BAHÇE 49 (Özel Sayı 1: II. Uluslararası Tarım Kongresi (UTAK 2019)): 159–165 (2020)
ISSN 1300–8943

CLIMATE CHANGE EFFECTS ON THE DISTRIBUTION OF TURKISH SALIX SPECIES

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Geliş Tarihi / Received: 24.11.2019 *Kabul Tarihi / Accepted: 30.01.2020*

ABSTRACT

Increasing energy demands and necessity to reduce the greenhouse gas emissions are key factors driving the understanding climate change effects on woody plants. Given the pace of climate change, the question is raised whether Salix trees and shrubs as bioenergy crops will be able to adapt to the future environmental conditions in Turkey. We select willows as study species because they are expected to expand their range in Turkey under drier and warmer climatic conditions from high latitude and wet areas. And also, selecting willow shrub and tree samples will provide data for the basic bioenergy research in the long run. Thus, our objective is to determine possible climate change observation area in Turkey according to the expected effects of climate change and possible scenarios on Turkish willows as economically valuable bioenergy crops. Two hundred and fourteen willow individuals were collected from all Turkey. The habitats of Turkish willows are generally from riparian areas and high wetlands. One willow map is created by using the locations of Turkish Salix species from field studies. Following this approach, we aim to evaluate and compare the approaches of latitudinal migration by constructing new possible stations in the suitable habitats due to the results of models. We used MAXENT algorithm to have preliminary predictions on the distribution of the species and its range shifts. This study provides the first results of species distribution modeling results of Turkish Salix species. Selection of the localities was done based on the habitat suitability coefficients which gives a probability ranging from 0 to 1. Results showed that Ilgaz Mountains (Kastamonu) and Artvin and Erzurum province (Eastern Black Sea region) are observed to have available habitats for Turkish Salix species area in terms of bioclimatic suitability.

Keywords: Willows, Turkey, climate change, species distribution models, MAXEN

İKLİM DEĞİŞİKLİĞİNİN TÜRKİYE SALIX TÜR DAĞILIMINA ETKİLERİ

ÖZ

Artan enerji talepleri ve sera gazı emisyonlarını azaltma zorunluluğu, odunsu bitkiler üzerinde iklim değişikliğinin anlaşılmasına neden olan temel faktörlerdir. İklim değişikliğinin hızına bakıldığında, biyoenerji bitkileri olarak Salix ağaç ve çalılarının gelecek Türkiye çevresel koşullara uyum sağlayıp sağlayamayacakları sorusu gündeme gelmektedir. Söğütleri çalışma türü olarak seçiyoruz çünkü Türkiye'de yüksek enlem ve sulak alanlardan daha kurak ve ılıman iklim koşullara yayılışlarını genişletmeleri beklenmektedir. Ayrıca, söğüt çalıları ve ağaç örneklerinin seçilmesi uzun vadede temel biyoenerji araştırmaları için veri sağlayacaktır. Bu nedenle hedefimiz, iklim değişikliğinin beklenen etkilerine göre Türkiye'deki muhtemel iklim değişikliği gözlem alanını ve olası senaryoları, ekonomik olarak değerli biyoenerji bitkileri olan Türkiye Söğütleri üzerine belirlemektir. Tüm Türkiye'den 214 söğüt bireyi toplanmıştır. Türkiye Söğütlerinin habitatları genellikle nehir kıyısındaki bölgeler ve yüksek sulak alanlardır. Saha çalışmalarıyla elde edilen Türkiye Salix türlerinin lokasyonları kullanılarak bir Söğüt haritası oluşturulmuştur. Bu şekilde, model sonuçlarına uygun habitatlarda yeni olası istasyonlar inşa ederek, enlemesine yer değiştirme (göç) yaklaşımlarını değerlendirmeyi ve karşılaştırmayı hedefliyoruz. MAXENT algoritmasını türlerin dağılımı ve değişim aralıklarını ön tahminleri için kullandık. Bu çalışma, Türkiye Salix türlerinin tür dağılım modelleme sonuçlarını sunan ilk çalışmadır. Bölgelerin seçimi, 0 ile 1 arasında bir olasılık veren habitat uygunluk katsayılarına göre yapılmıştır. Sonuçlar göre Ilgaz Dağları (Kastamonu) ve Artvin-Erzurum alanının (Doğu Karadeniz Bölgesi) biyoklimatik olarak Türkiye Salix türlerine uygun habitatlar olduğu gözlenmiştir.

Anahtar Kelimeler: Söğütler, Türkiye, iklim değişikliği, tür dağılım modelleri, MAXEN

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INTRODUCTION

The biodiversity and characteristics of natural communities in a country can be measured by the number of native species, distribution of these and also their vegetation types. Among the European countries, Turkey can easily be considered as a key country for global biodiversity regarding these criteria. 26.8% of the total surface area of Turkey is covered by forests [11]. The most forested areas are located in the Black Sea region followed by the Mediterranean and Aegean geographic regions. One of the most significant and crowded member of the Anatolian dendroflora is Salicaceae species [19].

Today, it is accepted that the genus *Salix* L. is represented with more or less 500 species in the world [25]. They are extensively found in northern hemisphere and abundantly in China and former Soviet Union. 27 of them are naturally found in Turkey [1]. Besides, among them, the following four species are endemic to Turkey: *S. trabzonica* A. Skv., *S. purpurea* subsp. *leucodermis* L., *S. rizeensis* Güner and Zielinski [22] and *S. anatolica* Zielinski and Tomaszewski [26]. In *Salicaceae* family, two genus, Salix and Populus have many common characteristics as far as ecology is concerned. However, Salix are more adaptable, deciduous woody genus when it is compared with the Populus. Their habitats vary in much wider ranges. The members of the Salix L. genus prefer habitats with more water and higher light conditions. Species of the genus can survive from arid areas to wetlands, from beaches to high mountains. This adaptable characteristic of the genus comes from minute features of the seeds. Since they are very small and numerous, they are dispersed by the wind and germinate easily [19].

Economically, Salix species are outstanding candidates for many disciplines. The 'Cortex Salicis' is the source of salicin which is the pioneer substance of aspirin when transformed to salicylic acid molecule and it is used for cancer research nowadays [12]. Anthropogenic factors that caused dispersal of heavy metals are tried to be remediated by Salix species [7]. Accumulation of Zn and Cu metals in bark and wood system of Salix sp. are investigated by many researchers who determined the rate of metal accumulation in Salix species in contaminated soil [15]. Salix species are also candidates for bioenergy production [24]. Some of Salix clones are more preferred in forest biotechnology for quick growth, wide distribution, resistance to disease and stress features. Willow plantations has also positive effects against erosion and significant importance in afforestation. Some researchers found that short rotations coppice (15 years) periods in for Salicaceae members was optimize the reductions in CO_2 emissions to the atmosphere [6]. There are several climate change studies that their contents include observations of changes secondary metabolite, genetic background and growing rhythms under climate change factors on *Salix* sp. [18, 21]. However, the number of studied willows and their clones are limited in Turkey [2]. Although some studies was recently performed [4], this genus is one of the most poorly understood one in Turkey.

Climate models are the significant tools available for investigating the response of the climate structure to various forcing's, for making climate predictions and projections of future climate over the coming 50 years and beyond [10]. Anthropogenic effects is affecting global climate dynamics and changing land atmosphere interactions at large scales, an evaluation of the long term impacts of climate change on water resources is essential to plan for future conservation strategies [9]. According to many studies showing climate change scenarios, climate change affects dynamics of riparian area in the long term [13]. All the scenarios represent the current and future situations provided that stream gain, base flow will decrease and the effects on the riparian habitats including many Salix species could be significant [8]. Anthropogenic effects and climate change resulting in increasing CO_2, changing soil composition, warming, drought and increasing Ultraviolet-B (UV-B) radiation have considerable effects on riparian dendroflora. These changes increase especially water stress on riparian plants. Thus, it is really important to understand and develop programmers for climate change threats to riparian habitats.

The aim of this study is to reveal the consequences of climate change on shrubs/trees of riparian biodiversity focusing on the members of Turkish Salix genus in different spatial and temporal scales. Main drivers of climate change are taken into consideration to comprehend the challenges on distribution of species especially in riparian biodiversity and their habitats. The Salix species' distribution models and their projections into future climate scenarios (e.g. IPCC WorldClim) will be predicted with the potential effects of changing climate species' habitat in sense of decreasing available habitats, migrations or availability of new habitats which are not suitable for the species currently. According to climate change scenarios, the conservation areas for Salix species were detected in the current study. In order to obtain this, species distribution modeling approach by using MAXENT algorithm was utilized to model both Turkish willow potential distributions in 2050 by considering the possible effects of global climate change in near future.

MATERIALS AND METHODS

Field Collections

The plant materials used in this study were collected during field studies extending from 2011 to 2016 [1]. The literature records were examined for naturally distributed Salix genus in Turkey and the field works were planned according to them. The periods of field studies were limited to spring and early summer. Total 214 samples belonging to 25 Salix taxa and one hybrid from different regions of Turkey were collected and identified (Figure 1). The species sampled in the study are; *S. acmophylla* Boiss., *S. triandra* subsp. *triandra* L., *S. triandra* subsp. *bornmuelleri* (Hausskn.) A. Skv., *S. pentandroides* A. Skv., *S. alba* L., *S. excelsa* J.F. *Gmelin, S. fragilis* L., *S. babylonica* L., *S. apoda* Trautv., *S. myrsinifolia* Salisb., *S. caucasica* Andersson, *S. pedicellata* subsp. *pedicellata* Desf., *S. caprea* L., *S. aegyptiaca* L., *S. cinerea* L., *S. pseudomedemii* E. Wolf, *S. pseudodepressa* A. Skv., *S. viminalis* L., *S. armenorossica* A. Skv., *S. elaeagnos* Scop., *S. elbursensis* Boiss., *S. amplexicaulis* Bory and Chaub, *S. rizeensis* A. Güner et J. Zielinski (endemic), *S. purpurea* subsp. *leucodermis* L. (endemic), *S. wilhelmsiana* Bieb. and *S. albaxfragilis* (hybrid). Since collecting data from field studies was time and money consuming, most of modelling works was not formed with information obtained from field works. The related models in the current study were constructed by locations of the natural populations of Salix species.

Environmental Data

One of the most widely used environmental datasets is WORLDCLIM-Global Climate Data. WORLDCLIM database offers climatic models which are created with different modeling techniques and in different resolutions. There are about 20 bioclimatic variables on WORLDCLIM. In this study all 15 GCMs which are available in RCP 2.6 were used in both modeling Turkish willows for only year 2050.

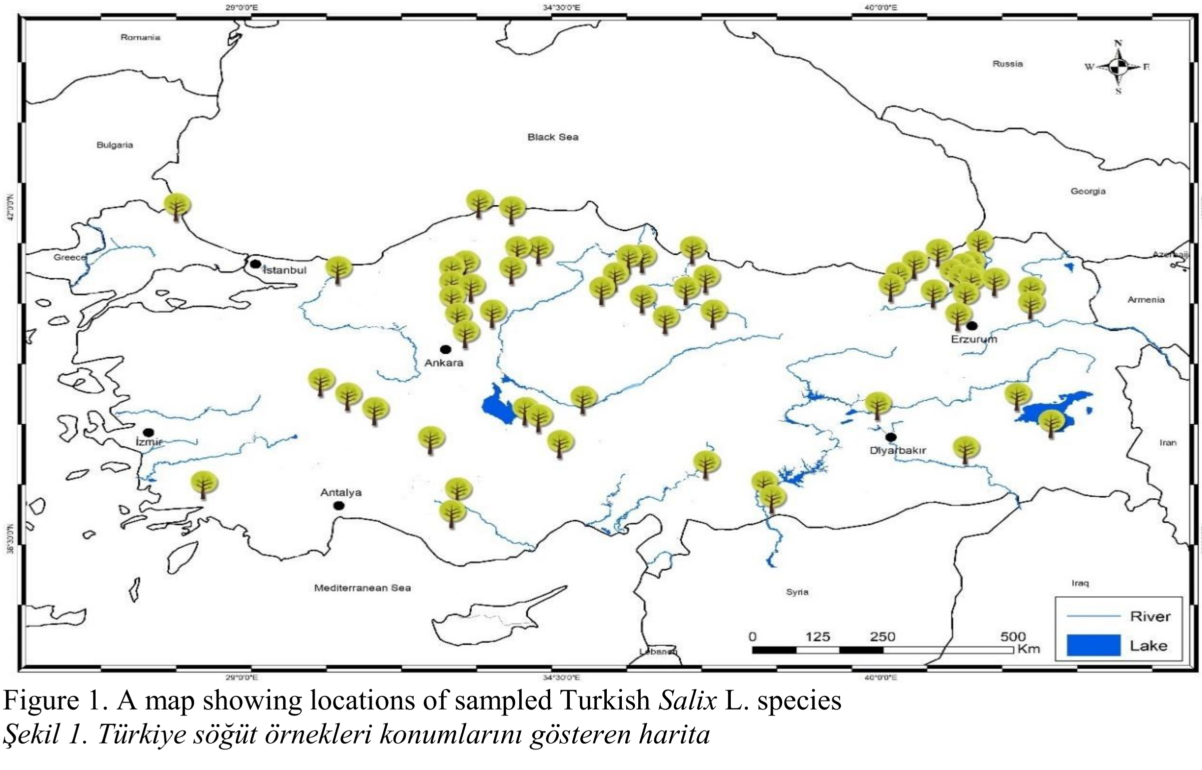

Figure 1. A map showing locations of sampled Turkish *Salix* L. species
Şekil 1. Türkiye söğüt örnekleri konumlarını gösteren harita

Modelling

The first step of the modeling process is to analyses the correlations between bioclimatic variables because correlated variables causes bias in the model in terms of giving higher suitability to the areas of predicted distributions. A correlation matrix was built in R [16] and the variables which have correlation higher than 0.85 are excluded from the process. The removal of a variable from a correlated couple is carefully done according to the habitat requirements of the species. Finally; BIO1, BIO2, BIO3 and BIO6 were excluded from the modeling. In the second step, the geographical extent of the models were decided. Since the survey counts covers almost the whole Turkey, the latitudes between 43.5 & 35.5 and the longitudes between 25.5 & 45.5 were selected. The survey counts have occurrences which are very close to each other. This situation oftenly causes a bias by over predicting habitat suitability. To be able to prevent this kind of bias, rarefaction of the occurrence data was done by using "Spatially Rarefy Occurrence Data" tool in SDMToolbox which ArcGIS offers. The rarefaction distance was selected as 10 km to be able to have homogenous occurrence data. The fourth step was to create a bias file to be used in MaxENT [14] with SDMToolbox. "Sample by buffered MCP" method is used and the buffer distance is selected as 10 km. The fifth and last step was to build models in MaxENT. Both current and 15 future models were built and the average of 15 future models were taken for the final model. The parameters used are; Regularization parameter: 1, Repeat for each model: 20, Features: Auto, Output format: Logistic, replicated run type: Cross validate.

RESULTS AND DISCUSSION

SDM Results for Turkish Willows

In this study, species distribution modeling (SDM) approach was used to analyze the conservation priority areas for Turkish willows to comprehend the habitat conflict favoring Turkish willows in certain habitats. The reason this study only focus on 2050 as future climate scenario is to promote rapid action to conserve Turkish willows. The SDM result map of current and future climatic variables showed best fit habitat areas for Turkish willows (red areas on the map) (Figure 2, 3).

Demircan et al. [5] investigated the possibilities of future climate change including temperature and precipitation projections for Turkey and its surroundings with the regional climate model. The results of the 2099 projections showed that temperature will increase in every seasonal time and increases in precipitations will be in winter. Şen et al. [20] also concluded that in general, temperature, sea level, solar radiation and wind speed will increase whereas the precipitation rate will decrease in Turkey according 2070 projections and added that the significant precipitation rate will rise at Central and Eastern Black Sea regions. After the careful modeling studies, it is revealed that Ilgaz Mountains, Kastamonu (Central Black Sea Region) and Artvin-Erzurum province (Eastern Black Sea Region) are the most predicted suitable habitats for the Salix species which is conformed with data of Şen et al. [20]. The yellow and orange colored, drought and temperate places are also suitable habitats; Kayseri, Konya and Gaziantep as it is shown in Figure 3. However, it is an only prediction with low probilities according to models.

Most of the Salix species are found in and adapted to wet and cool climates of the high latitude and altitude habitats of Northern and Eastern Turkey [1]. Thus increasing Ultraviolet-B (UV-B) radiation will directly affected the high habitats which they are distributed more. Both Ilgaz Mountains and Artvin-Erzurum province which are high habitats can also be defined as mixed zones as far as Salix diversity is concerned [1]. Thus, the willow populations in Ilgaz Mountains and Artvin-Erzurum province (red areas in the map) are under treat due to global climate change. There are national parks in these area as Mount Ilgaz and Hatila Valley National Park. Identifying conservation priority areas will provide further suggestions for conservation strategies and for potential bioenergy plantations of Turkish Salix species.

Bioenergy is not an only land use activity, is an alternative way for preventing erosion, restoring degraded lands, decreasing effects of climate change [3]. Especially, small-scale bioenergy activities can provide cost-effective alternatives for mitigating climate change, at the same time helping conservation of related species. Besides, increasing and conserving the forested areas even if it is fast-growing plantations contribute to mitigate the effect of high CO_2 concentrations. Thus, the selected areas of Turkish Salix species may also use as possible clone plantations for both conservation and bioenergy purposes.

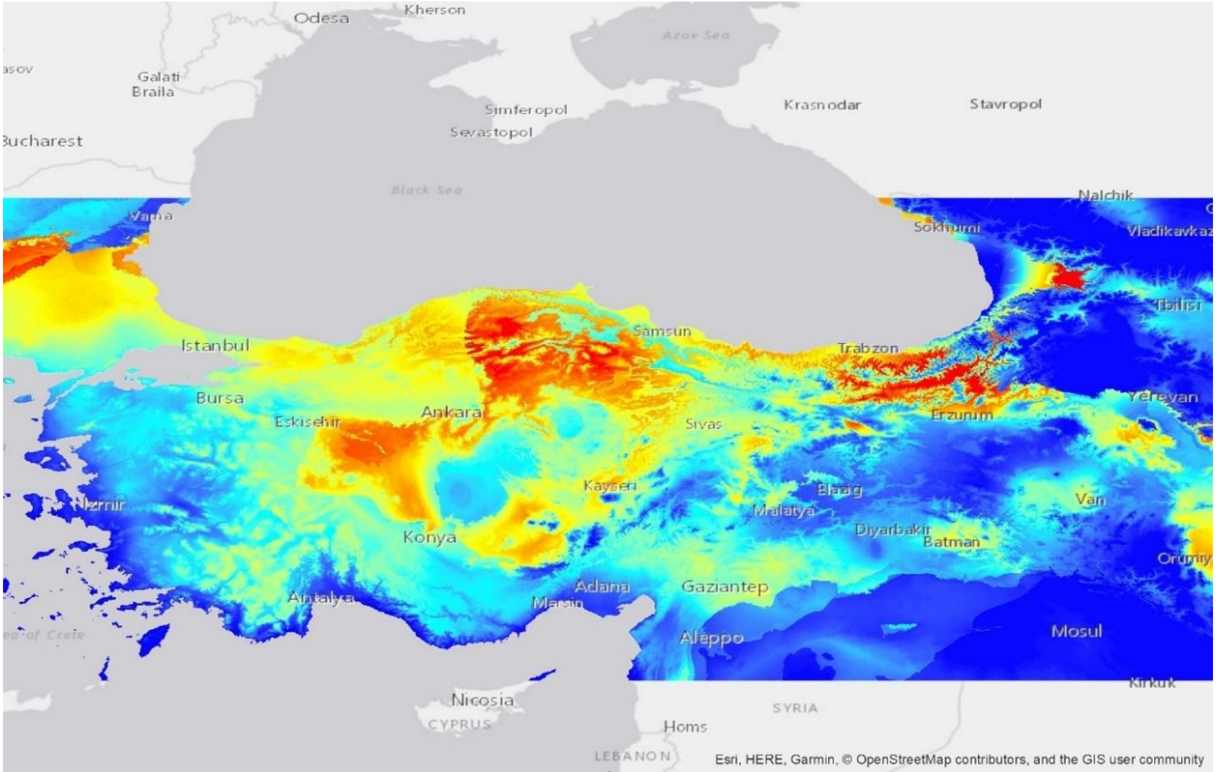

Figure 2. Current predicted available habitats for Turkish *Salix* sp.
Şekil 2. Türkiye Salix sp. için tahmini mevcut yaşam alanları

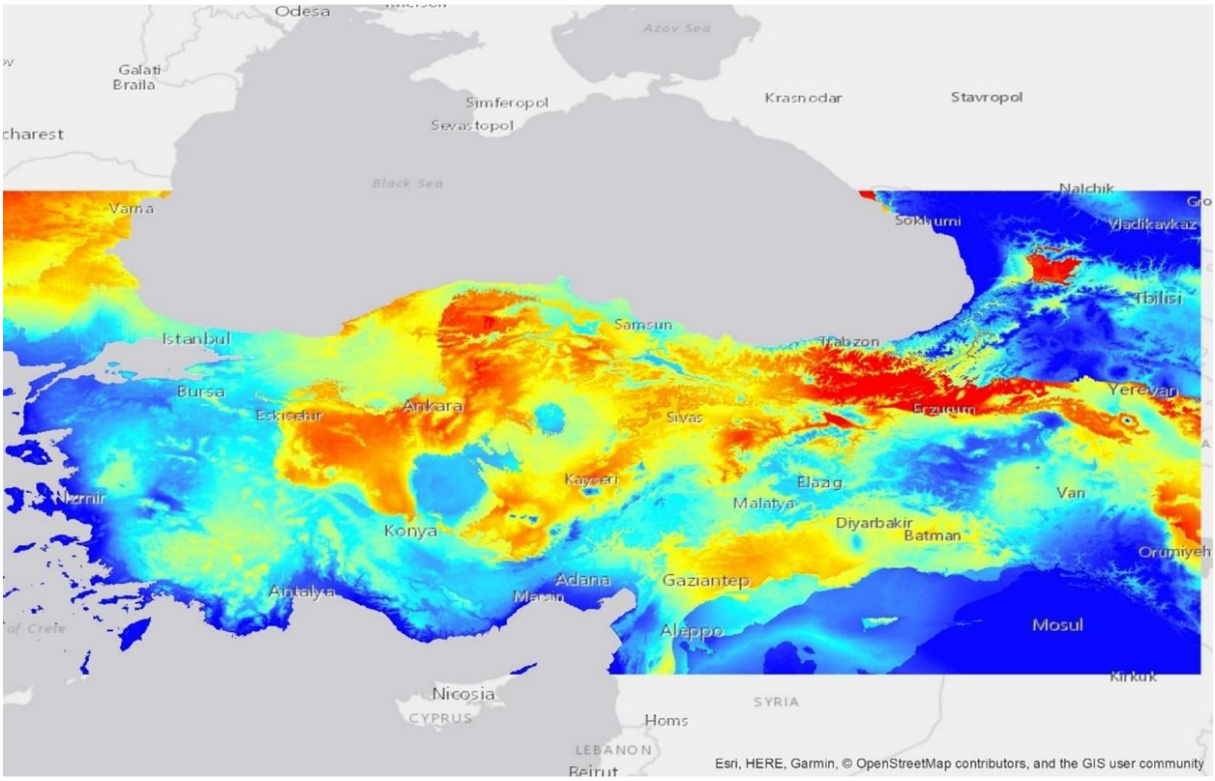

Figure 3. Future predicted available habitats for Turkish *Salix* sp.
Şekil 3. Türkiye Salix sp. için tahmini gelecek yaşam alanları

CONCLUSION

The reason this study only focus on 2050 climate scenario is to promote immediate action to conservation areas of Salix. The results of the study revealed that Ilgaz Mountains in Kastamonu and Artvin-Erzurum province in Eastern Black Sea Region are the most important habitats for Turkish Salix species and clones according to both currently and in 2050 climate projections. Thus, it is important that conversation practices should be taken into consideration in these areas. The species distribution models have certain advice ability to represent the situation of the species both current and future and those guidance can be used to get new insights to conservation and bioenergy approaches on Salix sp.

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