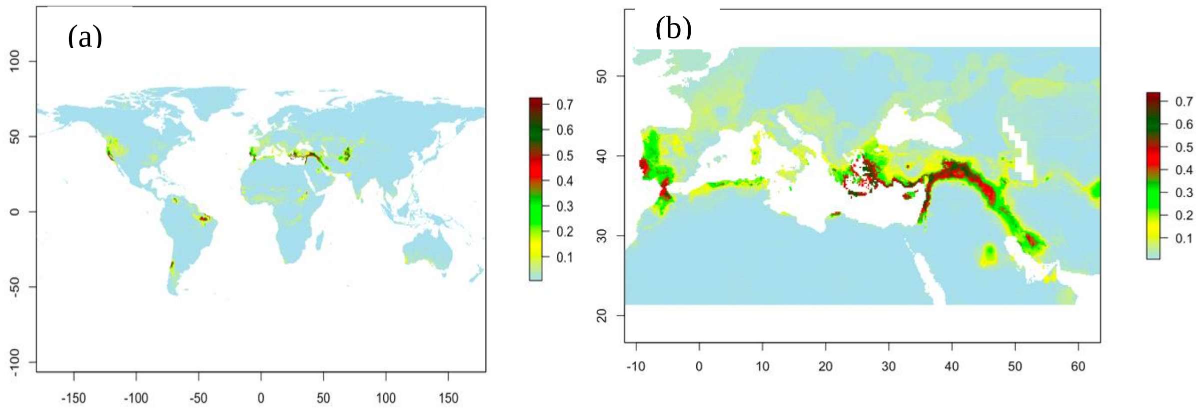

Figure 3 (a) Potential distribution areas of *Ferulago humilis* Boiss. for the future (projected as 2070) time across the World, (b) Potential distribution areas of *Ferulago humilis* Boiss. for the future (projected as 2070) time in Mediterranean region

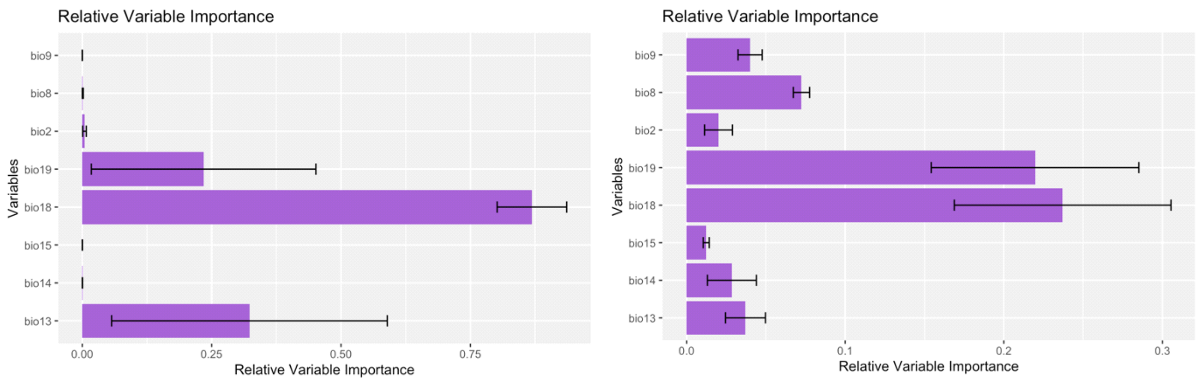

Figure 4 Relative Variable Importances (RVI) of the variables of the Boosted Regression Trees (BRT, top) and Random Forest (RF, bottom) models

4. DISCUSSION

Generally, both models performed well based on the results of the model performances as AUC. AUC is calculated based on the area under the Receiver operating characteristic (ROC) curve, which understandings of the model performance. In our case, models of BRT and RF showed 1 value, which is quite high values from 0.8, which is a critical threshold for a model. The deviance was higher in BRT model than RF model, while other values were the same.

Current distribution potential of the *Ferulago humilis* in Turkey is mostly in the southern parts of the country including the West Aegean, Mediterranean part as well as southeastern parts. It is clearly seen that more areas are possible in the southeastern parts than other parts of the country. Regarding other countries, the species has potential distribution areas in southern parts of Greece to Italy as well as Spain in the scope of Europe. The potential areas include Morocco and northern Africa, which is exposed to a Mediterranean climate type, Cyprus, Mediterranean Sea region in Middle East as well as from Iraq to Iran alongside the borders of Turkey.

The variable of precipitation is clearly a considerable for both models. Obviously, drier regions rather than humid areas are more preferable for the species based on our analysis for the current time. However, we detected only weak differences for the future climatic projections. According to the analysis, main distribution areas did not change as a country level, however it still includes minor differences. For Turkey, slight increase in potential distribution areas occure in southeastern parts to eastern parts. Potential areas also slightly increased in coastal Aegean to inner Aegean parts of the country.

However, distirubition areas relatively decreased in inner Anatolia, which is quite a dry region of Turkey. This difference clearly revealed that the species moved towards relatively colder areas. These patterns were also supported for Europe. In Europe, potential areas of the species distribution increased to higher latitudes. It increases from Spain towards France. Slight increases were also visible in the northern part of the Black Sea. This pattern is already expected based on our previous foresight, that the colder regions are more favorable for the future. In fact, an upward shift along higher altitudes for the plant species is a well-kown pattern [48]. Plant species are tended to be locate in higher altitudes since these areas would be more preferable and favorable for the future climatic conditions.

5. CONCLUSION

In conclusion, our study revealed that potential distribution areas are slightly changed for the future climatic conditions rather than current conditions. In most parts, the species preferred more colder regions than warmer regions. The species distributed mainly Mediterranean type climatic region. In addition, as an endemic species, *Ferulago humilis,* is likely taken into account for the conservation practices for the future projections as well. We believe that more researches on the different endemic plant species would be useful for the conservation management of the plants.

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Authors' Contribution
The authors contributed equally to the study.

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No conflict of interest or common interest has been declared by the authors.

The Declaration of Ethics Committee Approval
This study does not require ethics committee permission or any special permission.

The Declaration of Research and Publication Ethics
The authors of the paper declare that they comply with the scientific, ethical and quotation rules of SAUJS in all processes of the paper and that they do not make any falsification on the data collected. In addition, they declare that Sakarya University Journal of Science and its editorial board have no

responsibility for any ethical violations that may be encountered, and that this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science.

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