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Possible Change in Distribution Areas of *Abies* in Kastamonu due to Global Climate Change

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Abstract

Aim of the study: In the process of global climate change (GCC), the migration mechanism needed especially for forest trees must be provided by humans. For this purpose, contrary to the previous studies, detailed studies to be carried out on small areas are needed.

Area of study: In the present study carried out in Kastamonu Regional Directorate of Forestry, which performs the highest level of wood production in Türkiye, it was aimed to specify the actual distribution areas of the *Abies* and the change in their suitable distribution areas due to GCC.

Material and methods: In this study, besides the existing distribution areas and the potential future distribution areas, also the suitable distribution areas were determined by using SSP 126, SSP 370, and SSP 585 scenarios for the years 2040, 2070, and 2100 for *Abies* at Kastamonu.

Main results: The results achieved there showed that, depending on the results of climate change, distribution areas of *Abies* populations would change in the future and this change would be in form of an increase in general.

Research highlights: This species (*Abies*) seems incapable of keeping up with such changes without human intervention. Thus, considering the study results, it is recommended to make necessary amendments to the forest management plans.

Keywords: Global Climate Change, *Abies nordmanniana*, *Abies*, SSPs Scenarios

Kastamonu'da Küresel İklim Değişikliğine Bağlı Olarak *Abies* Yayılış Alanlarının Olası Değişimi

Öz

Çalışmanın amacı: Küresel iklim değişikliği (GCC) sürecinde özellikle orman ağaçları için ihtiyaç duyulan göç mekanizmasının insanlar tarafından sağlanması gerekmektedir. Bu amaçla daha önce yapılan çalışmaların aksine küçük alanlarda yapılacak detaylı çalışmalara ihtiyaç bulunmaktadır.

Çalışma alanı: Türkiye'nin en yüksek düzeyde odun üretimini gerçekleştiren Kastamonu Orman Bölge Müdürlüğü'nde gerçekleştirilen bu çalışmada *Abies*'lerin gerçek yayılış alanlarının belirlenmesi ve uygun yayılış alanlarındaki değişimlerin belirlenmesi amaçlanmıştır.

Materyal ve yöntem: Bu çalışmada Kastamonu'da *Abies* için mevcut dağılım alanları ve gelecekteki potansiyel dağılım alanlarının yanı sıra 2040, 2070 ve 2100 yılları için SSP 126, SSP 370 ve SSP 585 senaryoları kullanılarak uygun dağılım alanları belirlenmiştir.

Temel sonuçlar: Bu çalışmada elde edilen sonuçlar, iklim değişikliğinin sonuçlarına bağlı olarak *Abies* populasyonlarının dağılım alanlarının gelecekte değişeceğini ve bu değişimin genel olarak artış şeklinde olacağını göstermiştir.

Araştırma vurguları: Çalışmaya konu tür (*Abies*), insan müdahalesi olmadan küresel iklim değişikliğine ayak uyduramayacaktır. Bu nedenle çalışma sonuçları dikkate alınarak orman amenajman planlarında gerekli değişikliklerin yapılması önerilmektedir.

Anahtar Kelimeler: Küresel İklim Değişikliği, *Abies nordmanniana*, *Abies*, SSPs Senaryoları

Introduction

Rapidly growing in the last century, the world population approximated to 8 billion (Ghoma et al., 2022). Besides that, due to the advancements in industries, population density increased in urban areas because of the rural-to-urban migration. Due to industrial advancements, extraction of underground elements in order to meet the need for raw material and then releasing them into the atmosphere made the environmental pollution one of the most critical glitches worldwide (Elsunousi et al., 2021). Furthermore, the air pollution and especially the change in the composition of the atmosphere caused GCC (Savas et al., 2021). In conclusion, the advancements in the industry made urbanization (Kilicoglu et al., 2021) and environmental GCC (Canturk & Kulaç, 2021) two irreversible problems that the world has to cope with (Sulhan et al., 2022).

A region's average weather conditions that hold steady over an extended period of time are referred to as its climate (Tekin et al., 2022). Because all of an organism's phenotypic traits are shaped in response to its environment, changes in the climate have an impact on all of organic life, either directly or indirectly (Sevik et al., 2021). Thus, the earth's climate affects not just people but also every other living thing and environment (Koç, 2022).

However, due to their restricted migration ability, plants are most impacted by climate change (Varol et al., 2022a). Since plants' natural migration mechanism would not be able to keep up with the speed of GCC, it means that many plant species and populations would extinct due to the effects of GCC (Tekin et al., 2022). It is projected that, in the process of GCC, suitable habitats of the most of plant species would significantly change and migration mechanisms of plants would remain incapable of adapting to this change (Dyderski et al., 2018; Varol et al., 2021). It is noted that the species subject to the study will be among the species that will be most affected by the GCC (Tekin et al., 2022).

Forest ecosystems are among the ones that will be affected by this process the most. In addition to being the world's largest terrestrial carbon sink, forests are also the most practical and affordable tool for balancing greenhouse gas emissions globally (Huang et al., 2020; Cantürk & Kulaç, 2021). Hence, an area loss in forest areas that might occur as a result of GCC would further accelerate GCC. Thus, it is very critical to define the potential impacts of GCC especially on the forests and to take measures in order to prevent the loss of species and populations.

Many studies were carried out on the effects of GCC on the distribution areas of different tree species (Varol et al., 2021). In the present study, contrary to the previous studies, the natural distribution areas of the species were determined in detail first and then compared to the potential distribution areas on a map. The present study is one of the most detailed studies carried out on a small scale and can be an exemplary one.

For this reason, many studies investigating the effects of GCC on the suitable distribution areas of tree species have been carried out to date. However, those studies were generally carried out in large areas. Yet, detailed studies are needed in order to determine the silvicultural interventions aiming to protect the forest trees from climatic change that might occur due to GCC. In the present study carried out in Kastamonu Regional Directorate of Forestry, which performs the highest level of production in Türkiye, it was aimed to determine the present distribution regions of the *Abies* and the change in their suitable distribution areas due to GCC.

Material and Method

Stating that the morphologic differences claimed between *Abies nordmanniana* subsp. *equi-trojani* (*Abies nordmanniana* subsp. *equi-trojani* and *Abies nordmanniana* subsp. *bornmuelleriana* that are among the most essential plant species for Türkiye and Kastamonu were transitional, they are merged under the name *Abies nordmanniana* subsp. *equi-trojani* (Tekin et al., 2022)). It was aimed to model the change in the potential distribution areas because of GCC. Within the scope of the present study, *Abies* species naturally spreading in Kastamonu province was examined and the name of species is *Abies nordmanniana* subsp. *equi-trojani*. This species is endemic to Türkiye and Kastamonu province is the region, in which it has the largest distribution area (Akkemik, 2018).

Within the scope of this study, the current distribution area of *Abies* and then the potential distribution area at that moment were determined and then it was aimed to determine the future potential distribution regions in Kastamonu for the years 2040, 2070, and 2100. ArcGIS 10.5 (ESRI, 2017) was used to create map presentations, and MaxEnt 3.4.1 (Philips & Dudik, 2008) was used to predict the species' potential distribution ranges. First, the distribution of *Abies* was determined. In order to best express the natural and future distributions of the species, 19 bioclimatic variables preferred in many previous studies were used and these variables are presented in Table 1. These variables are the bioclimatic variables used in relevant studies the most (Canturk & Kulac, 2021; Varol et al., 2021).

Table 1. Bioclimatic variables used in modeling

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) comprise five primary SPPs (SSP 119, SSP 126, SSP 245, SSP 370, and SSP 585) (Saha et al., 2021). The present study employed SSP 126, SSP 370, and SSP 585 scenarios. Among these scenarios, SSP 126 is a scenario, in which sustainable development proceeds very rapidly, inequalities reduce, technological advancements are rapid, and environment-friendly processes such as low-carbon energy resources and high land productivity are preferred (Kim & Kwon, 2022). According to its radiative forcing pathway, the SSP 126 reflects the low emission scenario and predicts a warming of less than 2°C by 2100 (Wu et al., 2022). By 2100, a radioactive forcing level of 2.6 Wm^2 is the result of SSP 126 (Saha et al., 2021). SSP 126 scenario is an opportunistic scenario incorporating low difficulties related to adapting to and reducing the GCC (Bogoni & Tagliari, 2021).

SSP 370 scenario is a mixed one. According to McGregor et al. (2022), the SSP 370 scenario stabilized radiative forcing at 7.0 W/m^2 in 2100. In this scenario, a relatively rapid technological advancement is projected for low-carbon energy resources in main emission regions and a relatively higher level of decrease in places that are important for global emissions. In addition, it is projected that development would be slowed in other regions, that inequalities would remain at high levels, and that these regions would have difficulty in adapting to climate changes (Kim & Kwon, 2022).

According to Wu et al. (2022), the SSP 585 is a high-emission scenario that stabilized radiative forcing at 8.5 W/m^2 in 2100. This scenario is named “fossil-fuel development” scenario. This is a pessimistic scenario incorporating high levels of difficulty in adapting to and relieving the GCC (Bogoni & Tagliari, 2021). In this scenario, it is projected that energy demand would be high and this demand would be met mainly by using carbon-based fuels. It is foreseen that the investments in alternative energy technologies would be at low levels but economic development would be relatively faster, resources would be distributed more fairly, stronger institutions and lower population growth rates would be achieved, and there would be a less vulnerable world, which can better adapt to climatic effects (Kim & Kwon, 2022).

The atmospheric component of the Centre National de Recherches Météorologiques model version 6 (CNRM-CM6-1) with a 2.5-minute spatial resolution was utilized in this work to depict stratocumulus. ROC (Receiver Operating Characteristic) and AUC (Area Under Curve) values, as well as the Jackknife test, were used to validate these models (Varol et al., 2022b).

Results and Discussion

The validation values for the training and test data were determined to be 0.828 and 0.822 (AUC>0.5), respectively, based on the ROC curve that was obtained from the modeling that was done for this study. These findings imply that the model has a high degree of estimating power (Figure 1).

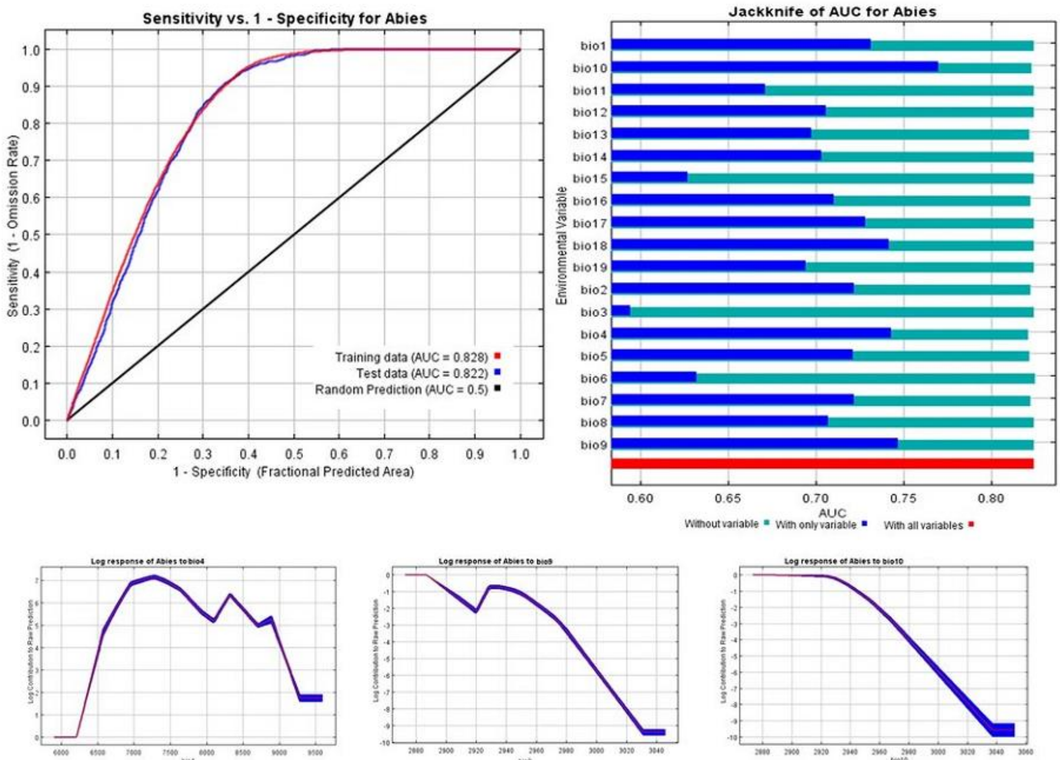

Figure 1. Impacts of environmental facets on distribution region of *A. nordmanniana*

In this model, given the achievement table that was prepared using the Jackknife option for *A. nordmanniana*, it was determined that the environmental variable to individually affect the distribution of species in training data was the mean temperature of the warmest quarter (Bio10), followed by the mean temperature of the driest quarter (Bio9) and the seasonal temperature (Bio4) variables. It shows that the species was notably influenced, particularly by the temperature. Current distribution areas, suitable distribution areas by the model, and distribution areas by GCC for *A. nordmanniana* are presented in Figure 2.

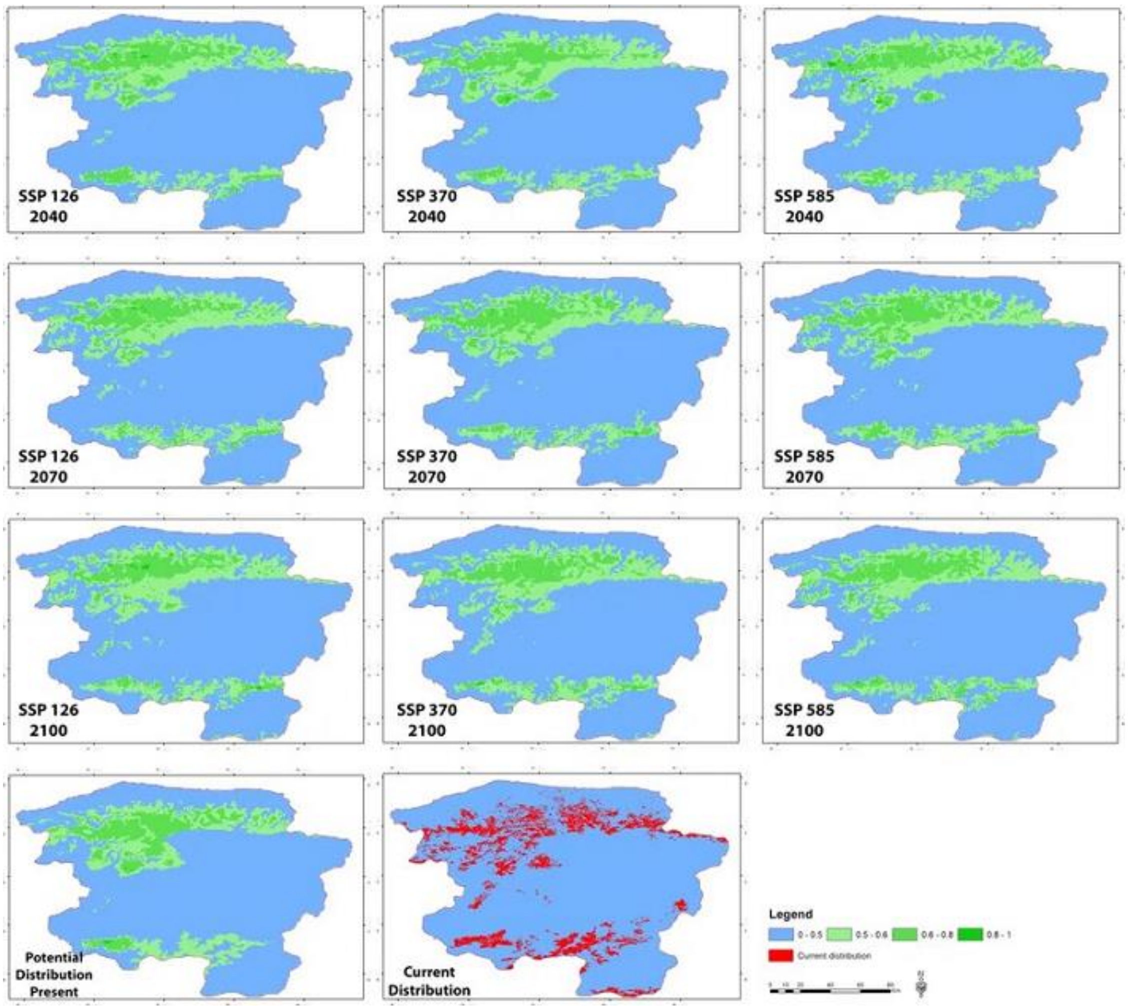

Figure 2. Changing distribution areas by GCC for *A. nordmanniana*

Given SSP126 scenario for *A. nordmanniana*, it can be stated that the species' appropriate distribution ranges for the year 2100 would be significantly larger in comparison to the years 2040 and 2070 and the current distribution areas. This increase would be observed mainly in the eastern parts of the province and a certain level of decrease would be seen in the western parts. For the year 2100, it is projected that the current very suitable distribution ranges in Küre mountains for previous years would slightly decrease and new very appropriate distribution regions would form in eastern parts of the Ilgaz mountain chain. Given SSP 126 scenario, the change of *A. nordmanniana*'s suitable distribution areas in the years 2040, 2070, and 2100 in comparison to the current moment is illustrated in Table 2.

Table 2. Change of the *A. nordmanniana* suitable distribution zones according to the SSP 126 scenario

Suitability	2020 current (km^2)	2020 potential (km^2)	Ssps126		
			2040 (km^2)	2070 (km^2)	2100 (km^2)
0-0.5	11440.7	10083.4	9921.8	9812.3	9766
0.5-0.6		1885.2	2006.3	2233.5	2327.5
0.6-0.8	1611.5	1077.8	1113.2	999.3	939.4
0.8-1		5.8	10.9	7.1	19.3
Total (km^2)	13052.2	13052.2	13052.2	13052.2	13052.2

Given the values in Tablo 1, it can be seen that *A. nordmanniana* currently has a potential distribution area of 2968.8 km^2 (1885.2 km^2 suitable, 1077.8 km^2 considerably suitable, and 5.8 km^2 very suitable) but the actual distribution area of *A. nordmanniana* was 1611.5 km^2 in total. Given the SSP 126 scenario and examining the change of proper distribution ranges of *A. nordmanniana* in near future, it is projected that there would be a constant increase in the total distribution area. While the current suitable distribution area of *A. nordmanniana* is 1885.2 km^2, it is projected to increase to 2006.3 km^2 by the year 2040, 2233.5 km^2 by the year 2070, and 2327.5 km^2 by the year 2100. Considerably suitable distribution area, which is 1077.8 km^2 at this moment, is calculated to be 1113.2 km^2 in the year 2040, 99.3 km^2 in the year 2070, and 939.4 km^2 in the year 2100. Besides that, very suitable distribution area is 5.8 km^2 at this moment and is estimated to be 10.9 km^2 in the year 2040, 7.1 km^2 in the year 2070, and 19.3 km^2 in the year 2100. Hence, according to the SSP 126 scenario, the total appropriate distribution range, which is 2968.8 km^2 at this moment, is estimated to possibly increase to 3130.4 km^2 in the year 2040, 3239.9 km^2 in the year 2070, and 3286.2 km^2 in the year 2100.

According to the SSP 370 scenario, *A. nordmanniana*'s suitable distribution areas would shift towards the east; while the suitable areas in the east slightly increase, there might be losses in suitable distribution areas in the west. Moreover, according to the calculations, the decrease in very suitable distribution areas in the year 2070 would compensate itself and the very proper distribution ranges of the species would increase back to their level in the year 2040. The changes in the appropriate distribution regions of *A. nordmanniana* in comparison to the current situation according to the SSP 370 scenario are presented in Table 3.

Table 3. Change of proper distribution regions of *A. nordmanniana* by SSP 370 scenario

Suitability	2020 current (km^2)	2020 potential (km^2)	ssps126		
			2040 (km^2)	2070 (km^2)	2100 (km^2)
0-0.5	11440.7	10083.4	9854.2	9953.3	9783.4
0.5-0.6		1885.2	2193.6	1983.1	2265.1
0.6-0.8	1611.5	1077.8	998	1111.9	997.3
0.8-1		5.8	6.4	3.9	6.4
Total (km^2)	13052.2	13052.2	13052.2	13052.2	13052.2

Given the change of proper distribution regions of *A. nordmanniana* according to the SSP 370 scenario, it can be stated that, in comparison to the existing state, the total of appropriate distribution ranges would increase in the year 2040 but it would decrease in the year 2070 in comparison to the year 2040 and then it would increase again in the year 2100. According to the calculations, the suitable distribution area that is 1885.2 km^2 today is projected to be 2193.6 km^2 in 2040, 1983.1 km^2 in 2070, and 2265.1 km^2 in 2100. The total of considerably suitable distribution areas that is 1077.8 km^2 today is calculated to be 998.0 km^2 in 2040, 1111.9 km^2 in 2*70, and 997.3 km^2 in 2100. Furthermore, the total of very suitable distribution areas that is 5.8 km^2 today is estimated to be 6.4 km^2 in 2040, 7.1 km^2 in 2070, and 6.4 km^2 in 2100. Hence, the total of suitable distribution areas that is 2968.8 km^2 today is projected to be (according to the SSP 370 scenario) 3198.0 km^2 in 2040, 3098.9 km^2 in 2070, and 3268.8 km^2 in 2100.

Examining the proper distribution regions of *A. nordmanniana* in the year 2100 according to the SSP 585 scenario, it is projected that the total of proper distribution ranges would not significantly change over time but the very suitable distribution areas would first slightly decrease and then reach the current level by increasing again. The new suitable distribution areas would be distant from each other and small ones. The change in suitable distribution areas of *A. nordmanniana* in comparison to the current situation according to the SSP 585 scenario is presented in Table 4.

Table 4. Change of proper distribution regions of *A. nordmanniana* by SSP 585 scenario

Suitability	2020 current (km^2)	2020 potential (km^2)	ssps126		
			2040 (km^2)	2070 (km^2)	2100 (km^2)
0-0.5	11440.7	10083.4	9945.6	9857.4	9872.8
0.5-0.6		1885.2	2128.6	2098.3	2066.8
0.6-0.8	1611.5	1077.8	951.6	1095.2	1107.4
0.8-1		5.8	26.4	1.3	5.2
Total (km^2)	13052.2	13052.2	13052.2	13052.2	13052.2

Given Table 3 representing the variations in suitable distribution ranges of *A. nordmanniana* according to the SSP 585 scenario, it can be stated that the total of proper distribution regions would increase in 2040 in comparison to the current situation, the increase would continue as of the year 2070, then the increase would stop as of the year 2100, and the total values in 2070 and 2100 would be similar to each other. According to the calculations for SSP 585 scenario, the total of suitable distribution areas (1885.2 km^2 today) is estimated to be 2128.6 km^2 in the year 2040, 2098.3 km^2 in the year 2070, and 2066.8 km^2 in the year 2100. The total of considerably suitable distribution areas, which is approx. 1077.8 km^2 today, was calculated to be 951.6 km^2 in 2040, 1095.2 km^2 in 2070, and 1107.4 km^2 in 2100. The total of very suitable distribution areas, which is 5.8 km^2 at this moment, is projected to be 26.4 km^2 in the year 2040, significantly decrease to 1.3 km^2 as of the year 2070, and then increase back to 5.2 km^2 by the year 2100. Hence, according to the SSP 585 scenario, the total of proper distribution areas that is 2968.8 km^2 at this moment is estimated to be 3106.6 km^2 in 2040, 3194.8 km^2 in 2070, and 3179.4 km^2 in 2100.

The results acquired revealed that the suitable distribution areas of *Abies* populations in Kastamonu would change due to the effects of GCC and this change would be in form of an increase in general. However, it was also selected that some of the current proper distribution regions of *Abies* would not be suitable distribution areas in the future and population loss would be inevitable in that case. Different studies examining this subject reported similar results. In a previous study carried out on Türkiye in general, it was expected that, according to the S245 scenario, the proper distribution ranges of *A. bornmuelleriana* would decrease in the future, especially at elevations upper than 1400m, but generally increase at the elevations among 200 and 600m. It is projected that the increase might exceed 66% in 2040 for the altitudes between 200 and 400 m and the rise would be approx. 36% in the year 2100. It is estimated that the maximum losses would be observed at the elevations upper than 1800m and the proper distribution regions at the elevations of 1800-2000m as of the year 2100 might decrease to 38.5% of the current level (Tekin et al., 2022).

It was stressed in earlier research on several species that the effects of the GCC would cause notable changes in the natural distribution ranges of the species, and that these changes would typically take the form of a decline (Koç, 2022). According to estimates, *Tilia tomentosa*'s distribution regions in the southern Anatolian region (Hatay) and the Black Sea region would shrink significantly, *Tilia cordata*'s distribution regions in the western Marmara region would almost completely disappear, and the distribution ranges of *Tilia platypyllos* species in the eastern Anatolian region would noticeably decrease (Canturk & Kulac, 2021). Again, in a previous research carried out on Türkiye, it was reported that distribution areas of *Fraxinus excelsior* L might decrease by 7.58% as of the year 2100 (Varol et al., 2021). It was estimated that the loss of population might be higher than 25% and 30% for *Carpinus betulus* at elevations lower than 1600m and *Carpinus orientalis* at elevations lower than 1000m, respectively (Varol et al., 2022a). It was determined that the ratio of geographical distribution of *P. pinea* to the geographical area of Türkiye is 16.08% at this moment and it might decrease to 2.28% as of the year 2070; the loss of distribution region might reach 85% (Akyol & Örücü, 2020). Similarly, it was estimated that the appropriate distribution region of *Quercus* *libani* in Türkiye, which is 72819 km^2 today, might decline to 63390 km^2 in 2070 (Çoban et al., 2020).

Prior studies on distinct areas throughout the world noted parallel results. It is evaluated that the loss of potential distribution area for *F. Sylvatica* in Europe might be up to 56% (Thurm et al., 2018), that the loss of habitat for different species in the mountainous provinces of Mexico until the year 2060 might approximate 46-77% (Gomez-Pineda et al., 2020), and that *Pinus armandii*'s ideal habitat in Hengduan Mountains in China would slowly disappear (Ning et al., 2021). It is claimed that the distribution region of *Betula pendula*, *Larix decidua*, *Picea abies*, and *Pinus sylvestris* will be reduced in Europe (Dyderski et al., 2018). It is emphasized that the GCC would substantially impact plantation sites and the natural forests (Quinto et al., 2021).

Study outcomes showed that, according to some scenarios, the total proper distribution region of the species would slightly decline between 2040 and 2070 and there might be an increase until the year 2100. It is expected that the appropriate distribution provinces of *Abies* in the year 2100 at elevations between 400 and 600m would parallel the current situation, but there would be approx. 70% in the year for the same altitude range (Tekin et al., 2022). Parallel outcomes were also noted in prior studies on various species. It was noted that *Buxus sempervirens* might have losses up to 6% in the years 2040-2060 and its possible distribution region would increase by 1-4% in comparison to the present situation (Varol et al., 2022b). Thus, a decline and then an expansion in the proper distribution regions suggest that the risk of a potential decrease in these populations is very high. *Abies* having a limited migration mechanism would not adapt to this change and there would be significant population losses. Hence, human support would be needed in order to transport the species to the new proper distribution zones.

Previous studies examining different tree species reported similar results. Hirata et al. (2017) stated that there might be up to 50% expansion in possible distribution regions of *Pinus* until the 2070s, Lopez-Tirado et al. (2021) reported that possible distribution zones of *Cedrus libani* would considerably increase, and Ouyang et al. (2021) emphasized that the most appropriate distribution ranges of *Eucalyptus grandis* would expand towards lower altitudes until 2070s but they should be transported to new proper distribution zones by human hand (Tekin et al., 2022).

It is estimated that the effects of GCC would emerge in a multifaceted way. Because all phenotypical features of organisms are formed under the influence of climate (Sulhan et al., 2022; Karacocuk et al., 2022). It was found that the changes in climatic parameters (i.e., GCC) would directly or indirectly affect the forests by increasing the distribution of fungi and insects (Iverson et al., 2016; Oberle et al., 2018; Toczydlowsk et al., 2020), the forest fires (Kucuk et al., 2018; Bilgili et al., 2021; Ertugrul et al., 2021) and the invasion by foreign species (Tekin et al., 2022) and influencing the water and food availability and precipitation routine (Peñuelas et al., 2018).

Former studies revealed that GCC would impact numerous factors that are related to each other. For instance; the increase in CO_2 concentration would bring a rapid increase in growth (Brundu & Richardson, 2016; Walker et al., 2019) but it will also cause results that are stress factors for several species such as UV-B increase (Ozel et al., 2021), temperature increase and drought (Koç et al., 2022). Since plant expansion is formed under the influences of climatic features (Yigit et al., 2021), these stress factors would negatively affect the plant development (Sevik et al., 2021). Hence, the climatic changes that might occur in the future might cause multifaceted effects, which are related with each other, on the ecosystems. For instance; it was reported that, in Bangladesh, the radial tree growth in *Chukrasia tabularis, Lagerstroemia speciosa,* and *Toona ciliata,* species would decrease by 9-20% because of the effects of GCC and according to Rahman et al. (2018), it could have a negative impact on tropical forests' carbon balance.

In conclusion, GCC is a process that is one of two irreversible issues that the world is currently grappling with and that could have an impact on all living things and ecosystems, either directly or indirectly (Yayla et al., 2022). The plants that are unable of moving effectively will be the group most impacted by this procedure. Since organic life is directly or indirectly dependent upon plants (Yigit et al., 2021; Kurz et al., 2022), it is inevitable for all the organisms on earth to be affected by GCC. In order to lessen the outcome of this process and to minimize the species and population losses, precaution should be taken and plans should be made in accordance with the possible future changes by estimating the changes that will possibly occur in the future.

Conclusions

Study results showed that there would be noteworthy alterations in the distribution regions of *Abies* in Kastamonu. The species seem to be unable to adapt to these changes without human intervention. Thus, it is recommended to make necessary amendments to the forest management plans by considering the study results.

The fact that GCC has different effects on the forests means that species require different silvicultural interventions. The ecological context of the forest and the species' capacity for adaptation should be used to decide which silvicultural actions would be most beneficial for which species. As a result, it is necessary to evaluate and adapt the current management plans and forestry practices in light of the GCC.

This study can be a model for similar studies. To reduce the population and species losses, it is very essential to create new models in parallel with changing climatic and environmental conditions by carrying out parallel studies on different regions and species, define the most faithful scenarios, and unnaturally conduct the migration of species to the regions, which will have the appropriate growth environments in the future.

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Ethics Committee Approval

N/A

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Author Contributions

Conceptualization: N.E., B.A., H.S., Investigation: N.E., B.A.; Material and Methodology: N.E., H.S., B.A.; Supervision: B.A., N.Y.; Visualization: B.A., N.Y.; Writing-Original Draft: N.E., H.S.; Writing-review & Editing: B.A., N.Y.; Other: All authors have read and agreed to the published version of manuscript.

Conflict of Interest

The author has no conflicts of interest to declare.

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