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Altitudinal Migration of Species of Fir (*Abies* spp.) in Adaptation to Climate Change

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Abstract Global climate change is considered an irreversible problem, which might directly or indirectly affect all the organisms and ecosystems on the earth and the world has to struggle with. Plants having no effective movement mechanism are the group that global climate change will affect the most. In order to minimize the species and population losses, it is important to estimate the changes in the available distribution areas of species and to ensure the migration mechanism, which the species will need, by the hand of humans. The present study aims to reveal how potential distribution areas of fir, which is among the significant tree species of Turkey and significant portion of global distribution of which is in Turkey, will change from an altitudinal aspect because of the climate change. The results achieved showed that, because of the effects of global climate change, the suitable distribution areas of *Abies nordmanniana* subsp. *nordmanniana* will significantly decrease especially at high altitudes and that suitable distribution areas of *Abies nordmanniana* subsp. *equi-trojani* will reduce at altitudes higher than 1400 m but increase generally at the altitudes between 200 and 600 m. Moreover, suitable distribution areas of *Abies cilicica* will shift towards higher altitudes.

Keywords Global climate change · *Abies nordmanniana* · *Abies bornmuelleriana* · *Abies cilicica* · Altitudinal shift · Shared socio-economic pathways

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1 Introduction

The changes in the climate because of the growth of global population in the recent century, the raw materials used in the industry advancing in order to meet the needs and demands of this growing population, and the use of fossil fuels in meeting the energy needs became an irreversible problem that the world has to struggle with (Savas et al., 2021; Varol et al., 2022). Climate is defined as the average weather conditions remaining the same in a large area for a very long time. All the phenotypic characteristics of organisms are shaped under the effect of climate and, thus, climate does not affect only humans but also all the organisms and ecosystems on the earth (Adiguzel et al., 2022; Bozdogan Sert et al., 2021; Cetin et al., 2022; Yigit et al., 2021). Hence, the changes in climate parameters directly or indirectly affect all the organisms (Cetin & Jawed, 2022; Cetin et al., 2018; Sevik et al., 2021).

However, the plants constitute the group that will be influenced by climate change the most since these species have a limited migration capacity and cannot adapt to the pace of climate change. Actually, climate has changed many times throughout the history of the world estimated to be approx. 4.6 billion years old. For instance, it was reported that the temperature in Cretaceous period was 10 °C higher than nowadays and the carbon dioxide concentration was 4 to 8 times higher (Serkan, 2019). However, unlike the climate changes throughout the history, the current global climate change will happen in a very short period. Thus, it is estimated that there will be significant changes in suitable habitats of most species and the migration mechanism of plants will fall short of adapting to the pace of this change (Booth, 2017; Dyderski et al., 2018; Varol et al., 2021).

Forest ecosystems are remarkably influenced by climate change and they also influence its pace (Cantürk & Kulaç, 2021; Huang et al., 2020; Zeren Cetin & Sevik, 2020; Zeren Cetin et al., 2020). Forests are the largest terrestrial sinks on earth and they are the most effective and feasible tool to balance the global greenhouse gas emissions.

The higher temperatures and the precipitation regimes changing because of global climate change can result in longer growth seasons, increasing summer drought, and changes in distribution of tree species (Huang et al., 2020). Drought, which is one of the characteristic features of global climate change, can be defined as the inability of meeting the water need (Varol et al., 2019). Drought is the leading dangerous natural disasters and the water deficit arising from the drought causes important stresses in lives of all organisms and even the losses of individuals, species, and population (Yigit et al., 2016). Turkey is located in the semi-arid/semi-humid middle latitude zone and approx. 51 million ha of land in Turkey is considered arid or semi-arid areas (Turan, 2018). Previous studies showed that the arid areas will further increase because of the global climate change (Cetin, 2020).

Hence, measures should be taken in order to prevent the large-scale forest losses because the arid areas will increase in Turkey and plants have a limited migration mechanism. The first step here is to determine the possible influences on forests and to consider these effects during the planning studies. In the present study, the present study aims to reveal how the potential distribution area of several fir species, which are among the most important tree species for Turkey, will change in terms of altitude because of climate change.

2 Material and Method

The analyses were conducted on three species naturally distributed in Turkey: *Abies cilicica*, *Abies nordmanniana* subsp. *nordmanniana* ve *Abies nordmanniana* subsp. *equi-trojani* (considering the transitional structure of morphological differences of *Abies nordmanniana* subsp. *equi-trojani* and *Abies nordmanniana* subsp. *bornmuelleriana*, these two species were combined under the name of *Abies nordmanniana* subsp. *equi-trojani*). Among these species, besides Turkey, *Abies nordmanniana* subsp. *nordmanniana* show distribution in Caucasia (Mataracı & Kandemir, 2018) and *Abies cilicica* in Syria but the largest portion of their habitats in the world is within the borders of Turkey (Akkemik, 2018).

Within the scope of the present study, current and potential distribution areas of these species were modeled using MaxEnt 3.4.1 (Phillips & Dudík, 2008) and map views were prepared using ArcGIS 10.5 (ESRI, 2017) software. Before modeling the species distributions by using the WorldClim data, the distributions fir species were tested using 19 bioclimatic variables (available at https://www.worldclim.org/data/bioclim.html), and environmental variables such as altitude and aspect. In this study, the climate model of CNRM-CM6-1 (Centre National de Recherches Météorologiques model version 6) with approx. 2.5 min spatial resolution (approx. 20 km^2) developed by CNRM (National Center for Meteorological Research)/CERFACS (Centre European de Recherche et de Formation Avancee en Calcul Scientifique) modeling group for CMIP6 was used. The validation of models was performed ROC (Receiver Operating Characteristic) and AUC (Area Under Curve) values and Jackknife test (Varol et al., 2022). Selecting SSPs 585 (8.5 W/m2- the most extreme) and SSPs 245 (4.5 W/m2- an intermediate) scenarios, the distribution areas of fir were estimated for four periods (2040, 2060, 2080, and 2100). These scenarios represent the concentrations of pollutants and greenhouse gases arising from the human activities. The final consensus map for the present plus the expected future explanatory variables downloaded from WorldClim v2.1 project (Hijmans et al., 2005) were the base for building the scenario maps along the twenty-first century.

3 Results

3.1 Change of Suitable Distribution Areas of *Abies nordmanniana subsp. Nordmanniana*

The validation value of training data of ROC curve obtained from modeling was found to be 0.972 (AUC > 0.5) and that of test data to be 0.970 (AUC > 0.5). The model was found to have a high estimation power (Fig. 1). Given the achievement table established in the model using Jackknife option for *Abies nordmanniana* subsp. *nordmanniana*, 3 environmental variables influencing the distribution of species the most in training data were the maximum temperature of warmest month [Bio5], the mean temperature of driest quarter [Bio9], and the maximum temperature of warmest quarter. This finding suggests that the species are significantly affected by the temperature. These three variables are followed by Precipitation Seasonality [Bio15], Precipitation of Driest Quarter [Bio17], and Precipitation of Warmest Quarter [Bio 18].

According to the response curves representing the relationships between environmental factors and existence of species, *Abies nordmanniana* subsp. *nordmanniana* prefers the regions with maximum temperature of warmest month not exceeding 30 °C, mean temperature of driest quarter ranging between 0 and 25 °C, and mean temperature of warmest quarter ranging between 15 and 25 °C (Fig. 1).

It was aimed to analyze and explain the current and potential future condition of suitable distribution areas of *Abies nordmanniana* subsp. *nordmanniana* according to SSPs245 and SSPs585 scenarios as seen in Table 1 and Fig. 2.

Given the values presented in Table, it is projected that, according to SSPs245 and SSPs585 scenarios, suitable distribution areas of *Abies nordmanniana* subsp. *nordmanniana* would decrease especially at low and high altitudes and generally increase at the altitudes between 1000 and 1800 m in the future. The increase will be more remarkable especially between the altitudes of 1200 and 1600 m and the suitable distribution areas in year 2100 might be 25% larger than the current. It is projected that the largest losses would occur at low altitudes and the suitable distribution areas at altitudes lower than 400 m might be decreased to 16.7% of the current area. Considering the general results, no significant change is projected but the increase in year 2100 by the scenario SSPs245 and the continuity of population loss by the scenario SSPs585 should be interpreted that the risk of population loss is high. For this reason, although altitude remains behind many variables in terms of the effect on the species distribution for both *Abies nordmanniana* subsp. *Nordmanniana* and *Abies nordmanniana* subsp. *equi-trojcani*, the spatial changes by altitude are important.

3.2 Change of Suitable Distribution Areas of *Abies nordmanniana subsp. equi-trojani*

Validation value of training data in ROC curve obtained from the modeling conducted within the scope of the present study was found to be 0.972 (AUC > 0.5), whereas that of test data was found to be 0.970 (AUC > 0.5). The model was found to have a high estimation power (Fig. 3). Given the achievement table established in the model using Jackknife option for *Abies nordmanniana* subsp. *equi-trojani*, 3 environmental variables influencing the distribution

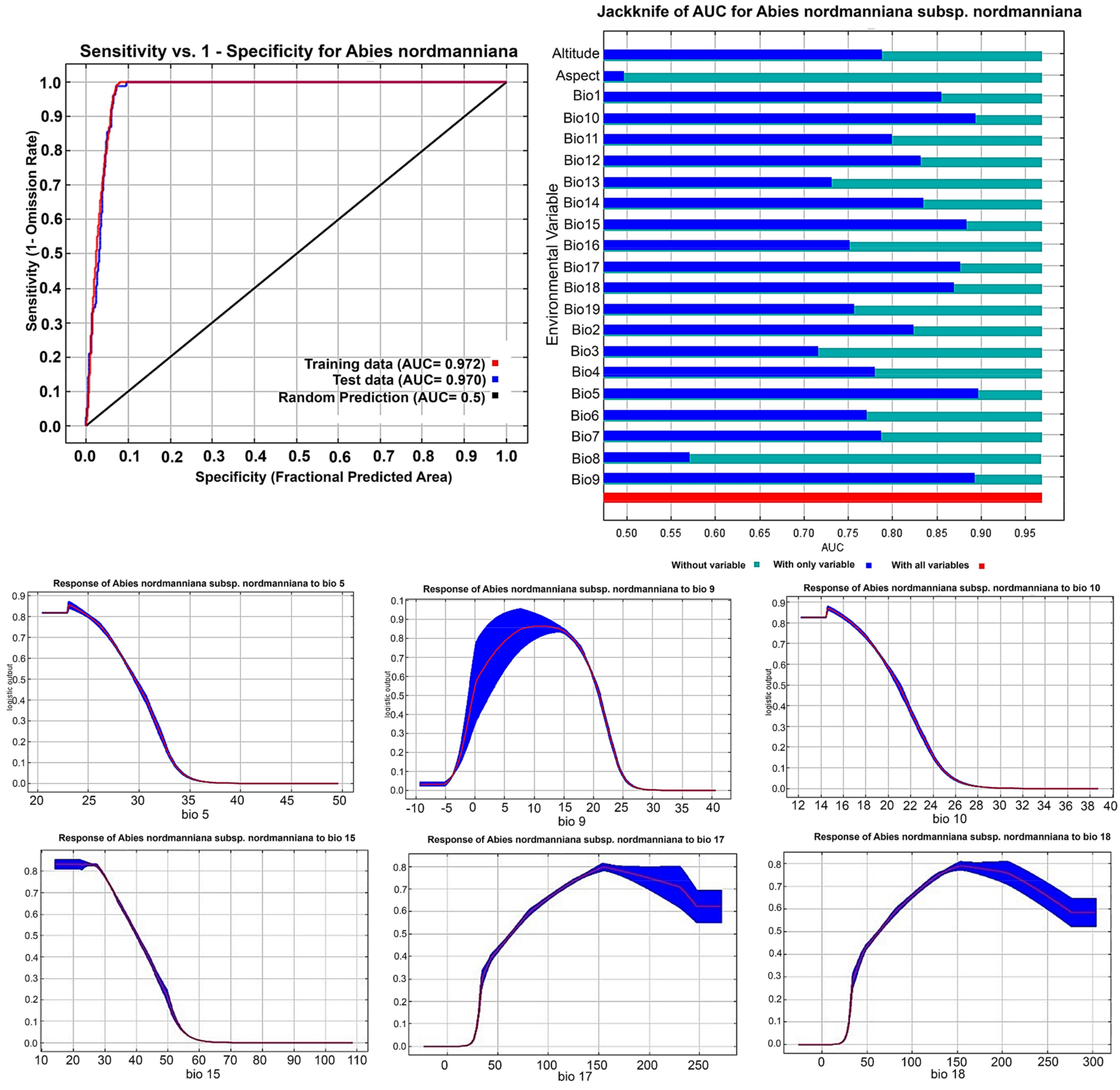

Fig. 1 Effect of environmental factors on the distribution area of *Abies nordmanniana* subsp. *nordmanniana*

of species the most in training data were precipitation of driest month [Bio14], precipitation of driest quarter [Bio17], and precipitation of warmest quarter [Bio18]. It suggests that this species is significantly affected especially by the precipitation in dry and warm season.

According to the response curves representing the relationships between environmental factors and existence of species, the most suitable distribution areas for *Abies nordmanniana* subsp. *equi-trojani* were found to be the areas having > 10 mm of precipitation of driest month, > 45 mm of precipitation of driest quarter, and > 50 mm of precipitation of the warmest quarter (Fig. 3).

The current and potential future suitable distribution areas of *Abies nordmanniana* subsp. *equi-trojani* according to SSPs245 and SSPs585 scenarios are presented in Table 2 and Fig. 4.

Given the values presented in Table, intermittent changes are projected for the suitable distribution

Table 1 Change of suitable distribution areas of *Abies nordmanniana subsp. nordmanniana* by the scenarios

Altitudes	Years	SSPs245 scenarios				SSPs585 scenarios			
	2020	2040	2060	2080	2100	2040	2060	2080	2100
200–400	100	100	100	16,7	50	50	100	16,7	116,7
400–600	100	66,7	100	66,7	66,7	33,3	100	66,7	100
600–800	100	107,7	123,1	92,3	84,6	100	123,1	92,3	107,7
800–1000	100	81,5	92,6	74,1	77,8	103,7	92,6	74,1	85,2
1000–1200	100	87,8	114,6	87,8	109,8	124,4	114,6	87,8	109,8
1200–1400	100	110,4	111,7	101,3	122,1	133,8	111,7	101,3	119,5
1400–1600	100	106,3	114,4	111,7	125,2	126,1	114,4	111,7	125,2
1600–1800	100	98,4	100	103,1	110,2	104,7	100	103,1	98,4
1800–2000	100	94,6	84,6	89,9	96	94,6	84,6	89,9	89,3
2000–2200	100	100	86	91,6	95,3	97,2	86	91,6	84,1
2200–2400	100	97,9	96,8	96,8	90,5	92,6	96,8	96,8	83,2
2400–2600	100	100	100	92,5	85,1	80,6	100	92,5	79,1
2600–2800	100	105,4	105,4	110,8	83,8	91,9	105,4	110,8	81,1
2800–3000	100	97	97	100	90,9	87,9	97	100	93,9
3000–3200	100	95,2	90,5	95,2	90,5	81	90,5	95,2	85,7
3200–3400	100	75	75	100	50	75	75	100	25
General	100	99,13	98,8	96,73	100,76	102,61	98,8	96,73	96,19

areas of *Abies nordmanniana* subsp. *equi-trojani* from the altitude of 1400 to 400 m (increase in 200–600 m, decrease in 600–1000, and increase in 1000–1400 m) for both SSPs245 and SSPs585 scenarios; however, scenario SSPs245 projects a spatial shrinkage at the altitudes higher than 1400 m, whereas SSPs585 predicts it at the altitudes higher than 2000 m. The highest increase projections were more than 66% for the year 2040 at 200–400 m altitudes in scenario SSPs245 and 20% for the year 2060 at 400–600 m altitudes in scenario SSPs585. The maximum spatial shrinkage prediction was 61.5% for SSPs245 and 46.2% for SSPs585. In general, it can be seen that no significant differences are projected in spatial changes of species.

3.3 Changes of Suitable Distribution Areas of *Abies cilicica*

In the ROC curve obtained from the modeling performed within the scope of present study, validation value of training data was found to be 0.928 (AUC > 0.5) and that of test data to be 0.924 (AUC > 0.5). The model was found to have a high estimation power (Fig. 5). Given the achievement table established in the model using Jackknife option for *Abies cilicica*, 3 environmental variables influencing the distribution of species the most in training data were seasonal temperature (standard deviation * 100) [Bio4], seasonal precipitation (variation coefficient) [Bio15], and precipitation of driest quarter [Bio17]. It indicates that this species is affected especially by temperature and precipitation. These three variables are followed by Precipitation Seasonality [Bio14] and Temperature Annual Range (Bio5-Bio6) [Bio7], respectively.

According to the response curves representing the relationships between environmental factors and existence of species, it was determined that the most suitable distribution areas for *Abies cilicica* are the places with seasonal temperature standard deviation of 9–10, seasonal precipitation variation coefficient of 50–70, and precipitation of driest quarter higher than approx. 15 mm (Fig. 5). These values show that the distribution areas of *Abies cilicica* are largely affected by temperature-precipitation relationship.

It was aimed to examine and explain the current and future distribution areas of *Abies cilicica*, the final fir species examined in the present study, by the scenarios of SSPs245 and SSPs585 by separately analyzing from the altitudinal aspect (Table 3 and Fig. 6).

Given Table 3, it is projected according to the scenario SSPs245 that the suitable distribution areas of *Abies cilicica* will tend initially to decrease and then

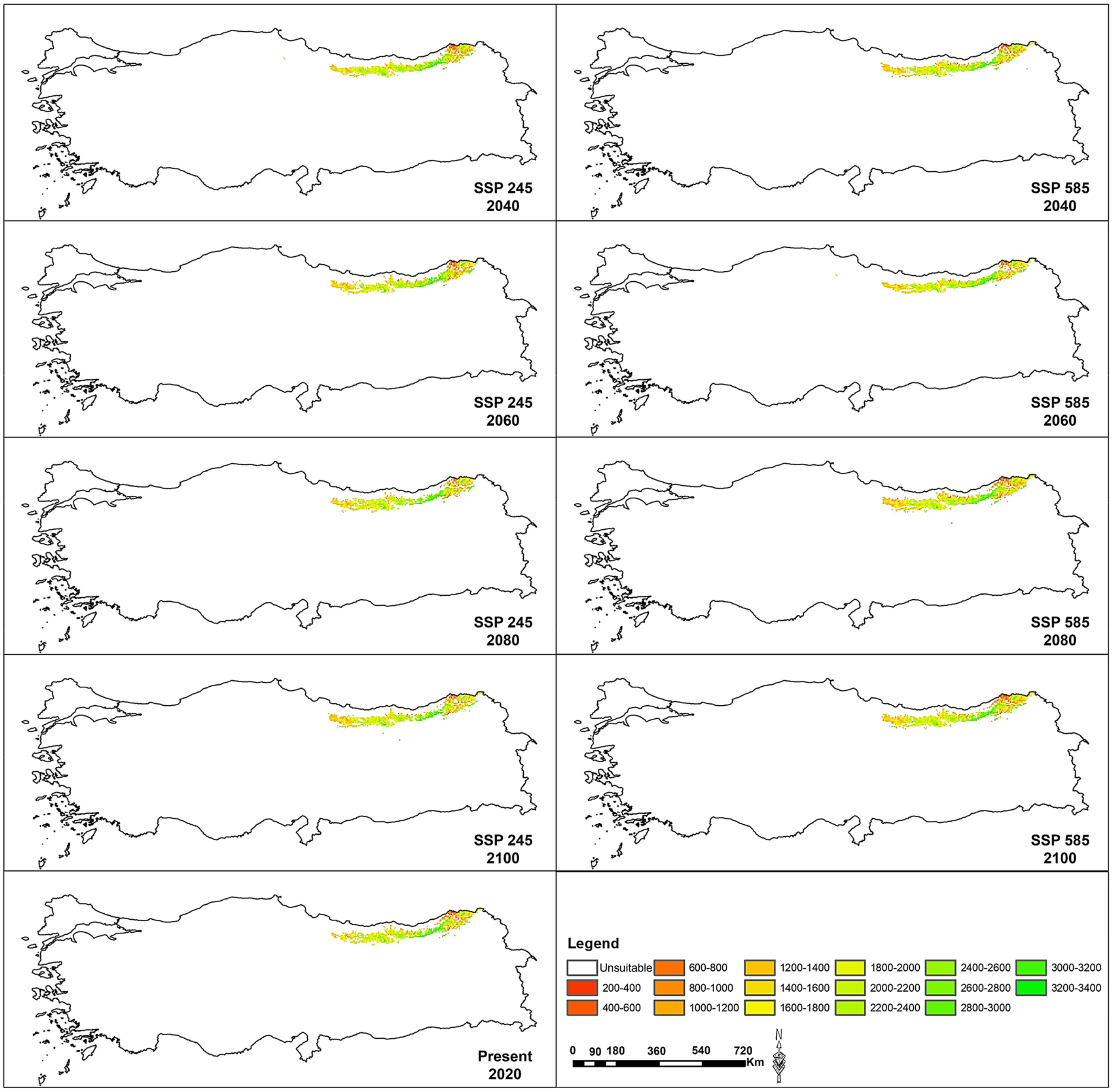

Fig. 2 Current and future distribution areas of *Abies nordmanniana* subsp. *nordmanniana* by SSPs245 and SSPs585 scenarios

expand in the next year. In general, the distribution will significantly increase at high altitudes and the new suitable distribution areas will form at the altitudes higher than 3000 m, which are not currently suitable, since year 2080. It is also attention-grabbing that the suitable distribution areas by the year 2100 will be at very higher altitudes when compared to the current situation.

Examining the suitable distribution areas of *Abies cilicica* by the scenario SSPs585, it can be stated that an upward shift is projected from altitudinal aspect, that the suitable distribution areas will significantly

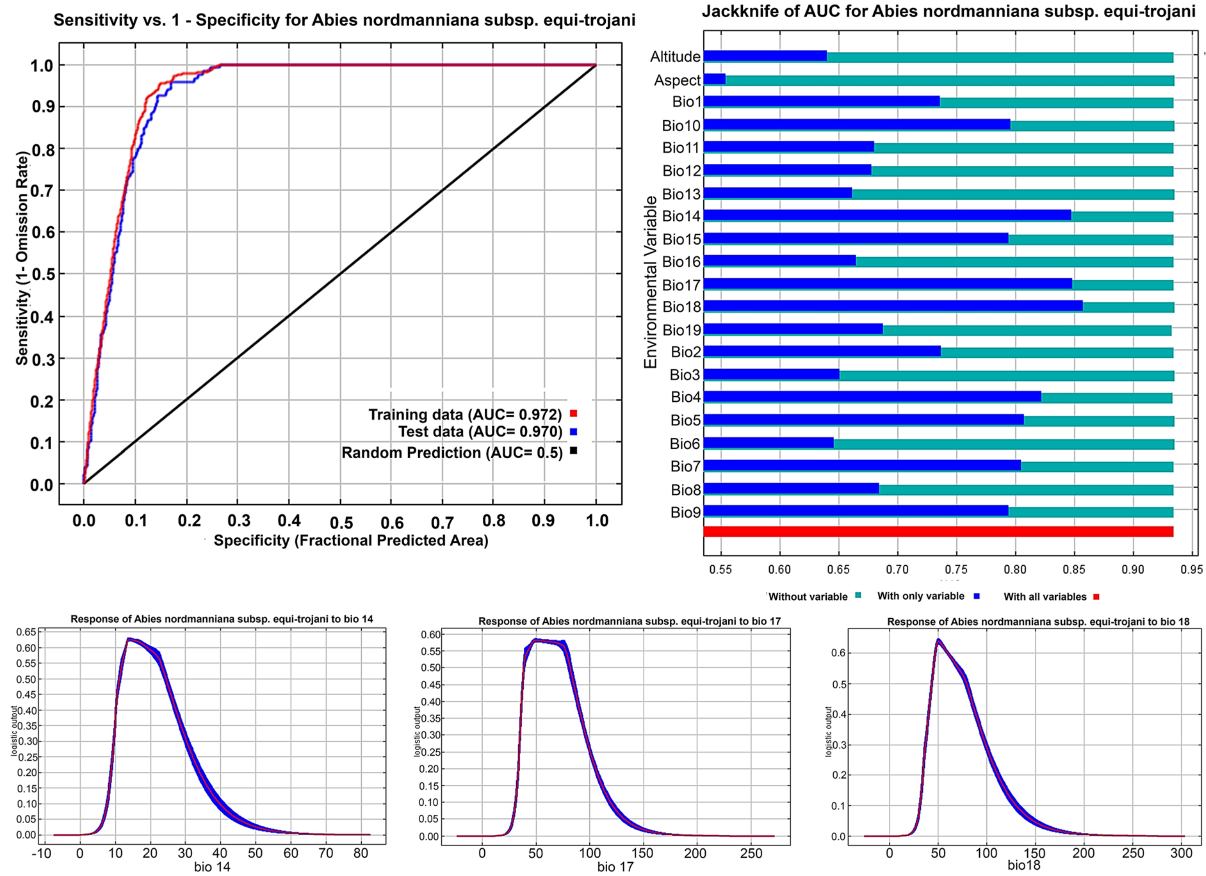

Fig. 3 Effect of environmental factors on distribution area of *Abies nordmanniana* subsp. *equi-trojani*

Table 2 Change of suitable distribution areas of *Abies nordmanniana* subsp. *equi-trojani* by scenarios

		SSPs245 senaryosuna göre				SSPs585 senaryosuna göre			
Rakım	2020	2040	2060	2080	2100	2040	2060	2080	2100
0–200	100	125	66,7	66,7	83,3	100	75	108,3	83,3
200–400	100	166,2	123,4	90,9	136,4	106,5	126	106,5	103,9
400–600	100	114,5	113,5	103,1	118,1	105,2	120,7	97,9	106,2
600–800	100	93,1	92,6	100,6	95,6	89	103,3	86,5	95,6
800–1000	100	92,1	97	102,4	95,7	95,9	106,9	95,7	95,5
1000–1200	100	101,6	100,6	105,3	101,6	104,9	111,3	103,7	102,1
1200–1400	100	101,1	97,8	99,4	100,6	102	104,2	99,7	94,7
1400–1600	100	95	90,5	96,5	81,9	108,5	104	85,9	76,9
1600–1800	100	95,3	96,5	90,6	70,6	114,1	117,6	88,2	87,1
1800–2000	100	61,5	61,5	100	38,5	107,7	153,8	100	53,8
2000–2200	100	75	75	75	75	150	150	75	75
2200–2400	100	100	66,7	66,7	66,7	66,7	100	66,7	66,7
Genel	100	100,43	98,44	100,74	98,4	100,78	109,00	96,10	95,76

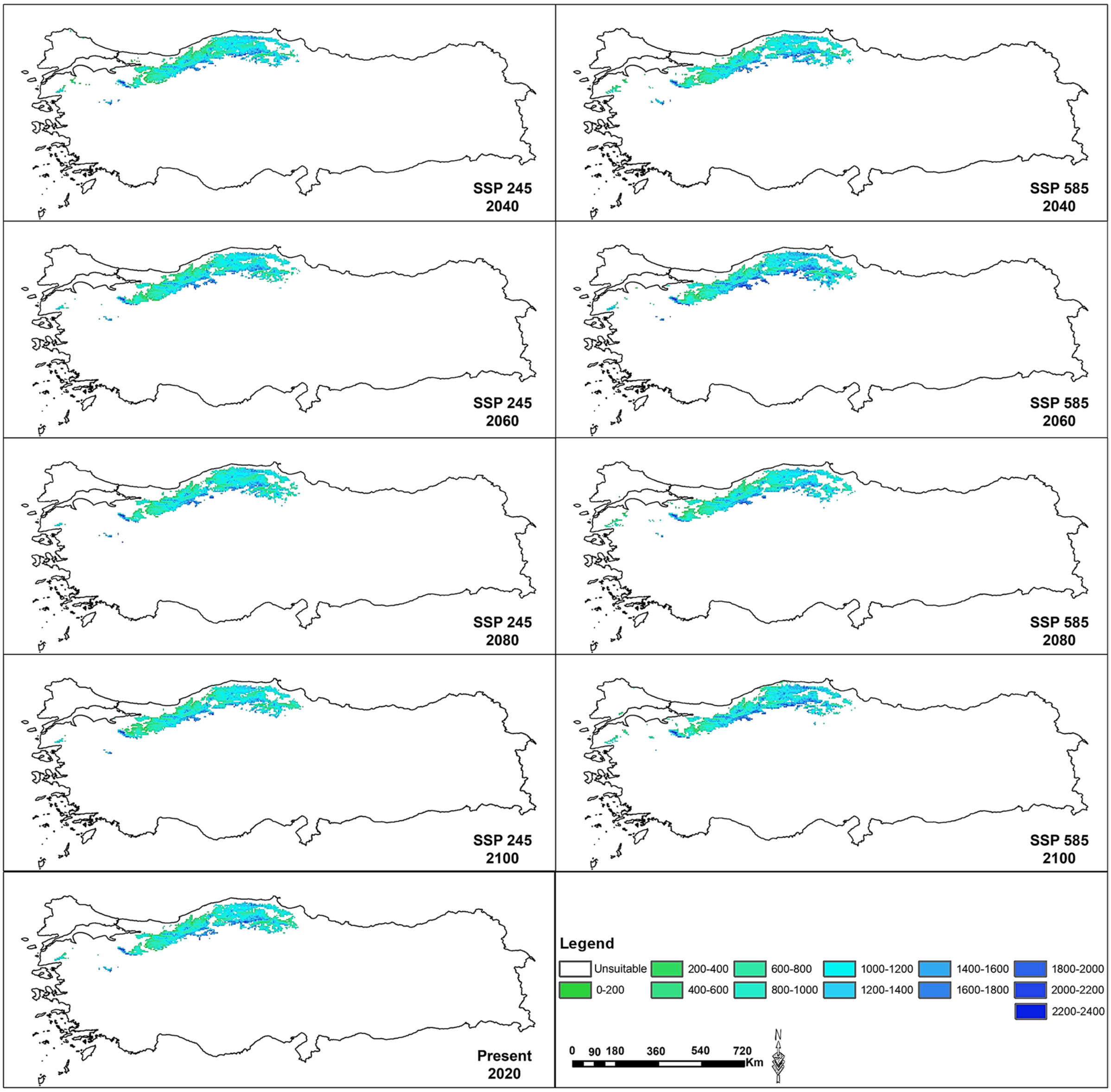

Fig. 4 Future suitable distribution areas of *Abies nordmanniana* subsp. *equi-trojani* by scenarios SSPs245 and SSPs585

expand especially at high altitudes, and that suitable distribution areas will form at the altitudes higher than 3000 m since year 2040. It is estimated that the increase in suitable distribution areas at high altitudes will be higher than 30% and may proximate to 50%.

4 Discussions

The results achieved here suggest that there will be significant changes in potential distribution areas of fir species in Turkey in the future as a result of climate change. According to the results achieved

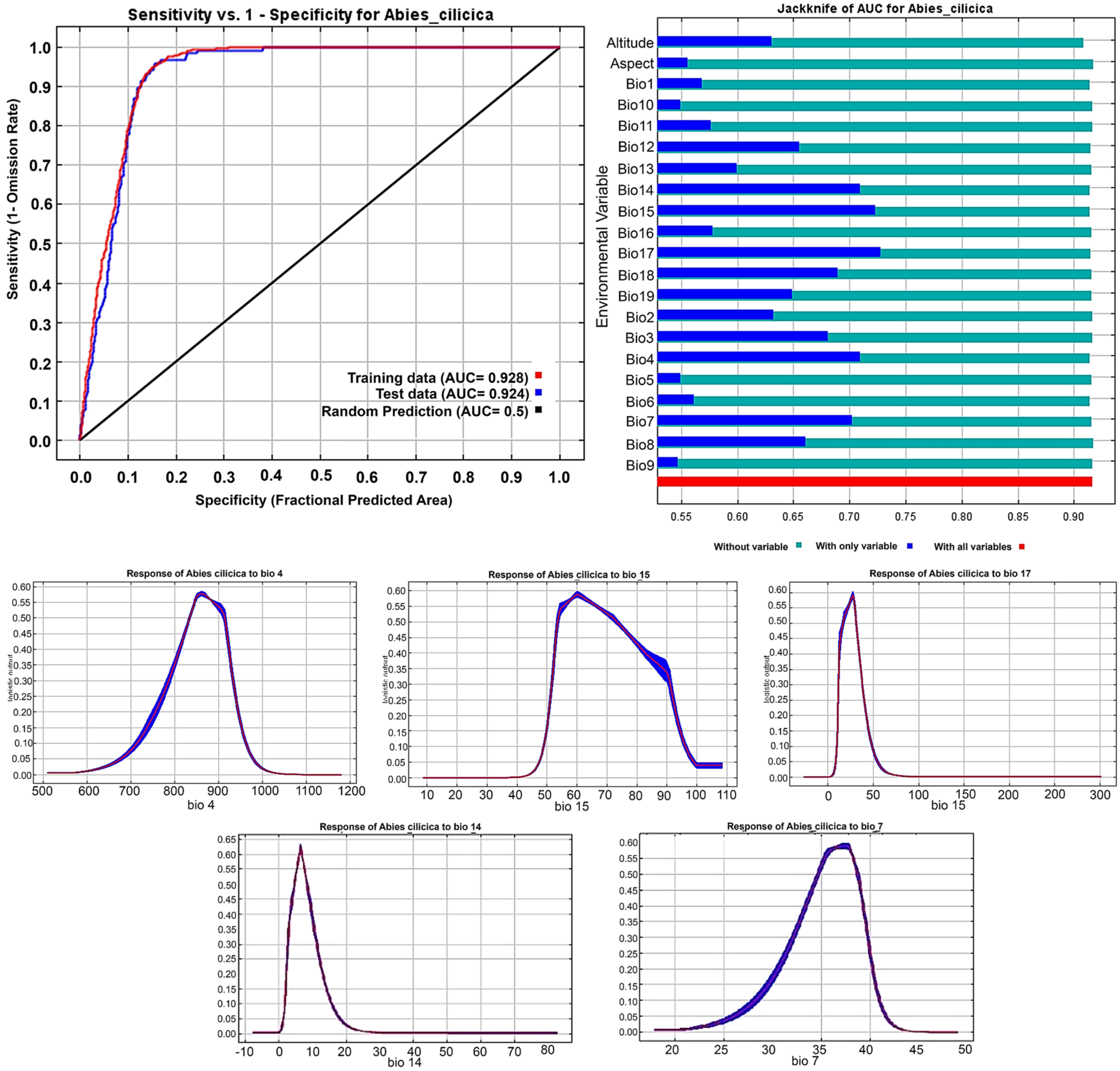

Fig. 5 Effects of environmental factors on distribution area of *Abies cilicica*

considering the scenario SSPs585, the suitable distribution areas of *Abies nordmanniana* will remarkably decrease especially at high altitudes and the suitable distribution areas at the altitudes between 1200 and 1600 m will generally increase. Considering the scenario SSPs245, it is projected that the suitable distribution areas of *Abies nordmanniana* subsp. *equi-trojani* will decrease especially at the altitudes higher than 1400 m but a general increase is predicted at the altitudes between 200 and 600 m. It predicted that the increase at the altitudes of 200–400 m might be higher than 66% in year 2040 and the increase will be approx. 36% by the year 2100. It is expected that the highest losses will occur at the altitudes higher than 1800 m and the suitable distribution areas at the altitudes of 1800–2000 m will reduce to 38.5% of the current level. Considering the suitable distribution areas of *Abies cilicica*, an upward shift is predicted from altitudinal aspect, the suitable distribution areas will expand especially at the high altitudes, and new suitable distribution areas will form at the altitudes higher than 3000 m since year 2040. The increases

Table 3 Change of suitable distribution areas of *A. cilicica* by the scenarios

		SSPs245 senaryosuna göre				SSPs585 senaryosuna göre			
Rakım	2020	2040	2060	2080	2100	2040	2060	2080	2100
0–200	100	200	83,3	166,7	150,0	166,7	166,7	250	83,3
200–400	100	113,8	87,5	128,8	125,0	116,3	122,5	147,5	115
400–600	100	100	85,7	124,2	151,6	103,3	109,9	128,6	149,5
600–800	100	95,9	99,2	100,0	128,7	102,5	96,7	100,8	126,2
800–1000	100	83,0	96,7	89,6	104,9	94	84,6	92,3	113,7
1000–1200	100	88,6	92,7	88,2	103,3	95,1	82,4	97,6	116,7
1200–1400	100	101,3	95,7	86,5	89,2	86,2	84,5	89,5	108,5
1400–1600	100	106,4	102,4	92,3	105,3	94,9	98,9	102,9	131,6
1600–1800	100	106,0	103,6	98,7	117,9	99,7	106,7	109,8	131,6
1800–2000	100	107,6	105,3	104,0	125,8	100	116,4	113,8	142,2
2000–2200	100	108,6	113,8	93,1	111,2	88,8	118,1	99,1	135,3
2200–2400	100	130,5	135,6	111,9	113,6	86,4	130,5	106,8	145,8
2400–2600	100	94,7	168,4	131,6	131,6	78,9	147,4	100	136,8
2600–2800	100	12,5	162,5	212,5	200,0	87,5	225	225	137,5
2800–3000	100		133,3	133,3	75,0	91,7	100	91,7	41,7
3000–3200				xx	xx	xx	xx	xx	xx
3200–3400				xx	xx	xx	xx	xx	xx

in suitable distribution areas at high altitudes are expected to be higher than 30% and the expansion ratio will approximate to 50%.

The studies carried out to date reported that significant changes will occur in natural distribution areas of species because of the effects of global climate change and these changes will generally be in form of shrinkage in the distribution areas (Li et al., 2020; Quinto et al., 2021; Varol et al., 2022). As reported in a study carried out in Turkey, it was determined that the distribution area of *Tilia cordata* due to the global climate change will slightly increase in South Marmara but the distribution areas in West Marmara, which are currently very limited, will disappear. It is projected that the suitable distribution areas of *Tilia tomentosa* in Southern Anatolia (Hatay) and Black Sea regions will remarkably shrink and potential distribution areas in Thrace will increase. On the other hand, it is estimated that there will be significant decreases in distribution areas of *Tilia platypyllos* in Eastern Anatolia and Black Sea regions but the suitable distribution areas in Thrace and Çanakkale will increase. According to the results achieved, it can be stated that there will be changes in all three linden species and this change might result in 15% loss in *Tilia platypyllos* and it equals approx. 10,000 km^2 of distribution area (Cantürk & Kulaç, 2021). In a study carried out on *Fraxinus excelsior*, it was estimated using the SSPs 245 model that the potential distribution area, which is currently 165,910.3 ha, will be 154,473 ha by the year 2040, 154,423 ha by the year 2060, 152,210 ha by the year 2080, and 153,329 ha by the year 2100. Using the model SSPs 585, the potential distribution area is projected to be 153,085 ha by the year 2040, 154,068 ha by the year 2060, 152,612 ha by the year 2080, 155,819 ha by the year 2100 (Varol et al., 2021).

Similar results were achieved in studies carried out on different species in different regions of the world and it was determined that significant losses may occur in distribution areas of species. It was reported that *Fagus sylvatica* L. and *Picea abies* (L.) Karst. populations will decrease in Europe because of the effects of climate change (Eurostat, 2018; Hanewinkel et al., 2013; Ruiz-Labourdette et al., 2013) and the loss of potential distribution area of *Fagus sylvatica* might reach 56% (Thurm et al., 2018). Gómez-Pineda et al. (2020) reported that in Mexico, the habitat loss of different species in mountainous areas until 2060 might reach 46–77% and the species to be affected the most will be *Pinus hartwegii* and *Abies religiosa*.

Ning et al. (2021) estimated that the suitable habitat of *Pinus armandii* in Hengduan Mountains of China will slowly disappear. Taylor Aiken et al.

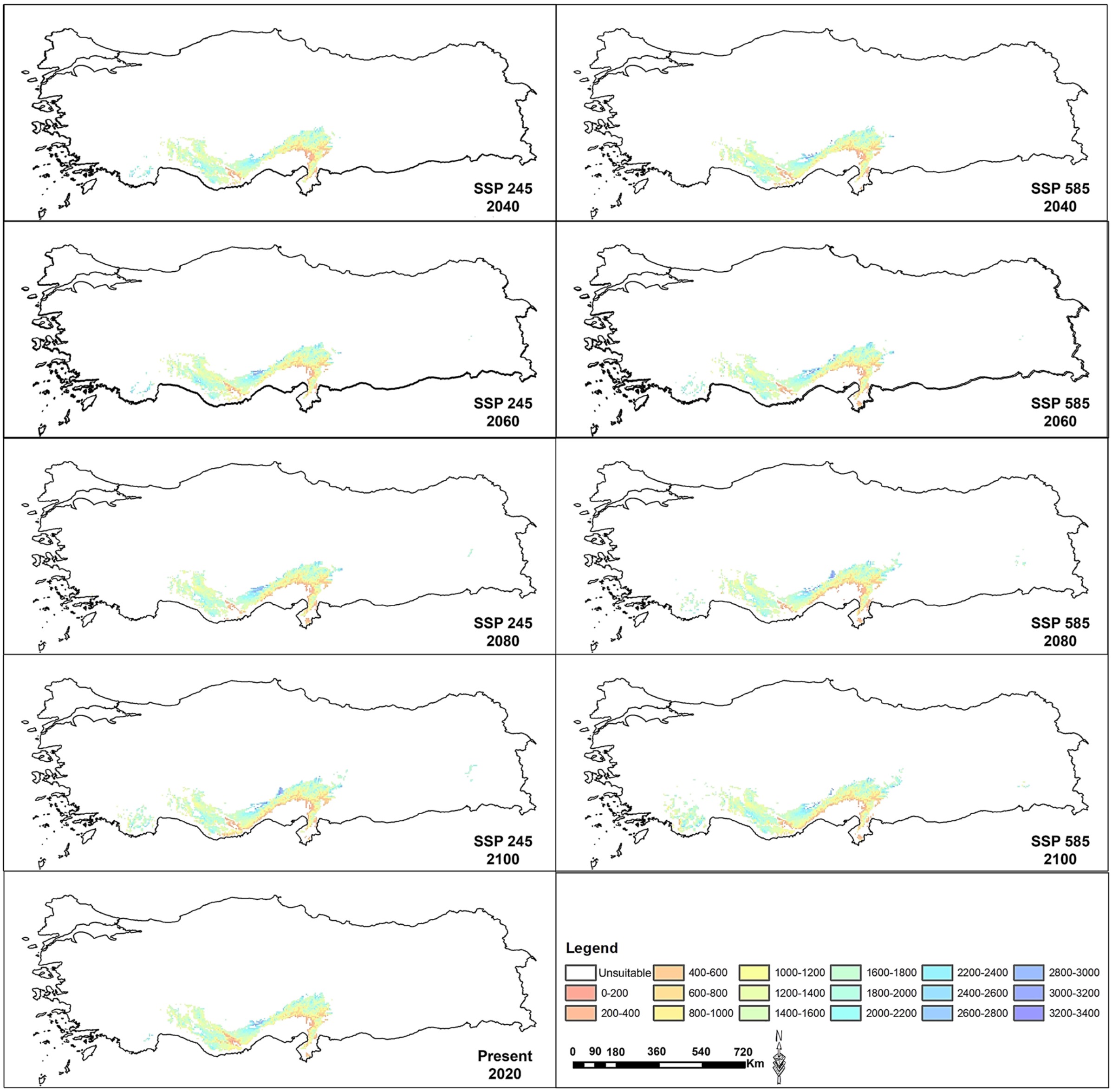

Fig. 6 Current and future distribution areas of *Abies cilicica* by the scenarios SSPs245 and SSPs585

(2017) determined that the main tree species in forests in Acadian region of Canada have difficulties in continuing their existence and, thus, they will start losing their "boreal" character. Li et al. (2020) emphasized that, according to different RCP scenarios, approx. 23–57% of trees in China will become defenseless or under threat in terms of universal migration until year 2070 and that the species originating from dry and monsoon regions will experience more losses when compared to those originating from Alpine regions under the effect of climate change. It was determined that, in this process, some of the species are under the risk of extinction and, even under the most conservative conditions (RCP2.6), 18% of trees will be defenseless or under threat (Li et al., 2020). There also are studies reporting that global climate change will remarkably affect not only natural forests but also the plantation areas (Quinto et al., 2021).

The results showed that there will be important decreases in suitable distribution areas for fir species at almost all altitude ranges. For instance, the suitable distribution areas in 2100 at the altitudes of 400–600 m will be similar to the current level but approx. 70% loss is predicted for the same altitude level for the year 2040. Hence, the possibility of an initial decrease and then an increase in suitable distribution areas should be interpreted as a very high risk of loss in these populations because establishing the new suitable distribution areas might be difficult for the species due to various factors such as competition with current species and human support would be needed.

Similar results were also reported in studies carried out on different tree species and it was recommended to transfer the species to new suitable distribution areas manually. Hirata et al. (2017) reported that, according to RCP 8.5 scenario, there will be approx. 50% increase in potential distribution areas of *Pinus* species as of the years of 2070s. Moreover, it was also stated that the potential distribution areas of *Cedrus libani* would increase remarkably (López-Tirado et al., 2021). Using the future climate scenarios, Ouyang et al. (2022) estimated that the most suitable distribution areas for *Eucalyptus grandis* would expand until 2070s, that suitable areas in Sichuan basin might expand towards lower altitudes in east, and that the suitable areas in hilly terrains in southeastern China might shift towards the areas with higher solar radiation and lower seasonal temperature changes.

Gómez-Pineda et al. (2020) emphasized that, in case the assisted-migration management system is not integrated into forestry, climate change might cause significant losses in current *Abies religiosa* forests in Canada (Gómez-Pineda et al., 2021). Hence, in order to minimize the harmful effects of global climate change on the forests, comprehensive studies should be carried out and the plants, which do not have any effective migration mechanism to adapt to the global climate change, should be provided the migration mechanism, which they will need during this process, by the hand of man.

Besides that, temperature increasing because of global climate change also intensifies the pest damages and increases the frequency of forest fires (Ertugrul et al., 2019, 2021). Such conditions jeopardizing the continuity of ecosystem cause various reactions in trees such as adapting to climate, local adaptation, migration, and loss of vitality (Reed et al., 2011; Torres-Dowdall et al., 2012; Benito Garzón et al., 2019). Moreover, the change in climate has also negative effects such as invasion by stranger species and positive effects such as increasing wood production because of increasing CO_2 concentration (Brundu & Richardson, 2016; Reeves et al., 2014; Walker et al., 2019). The effects of global climate change will be influenced by many interacting factors. It was reported in previous studies that this process would directly affect the tree species, as well as spread of insects and fungi (Iverson et al., 2016; Oberle et al., 2018; Toczydlowski et al., 2020), availability of water and nutrient, precipitation regime (Peñuelas et al., 2018), and forest fires (Ertugrul et al., 2021; Varol & Ertugrul, 2015).

It was emphasized that global climate change would affect the species not only from a spatial aspect but also in terms of health, quality, and development (Daniel et al., 2017) because global climate change will cause various results, which yield important stress factors in many species such as an increase in UV-B, increasing temperature, and drought (Ozel et al., 2021a, 2021b; Varol et al., 2022). Plant development is shaped under the effects of climatic factors (Yigit et al., 2021) and it is significantly affected by these stress factors (Sevik & Erturk, 2015). In a previous study carried out in Bangladesh on *Chukrasia tabularis*, *Toona ciliata*, and *Lagerstroemia speciosa*, it was found that the radial tree growth will reduce by 9–20% in all three species under the effects of global climate change and it might have severe effects on the carbon balance of tropical forests (Rahman et al., 2018).

It was reported that global climate change would cause increases in average temperature and it might cause an increase in the total forest area (Popp et al., 2017; Rogelj et al., 2018). However, it is estimated that there would be important changes in distribution areas of several plants in this process; it is projected that there will be significant habitat losses and distribution area shrinkages for some species (Varol et al., 2021), whereas there might be expansions in distribution areas of some others (Dyderski et al., 2018). For instance, it is estimated for Europe that the distribution areas of *Abies alba*, *Fagus sylvatica*, *Fraxinus excelsior*, *Quercus robur*, and *Quercus petraea* would increase, distribution areas of *Betula pendula*, *Larix* *decidua*, *Picea abies*, and *Pinus sylvestris* would decrease (Dyderski et al., 2018). It was reported that the population losses might go beyond 25% for *Carpinus betulus* at the altitudes lower than 1600 m and 30% for *Carpinus orientalis* at the altitudes lower than 1000 m, that there would be increases in suitable distribution areas at high altitudes and this increase may exceed 100% for *Carpinus orientalis* at the altitudes of 1000–2000 m (Varol et al., 2022). In China, it is projected that mixed and broad-leaved non-evergreen forests might expand towards the north (Yu et al., 2006).

The fact that global climate change process has different effects on different species means that the silvicultural materials, which species need, would differ. Which silvicultural interventions would yield the highest benefit for which species will vary depending on the ecological context of forest and the adaptation ability of species (Webster et al., 2018). Hence, the current forest management plans and silvicultural practices should be reviewed and redesigned considering the effects of global climate change (Vilà-Cabrera et al., 2018).

Turkey is very sensitive to climate change and also is among the "*countries under risk*" (UNDP, 2019). In projections regarding the future climate, it is predicted that the temperature in Turkey would increase throughout the country until the year 2100 but the increase in Aegean region might reach 6 °C (Dalfes et al., 2007). In previous studies, it was determined that the climate changes would differ between the regions of Turkey and especially the arid areas will increase (Cetin, 2020). Since climate change will occur at a pace that plants will have difficulty in adapting to, it is required to pre-determine the changes in order to take measures against species and population losses, especially for the species having limited distribution area.

5 Conclusions

Global climate change is a process, which will directly or indirectly affect all the organisms and ecosystems on the earth and is defined as irreversible. It was emphasized that the group that will be influenced by this process the most is the plants, which have no effective migration capability. Especially the species having a limited distribution area are under significant risk. In order to reduce the effect of this process on the organisms and minimize the species and population losses, future changes should be estimated as of today. Then, measures should be taken and plans should be made in this parallel.

The results achieved revealed that there would be significant changes in the distribution areas of fir species in Turkey and there might especially be altitudinal changes. It was determined that the species requiring an effective migration mechanism should be provided with a human-supported migration mechanism. For this purpose, it is recommended to consider the results of this study in forest management plans and to make the necessary modifications. Moreover, carrying out similar studies on other species, establishing new models for changing climate and environmental conditions, designing realistic scenarios, and artificially migrating the species to the areas, which will meet the suitable growth conditions in the future, by the hand of man might significantly decrease the species and population losses.

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