doi:10.55385/kastamonujes.1474468 KUJES 10(1): 29-37, 2024

Kastamonu University

Journal of Engineering and Sciences

e-ISSN 2667-8209

http://dergipark.gov.tr/kastamonujes

Possible Changes in Red Pine (*Pinus brutia* Ten.) Distribution Areas in Kastamonu due to Global Climate Change

Nihat Ertürk[a, *], **Burak Arıcak**[b]

[a] Department of Forest Engineering, Faculty of Forestry, Kastamonu University, Kastamonu, Türkiye

[b] Department of Forest Engineering, Faculty of Forestry, Bursa Technical University, Bursa, Türkiye

***Corresponding Author:** burak.aricak@btu.edu.tr

Received: **April 27, 2024** ◆ Accepted: **June 23, 2024** ◆ Published Online: **June 28, 2024**

Abstract: In this study, it was aimed to determine the current status of red pine (*Pinus brutia* Ten.) distribution areas in Kastamonu Forestry Regional Directorate, which is the Forestry Regional Directorate with the highest production in Türkiye, and the possible changes in suitable distribution areas due to global climate change. In the study, in addition to the current suitable distribution areas of red pine (*Pinus brutia* Ten.), suitable distribution areas in 2040, 2070 and 2100 according to SSP 126, SSP 370 and SSP 585 scenarios were determined. The results of the study show that there may be a loss of more than 15% (approximately 114,5 km^2) in the suitable distribution areas of red pine populations in Kastamonu until 2100 due to the effects of climate change. It does not seem possible for the species to adapt to these changes without human intervention. Therefore, it is recommended that necessary adjustments should be made in forest management plans taking into account the results of the study.

Keywords: Global climate change, *Pinus brutia* Ten., red pine, SSPs scenarios

Öz: Bu çalışmada, Türkiye'nin en fazla üretim yapılan Orman Bölge Müdürlüğü olan Kastamonu Orman Bölge Müdürlüğü'ndeki kızılçam (Pinus brutia Ten.) dağılım alanlarının mevcut durumunun ve uygun dağıtım alanlarında olası değişikliklerin belirlenmesi amaçlandı. küresel iklim değişikliği nedeniyle. Çalışmada kızılçamın (Pinus brutia Ten.) mevcut uygun yayılış alanlarının yanı sıra SSP 126, SSP 370 ve SSP 585 senaryolarına göre 2040, 2070 ve 2100 yıllarında uygun yayılış alanları belirlenmiştir. Araştırma sonuçları, Kastamonu'da kızılçam popülasyonlarının uygun yayılış alanlarında iklim değişikliğinin etkisiyle 2100 yılına kadar %15'ten fazla (yaklaşık 114,5 km2) kayıp olabileceğini göstermektedir. Türlerin insan müdahalesi olmadan bu değişimlere uyum sağlaması mümkün görünmüyor. Bu nedenle orman amenajman planlarında çalışmanın sonuçları dikkate alınarak gerekli düzenlemelerin yapılması önerilmektedir.

Anahtar Kelimeler: Küresel iklim değişikliği, *Pinus brutia* Ten., kızılçam, SSP senaryoları

1. Introduction

Climate is defined as the average weather conditions that remain the same over a wide area and over a very long time [1]. All phenotypic characters of living organisms are shaped under the influence of climate [2]. Therefore, changes in climatic parameters affect all living things directly or indirectly [3]. However, the living group most affected by climatic changes is plants, which have a limited migration mechanism [4]. It is often emphasized that the natural migration mechanism of plants cannot keep up with the speed of global climate change and therefore individual, population and species losses are inevitable [5]. It is stated that forest ecosystems will be the most affected by the global climate change process. Forests are the largest terrestrial carbon sink in the world and are the most effective and low-cost instruments that can be used to offset global greenhouse gas emissions. Therefore, the spatial loss of forest areas as a result of global climate change will further accelerate global climate change. Therefore, it is of great importance to determine the possible effects of global climate change especially on forests and to take the necessary measures, to provide the migration mechanism needed by plants by human hands, and to prevent species and population losses [6]. Due to the importance of the issue, many studies have been conducted on the change of suitable distribution areas of forest trees [1, 4-7].

However, these studies generally cover large areas and detailed studies are needed to plan appropriate silvicultural interventions. In this study, it was aimed to determine in detail how the suitable distribution areas of red pine (*Pinus brutia* Ten.) may change due to global climate change in Kastamonu Regional Forest Directorate, which is the Regional Forest Directorate with the highest wood raw material production in Türkiye. Unlike similar studies, the current distribution areas of the species were also evaluated within the scope of the study.

2. Material and Method

The study was conducted to model the changes in the potential distribution areas of red pine (*Pinus brutia* Ten.), one of the most important tree species for Türkiye and the Mediterranean basin, in Kastamonu due to global climate change. Within the scope of the study, firstly the current distribution area of the species subject to the study, then the current potential distribution area was determined. In the next stage, the potential distribution areas of the species in Kastamonu in 2040, 2070 and 2100 were tried to be determined. MaxEnt 3.4.1 software was used for modeling the potential distribution areas of the species and ArcGIS 10.5 software was used for map representation. In this study, 19 bioclimatic variables were used, which are the most frequently used variables in similar studies [7, 8]. The biological variables used in the study are given in Table 1.

Table 1. Bioclimatic variables used in modelling

Codes	**Bioclimatic variables**	**Unit**
Bio1	Annual Mean Temperature	˚C
Bio2	Mean Diurnal Range (Mean of monthly [max temp - min temp])	˚C
Bio3	Isothermality (Bio2/Bio7) (* 100)	-
Bio4	Temperature Seasonality (standard deviation *100)	(coeff. of variation ˚C)
Bio5	Max Temperature of Warmest Month	˚C
Bio6	Min Temperature of Coldest Month	˚C
Bio7	Temperature Annual Range (Bio5-Bio6)	˚C
Bio8	Mean Temperature of Wettest Quarter	˚C
Bio9	Mean Temperature of Driest Quarter	˚C
Bio10	Mean Temperature of Warmest Quarter	˚C
Bio11	Mean Temperature of Coldest Quarter	˚C
Bio12	Annual Precipitation	mm
Bio13	Precipitation of Wettest Month	mm
Bio14	Precipitation of Driest Month	mm
Bio15	Precipitation Seasonality (coefficient of variation)	percent
Bio16	Precipitation of Wettest Quarter	mm
Bio17	Precipitation of Driest Quarter	mm
Bio18	Precipitation of Warmest Quarter	mm
Bio19	Precipitation of Coldest Quarter	mm
Q	Emberger climate classification	-

Socio-economic pathways (SSPs) include five main SPPs (SSP 119, SSP 126, SSP 245, SSP 370, SSP 585). In this study, SSP 126, SSP 370 and SSP 585 scenarios were used. These scenarios and the method used in the study are among the methods and scenarios frequently used in similar studies [5, 10].

3. Findings

The validation values of the training data and test data in the ROC curve obtained as a result of the modeling performed within the scope of the study were determined as 0.960 (AUC>0.5). These findings show that the model has a very high predictive power (Figure 1).

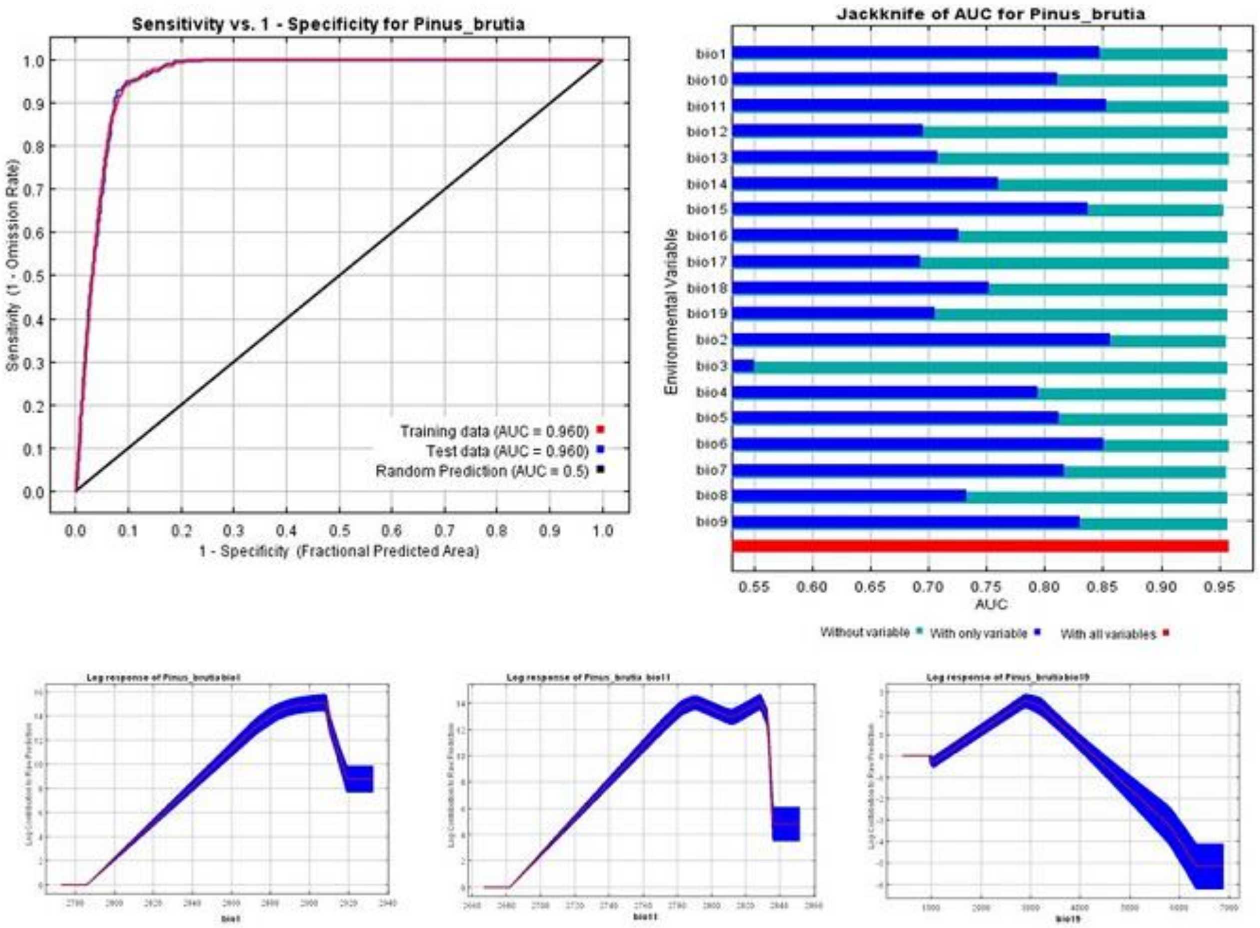

Figure 1. Effects of environmental factors on the distribution area of *Pinus brutia*

According to the gain table created for *Pinus brutia* with the Jacknife option in the model, the environmental variables that individually affect the distribution of the species in the training data at the highest level are determined as the average daily range (temperature range) [Bio2], the minimum temperature of the coldest month [Bio6] and the average temperature of the coldest quarter (3 months) [Bio11]. This reveals that the species is significantly affected by temperature. The current distribution areas of *Pinus brutia*, suitable distribution areas according to the model and distribution areas depending on global climate change are shown in Figure 2.

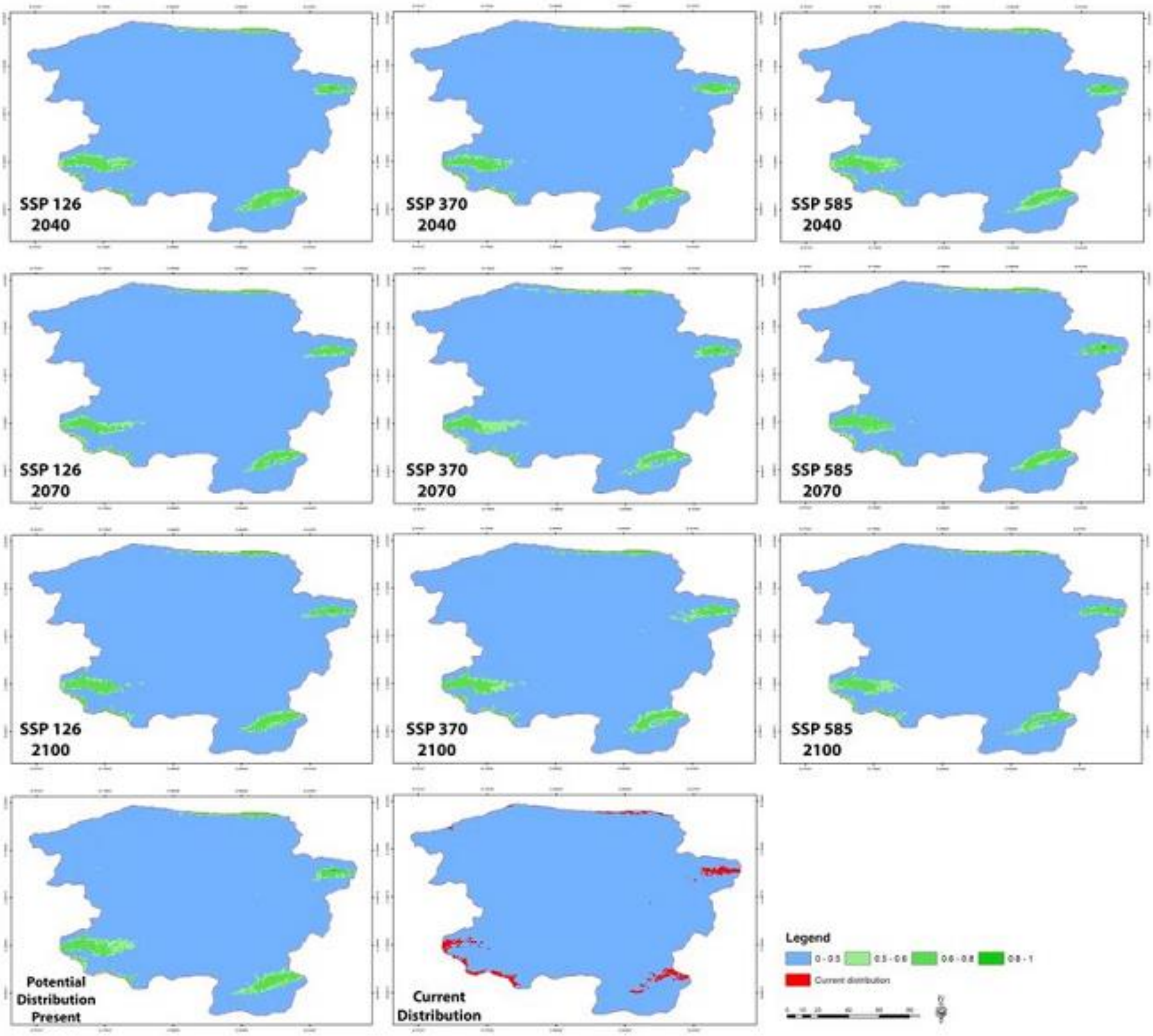

Figure 2. Suitable distribution areas of *Pinus brutia* depending on global climate change

When the current distribution areas of *Pinus brutia* are examined, it is seen that the distribution areas of *Pinus brutia* are located in the north of the province near the sea, in Hanönü district in the northeast, in Tosya district in the southeast and in Araç district in the southwest. These distribution areas are the regions where the altitude is quite low in Kastamonu. When the current suitable distribution areas of *P. brutia* are compared with the current distribution areas, it is seen that they are largely compatible. It was determined that the suitable distribution areas of the species are mostly in a narrow area in Tosya, Hanönü and Araç districts and on the coastline, as in the current distribution areas, and that there are local suitable distribution areas in very small areas. Apart from this, it can be said that there will be losses and gains in the suitable distribution areas of the species in general, but losses will definitely be seen in suitable distribution areas until 2100. According to the SSP 126 scenario, the rate of change in the suitable distribution areas of P. brutia in 2040, 2070 and 2100 compared to today is given in Table 2.

Table 2. Change of suitable distribution areas (km^2) of *P. brutia* according to SSP 126 scenario

Compliance	2020 available	2020 potential	SSPS 126		
			2040	2070	2100
0-0.5	12876	12317	12347.2	12410.9	12392.3
0.5-0.6		298.7	232.4	224.1	188.6
0.6-0.8	176.2	430.7	470.7	415.9	468.1
0.8-1		5.8	1.9	1.3	3.2
Total (km^2)	13052.2	13052.2	13052.2	13052.2	13052.2

When the table values are analyzed, it is calculated that *P. brutia* has a total potential distribution area of 735.2 km^2, of which 298.7 km^2 is suitable, 430.7 km^2 is highly suitable and 5.8 km^2 is very suitable, whereas the current *P. brutia* distribution area is 176.2 km^2. According to the SSP 126 scenario, when the change in the suitable distribution areas of *P. brutia* in the near future is analyzed, it is estimated that there will be a decrease in the total suitable distribution area until 2100, and there will be some increase in 2100, but this amount will still be lower than today. While the suitable distribution area of *P. brutia* is 298.7 km2 today, it is predicted to be 232.4 km^2 in 2040, 224.1 km^2 in 2070 and 188.6 km^2 in 2100.

The highly suitable distribution areas, which are 430.7 km^2 today, are estimated to be 470.7 km^2 in 2040, 415.9 km^2 in 2070 and 468.1 km^2 in 2100. The very suitable distribution areas, which are 5.8 km^2 today, are estimated to be 1.9 km^2 in 2040, 1.3 km^2 in 2070 and 3.2 km^2 in 2100. Therefore, the total area of suitable distribution area, which is 735.2 km^2 today, is projected to increase to 705.0 km^2 in 2040, 641.3 km^2 in 2070 and 659.9 km^2 in 2100 in the SSP 126 scenario. In these figures, it is noteworthy that, unlike other species in general, the amount of highly suitable distribution areas is higher than the amount of suitable distribution areas. According to the SSP 370 scenario, the rate of change in the suitable distribution areas of *P. brutia* compared to the present day is given in Table 3.

Table 3. Change of suitable distribution areas (km^2) of *P. brutia* according to SSP 370 scenario

Compliance	2020 available	2020 potential	SSPS 370		
			2040	2070	2100
0-0.5	12876	12317	12386.5	12368.4	12324.7
0.5-0.6		298.7	217.0	320.6	280.7
0.6-0.8	176.2	430.7	445.5	360.6	446.2
0.8-1		5.8	3.2	2.6	0.6
Total (km^2)	13052.2	13052.2	13052.2	13052.2	13052.2

According to the SSP 370 scenario, the total area of suitable distribution of *P. brutia* is expected to decrease in 2040 compared to today, but increase in 2070 compared to 2040 and in 2100 compared to 2070. However, these increases will not compensate for the losses until 2040. According to the calculations, according to the SSP 370 scenario, the area of suitable distribution, which is 298.7 km^2 today, will be 217.0 km^2 in 2040, 320.6 km^2 in 2070 and 280.7 km^2 in 2100. The highly suitable distribution areas, which are approximately 430.7 km^2 today, are estimated to be 445.5 km^2 in 2040, 360.6 km^2 in 2070 and 446.2 km^2 in 2100. On the other hand, it is estimated that the very suitable distribution areas will decrease from 5.8 km^2 today to 3.2 km^2 in 2040, 2.6 km^2 in 2070 and 0.6 km^2 in 2100. Therefore, according to the SSP 370 scenario, the total suitable distribution area, which is 735.2 km^2 today, is projected to be 665.7 km^2 in 2040, 683.8 km^2 in 2070 and 727.5 km^2 in 2100. According to the SSP 585 scenario, the rate of change of the suitable distribution areas of *P. brutia* compared to the present day is given in Table 4.

Table 4. Change of suitable distribution areas (km^2) of *P. brutia* according to SSP 585 scenario

Compliance	2020 available	2020 potential	SSPS 585		
			2040	2070	2100
0-0.5	12876	12317.0	12354.9	12410.9	12431.5
0.5-0.6		298.7	273.6	190.6	252.4
0.6-0.8	176.2	430.7	421.1	446.2	366.4
0.8-1		5.8	2.6	4.5	1.9
Total (km^2)	13052.2	13052.2	13052.2	13052.2	13052.2

When the table showing the change in the suitable distribution areas of *P. brutia* according to the SSP 585 scenario is analyzed, it can be said that the total suitable distribution area will decrease significantly in 2040 compared to the present day, will increase in 2070 compared to 2040, and this increase will continue until 2100. According to the calculations made, it is estimated that the area of suitable distribution, which is 298.7 km2 today, will be 273.6 km^2 in 2040, 190.6 km^2 in 2070 and 252.4 km^2 in 2100 according to the SSP 585 scenario. The highly suitable distribution areas, which are approximately 430.7 km^2 today, are estimated to be 421.1 km^2 in 2040, 446.2 km^2 in 2070 and 366.4 km^2 in 2100. It is predicted that the areas of very suitable distribution will decrease from 5.8 km^2 today to 2.6 km^2 in 2040, increase again to 4.5 km^2 in 2070 and decrease again to 1.9 km^2 in 2100. Therefore, the total suitable distribution area, which is 735.2 km2 today, is estimated to be 697.3 km^2 in 2040, 641.3 km^2 in 2070 and 620.7 km^2 in 2100 according to the SSP 585 scenario.

4. Discussion and Conclusion

The results of the study show that the suitable distribution areas of red pine populations in Kastamonu will change due to the effects of climate change. According to the calculations made, the amount of suitable distribution area in Kastamonu, which is currently 735.2 km^2, will decrease to 659.9 km^2 according to the SSP 126 scenario, 727.5 ^{km2} according to the SSP 370 scenario and 620.7 km^2 according to the SSP 585 scenario by 2100. Therefore, it is estimated that the amount of suitable distribution areas of the species in Kastamonu may be lost by more than 15% by 2100. In the studies conducted, it is estimated that different species will be affected by global climate change at different levels. For example, the total suitable distribution area of fir (*Abies bornmülleriana*) in Kastamonu, which is 2968.8 km^2 today, is estimated to be 3106.6 km2 in 2040, 3194.8 km^2 in 2070 and 3179.4 km^2 in 2100 according to the SSP 585 scenario [5]. Again in Kastamonu, the total suitable distribution area of beech, which is 3454.8 km^2 today, is estimated to be 3540.6 km^2 in 2040, 3648.7 km^2 in 2070 and 3622.3 km^2 in 2100 according to the SSP 585 scenario [5]. According to the SSP 585 scenario, the total area of chestnut (*Castanea sativa*) suitable distribution in Kastamonu, which is 868.6 km^2 today, is estimated to be 798.3 km^2 in 2040, 815.1 km^2 in 2070 and 800.9 km^2 in 2100 [10]. Therefore, according to the SSP 585 scenario in Kastamonu, it is predicted that there will be an increase in the total suitable distribution areas of fir and beech until 2100, but there will be significant losses in the suitable distribution areas of chestnut. It is stated that chestnut is the species most at risk among these species and that chestnut suitable distribution areas may disappear completely by 2100 [9]. Possible changes of different species have also been evaluated in studies conducted throughout Türkiye. In one study, according to the SSSP 245 scenario, the suitable distribution areas of A. bornmuelleriana are predicted to decrease in the coming years, especially at altitudes above 1400 m, whereas there will be a general increase at altitudes of 200-600 m [1]. According to another study, the distribution areas of Tilia cordata in western Marmara will almost completely disappear, while the distribution areas of Tilia tomentosa in southern Anatolia and the Black Sea region will decrease significantly [8]. It is stated that the distribution areas of Fraxinus excelsior L may decrease by 7.58% by 2100 [10]. It is estimated that Carpinus betulus may experience population losses exceeding 25% at altitudes below 1600 m and Carpinus orientalis may experience population losses exceeding 30% at altitudes below 1000 m [11]. Similarly, the Quercus libani suitable distribution area, which is currently 72,819 km^2 in Türkiye, is predicted to decrease to 63,390 km^2 by 2070 [12].

Türkiye is among the "countries at risk" and highly vulnerable to climate change, and future climate projections indicate that by 2100, Türkiye's annual temperature will increase across the entire country, especially in the Aegean region, where temperature increases can reach up to 6 ºC [7]. The Mediterranean region is dominated by red pine, and red pine is one of the species that will be most affected by this process. As a matter of fact, in a study, it is stated that while the ratio of the geographical distribution of *P. pinea* to the geographical area of Türkiye is 16.08% today, this ratio may decrease to 2.28% in 2070, that is, the loss of its potential distribution area may approach 85% [13]. Studies conducted in different parts of the world also indicate that some species may experience great losses in their suitable distribution areas. It is estimated that the reduction in the potential distribution area of F. sylvatica in Europe could reach 56% [14], the loss of habitat for different species in mountainous areas in Mexico could reach 46-77% by 2060 [15], and Pinus armandii suitable habitat in the Hengduan Mountains of China will gradually disappear [16].

Global climate change is considered as a process that will lead to significant changes in climate parameters. Because all phenotypic characters of living organisms are shaped by their genetic structure [17, 18] and environmental factors [19, 20]. Climate is one of the most important environmental factors [21, 22]. It is stated that changes in climatic parameters, i.e. global climate change, will directly or indirectly affect forests by increasing the spread of insects and fungi [23], forest fires [24], alien species invasions [1], affecting water and nutrient availability, precipitation regime [11]. It is emphasized that the most important effects of the global climate change process will be temperature increase and decrease in water resources [25, 26]. In addition, increased UV-B rays [27] and radiation will cause significant stress in plants [28]. Studies have estimated that the northern half of Türkiye will experience a much larger decrease in summer precipitation than the southern half [9]. It is stated that the increase in temperature and decrease in precipitation in cities such as Samsun [29], Düzce [30], Kastamonu [31], Düzce [32] which are located in the northern half of Türkiye, may cause aridification in the climate to occur very rapidly.

As a result, global climate change is a process that can directly or indirectly affect all living things and ecosystems on earth and is defined as one of the two irreversible problems that the world has to cope with [33, 34]. The living group that will be most affected by this process is plants, which do not have an effective mobility. Since the life on earth is directly or indirectly dependent on plants [35-39], it is inevitable that all living things in the world will be affected by global climate change.

5. Recommendations

The results of the study show that there will be significant changes in the distribution areas of the red pine populations in Kastamonu and that the loss of suitable distribution area may exceed 15% by 2100. It does not seem possible for the species to adapt to these changes without human intervention. Therefore, it is recommended that necessary adjustments be made in forest management plans taking into account the results of the study.

Global climate change is defined as an irreversible problem. Therefore, it is of great importance to take measures to ensure that plants are minimally affected by the effects of global climate change. Reducing the impact of this process in forests and minimizing species and population losses is possible by predicting the possible future changes from today and taking measures and planning according to the changes that may occur. The fact that this process has different effects on forests means that species need different silvicultural interventions. Which silvicultural interventions will provide the greatest benefit for which species should be determined depending on the ecological context of the forest and the adaptability of the species. Current silvicultural practices should therefore be reviewed and redesigned to take into account the impacts of global climate change.

Conflict of Interest

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

Ethics Committee Approval

Ethics committee approval is not required.

Author Contribution

Conceptization: BC, GS; methodology and laboratory analyzes: BC, GS; writing draft: BC, GS; proof reading and editing: Other: All authors have read and agreed to the published version of manuscript.

Acknowledgements

This research is Nihat ERTÜRK's PhD Thesis in Kastamonu University, Institute of Science, Programs of Forest Engineering conducted one of part of this research. We sincerely thanks to Kastamonu University Institute of Science.

6. References

[1] Tekin, O., Cetin, M., Varol, T., Ozel, H. B., Sevik, H., & Zeren Cetin, I. (2022). Altitudinal migration of species of Fir (Abies spp.) in adaptation to climate change. Water, Air, & Soil Pollution, 233(9), 1-16.

[2] Sevik, H., Çetin, M., & Kapucu, O. (2016). Effect of light on young structures of Turkish fir (Abies nordmanniana subsp. bornmulleriana). Oxidation Communications, 39(1), 485-492.

[3] Işınkaralar, Ö. (2024). Spatio-temporal change of the morphology in west corridor development region of Ankara city and 2022-2039 growth estimation. Megaron, 19(1).

[4] Varol, T., Cetin, M., Ozel, H. B., Sevik, H., Zeren Cetin, I. (2022a). The effects of climate change scenarios on Carpinus betulus and Carpinus orientalis in Europe. Water, Air and Soil Pollution, 233, 45.

[5] Ertürk, N., Arıcak, B., Yiğit, N., & Sevik, H. (2024). Potential Changes in the Suitable Distribution Areas of Fagus orientalis Lipsky in Kastamonu Due to Global Climate Change. Forestist, 74(2).

[6] Erturk, N., Aricak, B., Sevik, H., & Yigit, N. (2024). Possible Change in Distribution Areas of Abies in Kastamonu due to Global Climate Change. Kastamonu University Journal of Forestry Faculty, 24 (1), 81-91.

[7] Varol, T., Canturk, U., Cetin, M., Ozel, H. B., Sevik, H., & Zeren Cetin, I. (2022b). Identifying the suitable habitats for Anatolian boxwood (Buxus sempervirens L.) for the future regarding the climate change. Theoretical and Applied Climatology, 150(1), 637-647.

[8] Isinkaralar, O., Świsłowski, P., Isinkaralar, K., & Rajfur, M. (2024). Moss as a passive biomonitoring tool for the atmospheric deposition and spatial distribution pattern of toxic metals in an industrial city. Environmental Monitoring and Assessment, 196(6), 513.

[9] Cobanoglu, H., Canturk, U., Koç, İ., Kulaç, Ş., & Sevik, H. (2023). Climate change effect on potential distribution of anatolian chestnut (Castanea sativa Mill.) in the upcoming century in Türkiye. Forestist, 73(3), 247-256

[10] Erturk N., & Arıcak, B. (2024). Potential change of chestnut (Castanea sativa Mill.) distribution areas in Kastamonu due to global climate change, World Journal of Advanced Research and Reviews (In Press)

[11] Varol, T., Canturk, U., Cetin, M., Ozel, H. B., Sevik, H. (2021a). Impacts of climate change scenarios on European ash tree (Fraxinus excelsior L.) in Turkey. Forest Ecology and Management. Forest Ecology and Management, 491(2021b),119199.

[12] Çoban, H. O., Örücü, Ö. K., & Arslan, E. S. (2020). MaxEnt modeling for predicting the current and future potential geographical distribution of Quercus libani Olivier. Sustainability, 127, 2671.

[13] Akyol, A., & Örücü, Ö. K. (2020). Investigation and evaluation of stone pine Pinus pinea L. current and future potential distribution under climate change in Turkey. Cerne, 25, 415-423.

[14] Thurm, E. A., Hernandez, L., Baltensweiler, A., Ayan, S., Rasztovits, E., Bielak, K., Zlatanov, T. M., Hladnik, D., Balic, B., Freudenschuss, A., Büchsenmeister, R., & Falk, W. (2018). Alternative tree species under climate warming in managed European forests. Forest Ecology and Management, 430, 485–497.

[15] Gómez-Pineda, E., Blanco-García, A., Lindig-Cisneros, R., O'Neill, G. A., Lopez-Toledo, L., & Sáenz-Romero, C. (2021). Pinus pseudostrobus assisted migration trial with rain exclusion: Maintaining Monarch Butterfly Biosphere Reserve forest cover in an environment affected by climate change. New Forests, 52(6), 995–1010.

[16] Ning, H., Ling, L., Sun, X., Kang, X., & Chen, H. (2021). Predicting the future redistribution of Chinese white pine Pinus armandii Franch. Under climate change scenarios in China using species distribution models. Global Ecology and Conservation, 25, e01420.

[17] Hrivnák, M., Krajmerová, D., Paule, L., Zhelev, P., Sevik, H., Ivanković, M., ... & Gömöry, D. (2023). Are there hybrid zones in Fagus sylvatica L. sensu lato?. European Journal of Forest Research, 1-14.

[18] Sulhan, O. F., Sevik, H., & Isinkaralar, K. (2023). Assessment of Cr and Zn deposition on Picea pungens Engelm. in urban air of Ankara, Türkiye. Environment, development and sustainability, 25(5), 4365-4384.

[19] Özel, H. B., Şevik, H., Yıldız, Y., & Çobanoğlu, H. (2024). Effects of Silver Nanoparticles on Germination and Seedling Characteristics of Oriental Beech (Fagus orientalis) Seeds. BioResources, 19(2). 2135-2148.

[20] Koç, İ., Canturk, U., Isinkaralar, K., Ozel, H. B., & Sevik, H. (2024). Assessment of metals (Ni, Ba) deposition in plant types and their organs at Mersin City, Türkiye. Environmental Monitoring and Assessment, 196(3), 282.

[21] Işınkaralar, O., Işınkaralar, K., Sevik, H., Kucuk, O. (2023). Bio-climatic Comfort and Climate Change Nexus: A Case Study in Burdur Basin. Kastamonu University Journal of Forestry Faculty, 23(3), 241-249. https://doi.org/10.17475/kastorman.1394916

[22] Isinkaralar, K. (2022). Some atmospheric trace metals deposition in selected trees as a possible biomonitor. Romanian Biotechnological Letters, 27(1), 3227-3236.

[23] Toczydlowski, A. J., Slesak, R. A., Kolka, R. K., & Venterea, R. T. (2020). Temperature and water-level effects on greenhouse gas fluxes from black ash (Fraxinus nigra) wetland soils in the Upper Great Lakes region, USA. Applied Soil Ecology, 153, 103565.

[24] Ertugrul, M., Ozel, H. B., Varol, T., Cetin, M., & Sevik, H. (2019). Investigation of the relationship between burned areas and climate factors in large forest fires in the Çanakkale region. Environmental monitoring and assessment, 191, 1-12.

[25] Cetin, M., Sevik, H., Koc, I., & Cetin, I. Z. (2023). The change in biocomfort zones in the area of Muğla province in near future due to the global climate change scenarios. Journal of Thermal Biology, 112, 103434.

[26] Isinkaralar, O., Isinkaralar, K., Sevik, H., & Küçük, Ö. (2024). Spatial modeling the climate change risk of river basins via climate classification: a scenario-based prediction approach for Türkiye. Natural Hazards, 120(1), 511-528.

[27] Ozel, H. B., Abo Aisha, A. E. S., Cetin, M., Sevik, H., & Zeren Cetin, I. (2021a). The effects of increased exposure time to UV-B radiation on germination and seedling development of Anatolian black pine seeds. Environmental Monitoring and Assessment, 193, 388.

[28] Ozel, H. B., Cetin, M., Sevik, H., Varol, T., Isik, B., & Yaman, B. (2021b). The effects of base station as an electromagnetic radiation source on flower and cone yield and germination percentage in Pinus brutia Ten. Biologia Futura, 72, 359-365.

[29] Koç, İ. (2022). Determining the near-future biocomfort zones in Samsun province by the global climate change scenarios. Kastamonu University Journal of Forestry Faculty, 22(2), 181-192.

[30] Koç, İ. (2021). Changes that may occur in temperature, rain, and climate types due to global climate change: the example of Düzce. Turkish Journal of Agriculture-Food Science and Technology, 9(8), 1545-1554.

[31] Gur, E., Palta, Ş., Ozel, H. B., Varol, T., Sevik, H., Cetin, M., & Kocan, N. (2024). Assessment of Climate Change Impact on Highland Areas in Kastamonu, Turkey. Anthropocene, 100432.

[32] Koç, İ. (2021). Küresel iklim değişikliğinin Bolu'da bazı iklim parametreleri ve iklim tiplerine etkisi. Bartın Orman Fakültesi Dergisi, 23(2), 706-719.

[33] Yayla, E. E., Sevik, H., & Isinkaralar, K. (2022). Detection of landscape species as a low-cost biomonitoring study: Cr, Mn, and Zn pollution in an urban air quality. Environmental Monitoring and Assessment, 194(10), 1-10.

[34] Key, K., Kulaç, Ş., Koç, İ., & Sevik, H. (2022). Determining the 180-year change of Cd, Fe, and Al concentrations in the air by using annual rings of Corylus colurna L. Water, Air, & Soil Pollution, 233(7), 244.

[35] Yigit, N., Mutevelli, Z., Sevik, H., Onat, S.M., Ozel, H.B., Cetin, M., Olgun, C. (2021). Identification of Some Fiber Characteristics in Rosa sp. and Nerium oleander L. Wood Grown under Different Ecological Conditions. BioResources, 16(3): 5862-5874.

[36] Ghoma, W. E. O., Sevik, H., & Isinkaralar, K. (2023). Comparison of the rate of certain trace metals accumulation in indoor plants for smoking and non-smoking areas. Environmental science and pollution research, 30(30), 75768-75776.

[37] Koç, İ., & Nzokou, P. (2023). Combined effects of water stress and fertilization on the morphology and gas exchange parameters of 3-year-old Abies fraseri (Pursh) Poir. Acta physiologiae plantarum, 45(3), 49.

[38] Sevik, H., Yildiz, Y., Ozel, H.B. (2024). Phytoremediation and Long-term Metal Uptake Monitoring of Silver, Selenium, Antimony, and Thallium by Black Pine (Pinus nigra Arnold), BioResources, 19(3). 4824-4837.

[39] Koç, İ., Nzokou, P., & Cregg, B. (2022). Biomass allocation and nutrient use efficiency in response to water stress: Insight from experimental manipulation of balsam fir, concolor fir and white pine transplants. New Forests, 53(5), 915-933.