



The Effects of Climate Change Scenarios on *Carpinus betulus* and *Carpinus orientalis* in Europe

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Received: 14 November 2021 / Accepted: 21 January 2022 / Published online: 29 January 2022
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Abstract Occurring mainly as a result of human activities, global climate change is considered the most important problem of the current years. It was stated that global climate change will directly or indirectly influence the entire organic life on earth and that the group which will be affected by this process at most will be the plants, which have a limited migration mechanism, and especially the forests. In order to protect from the destructive effects of this process, it is important to determine the possible effects of climate change and to take measures addressing the future effects. Within the scope of this study, it was aimed to determine how the appropriate distribution areas of *Carpinus betulus* and *Carpinus orientalis* species widely spreading the European continent will be affected by the process of global climate change. In this parallel, by employing 15 bioclimatic variables by the RCP (Representative

Concentration Pathway) 4.5 and RCP 8.5 global climate scenarios from the WorldClim database, Maximum Entropy software was used in modeling the years 2040, 2060, 2080, and 2100 and the changes in appropriate distribution areas of these species were calculated in units of area and percentage. As a result of the study, it was determined that the population loss might exceed beyond 25% at the altitudes below 1600 m for *Carpinus betulus* and beyond 30% at the altitudes below 1000 m for *Carpinus orientalis*, that the appropriate distribution areas will expand at higher altitudes, and that this increase may be more than 100% at the altitudes of 1000–2000 m for *Carpinus orientalis*. However, it is projected that the species will not be able to migrate to the newly emerging appropriate distribution areas fast enough and, moreover, significant population losses may occur for this reason.

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Keywords *Carpinus betulus* · *Carpinus orientalis* · Climate change · RCP scenarios

1 Introduction

The changes which have occurred in the world during the last century created a process permanently influencing almost the entire organic life on the earth. Significantly increasing in the last century and peaked in the last 30–40 years, the advancements in industry and technology also increased the need for energy and raw material and the activities conducted in order to meet these needs resulted in the extraction of underground mineral sources and the use of these materials in industry as raw material (Adiguzel et al., 2020, 2021; bozdogan Sert et al., 2021; Cesur et al., 2021; Cetin, 2019, 2020a, 2020b; Gungor et al., 2021; Koc, 2021; Zeren Cetin & Sevik, 2020; Zeren Cetin et al., 2020). Intense use of raw mineral deposits increased the pollutants in the air, water, and soil (Adiguzel et al., 2020, 2021; Bayraktar, 2021; bozdogan Sert et al., 2021; Cetin, 2019, 2020a, 2020b; Gungor et al., 2021; Sevik et al., 2019; Turkyilmaz et al., 2020; Ucun Ozel et al., 2020; Zeren Cetin & Sevik, 2020; Zeren Cetin et al., 2020) and the use of fossil fuels in order to meet the need of energy increased the CO₂ concentration in the air (Cetin et al., 2019).

These abnormal changes, which occur in the atmosphere, resulted in global-scale climate changes. These changes, which are called global climate change, are defined as the most important problem that the world must struggle with (Cetin, 2020a, 2020b) because the climate directly and indirectly influences the entire organic life in the world (Ozkazanc et al., 2019; Sevik et al., 2021).

The group of organisms that will be affected by the global climate change at most was emphasized to be the plants, which do not have an effective movement and migration mechanism, and especially the forests that are distributed over large areas (Varol et al., 2021). It was stated that global climate change is irreversible but it can be slowed down via the measures to be taken. In this process, various scenarios are developed in order to determine the future changes and it is aimed to determine the possible measures addressing the potential changes (Akyol et al., 2020; Mechergui et al., 2021). Determining how the forest trees will be affected by this process is very important

in determining the measures to be taken, as well as the preservation strategies.

In this study, it was aimed to determine how the distribution areas of *Carpinus orientalis* and *Carpinus betulus*, which are the two most widely distributed varieties of *Carpinus* species that is one of the most important tree species of Europe, will be affected by the possible global climate changes. For this purpose, by using 15 different bioclimatic variables by the RCP (Representative Concentration Pathway) 4.5 and RCP 8.5 global climate scenarios from the WorldClim database, the years 2040, 2060, 2080, and 2100 were modeled using Maximum Entropy software.

2 Materials and Methods

In the present study, the database (Euforgen, 2020) of *Carpinus betulus* and *Carpinus orientalis*, which have wide distribution areas throughout Europe including Anatolia, Iran, Georgia, Armenia, and Russia, was used in determining the potential changes in the distribution areas of *Carpinus betulus* and *Carpinus orientalis* until the year 2100. MaxEnt 3.4.1 (Phillips & Dudík, 2008) using the principle of maximum entropy in estimating a series of functions relating the environmental variables and habitat suitability was used in modeling the current and potential distribution areas of these varieties and approaching the ecologic and potential geographical distribution of these varieties, whereas ArcGIS 10.5 (ESRI, 2017) was used for map presentations. ROC (receiver operating curve analysis) and AUC (receiver operating characteristic area under the curve) methods and Jackknife test were used in determining the performance of variety distribution models and quality of MaxEnt models. All the bioclimatic variables and the distributions of varieties examined here were tested and bioclimatic variables were used for this purpose. In the present study, the representation of stratocumulus by the atmospheric component of the Centre National de Recherches Météorologiques model version 6 (CNRM-CM6-1) with 2.5 min spatial resolution was used as climate model. The final consensus map for the present plus the expected future explanatory variables downloaded from WorldClim v2.1 project (Hijmans et al., 2005) was the base for building the scenario maps along the twenty-first century — reclassified in ten intervals

by means of ArcGIS 10.5. Then, two SSPs (Shared Socioeconomic Pathways) were run for each of two time zones. They were selected as the most extreme (SSPs 585–8.5 W/m²) and the intermediate (SSPs 245–4.5 W/m²) and the scenarios ending in year 2100 were employed (Varol et al., 2021).

3 Results

3.1 Changes in *Carpinus betulus*

The validation value of the training data in ROC curve obtained from the models within the scope of this study was found to be 0.922 (Fig. 1). These findings show that the model has a high level of estimation power. According to the achievement table established for *Carpinus betulus* by using Jackknife, the three environmental individual variables affecting the variety’s distribution in the training data at most

were found to be annual mean temperature [Bio1], min temperature of coldest month [Bio6], and mean temperature of coldest quarter [Bio11]. This finding suggests that the variety was significantly affected especially by the temperature regime.

According to the response curves representing the relationships between environmental variables and presence of varieties (Abolmaali et al., 2018; Varol et al., 2021), it can be stated that *Carpinus betulus* distributes in the environments with annual mean temperature not exceeding beyond 15 °C and min temperature of coldest month and mean temperature of coldest quarter exceeding beyond –5 °C (Fig. 1). The current potential distribution areas of *Carpinus betulus* and the appropriate distribution scenarios according to SSP245 and SSP585 for the future (2040, 2060, 2080, and 2100) are presented in Fig. 2.

Given the altitude changes of the current and future potential distribution areas of *Carpinus betulus* in Europe, it can be seen that the potential distribution

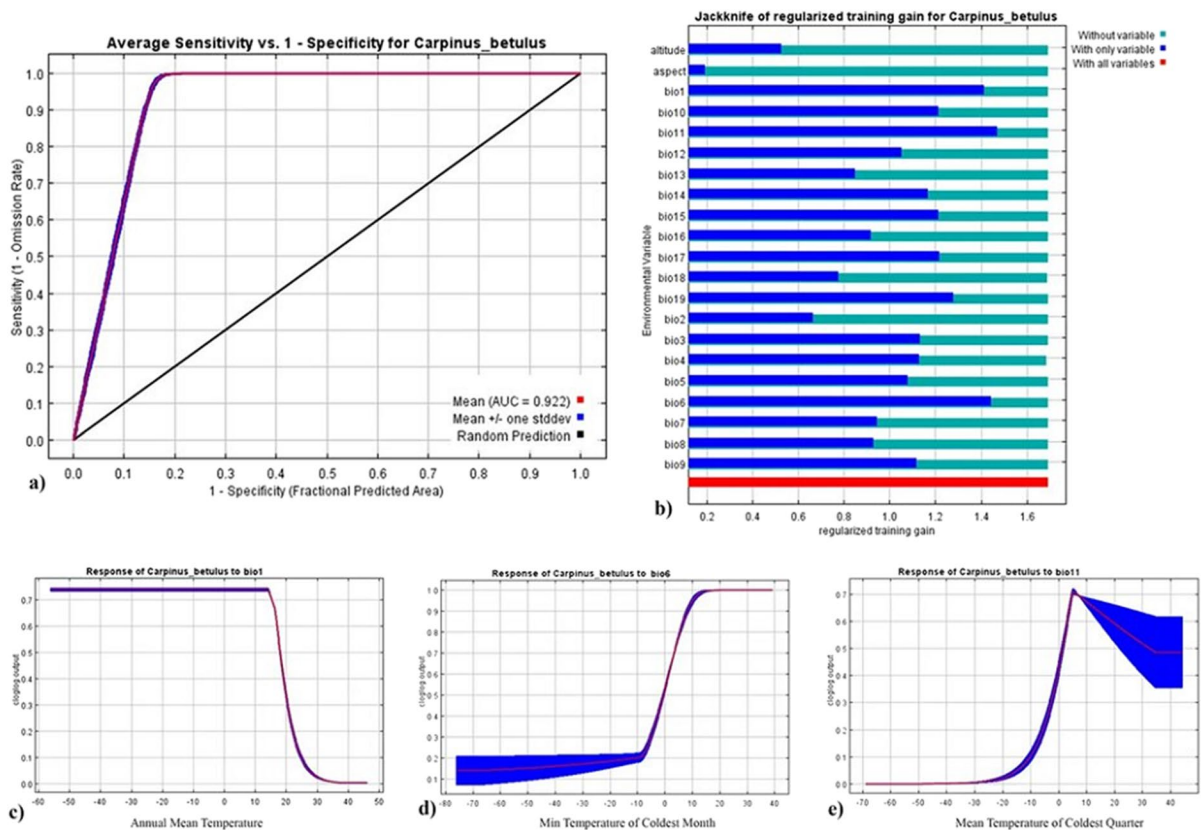


Fig. 1 ROC curve-AUC value of the model (a), impact of environmental variables (b), and response curves (c, d, e)

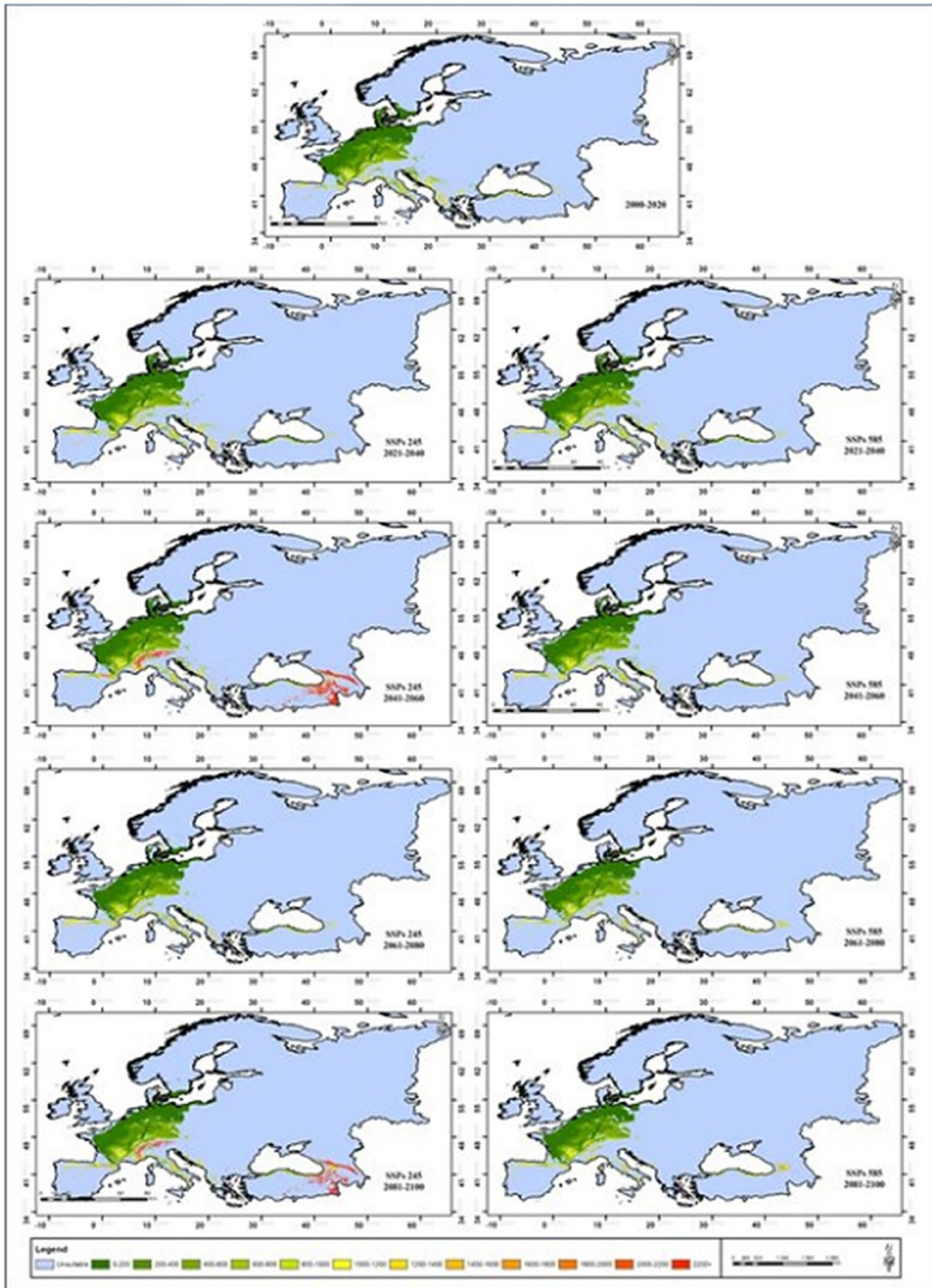


Fig. 2 Altitude changes in the potential distribution areas of *Carpinus betulus* in Europe

areas throughout Europe generally shifted to the higher altitudes. It was determined that the most significant changes will occur in northern Italy, that there will be significant losses in distribution areas in Georgia and Slovenia, and that appropriate distribution areas will form at high altitudes in eastern Turkey and in Azerbaijan and Georgia. The numerical results regarding the spatial changes in *Carpinus betulus* by the global climate change and by the altitude are presented in Table 1.

Given the values presented in Table 1, it can be seen that the most appropriate distribution areas of *Carpinus betulus* in Europe at this moment range between the altitudes of 0 and 200 m and that the

appropriate distribution areas decrease as the altitude increases, such that almost half (46.85%) of appropriate distribution areas consists of heights below 200 m. However, it is estimated that, depending on the global climate change, the appropriate distribution areas of *C. betulus* at low altitudes will gradually decrease and, as of the year 2100, the appropriate distribution areas below the altitude of 200 m, which currently is approx. 498,254.14 km², will decrease by 9.50% according to SSP 245 and by 19.80% according to SSP 585 (Table 2). Similarly, it is projected that the distribution areas of *C. betulus* at the altitudes higher than 1600 m will significantly decrease; it is estimated according to SSP

Table 1 The spatial (km²) change in *Carpinus betulus* distribution areas by the global climate change and altitude

Altitude (m)	2020	SSPs 245				SSPs 585			
		2040	2060	2080	2100	2040	2060	2080	2100
0–200	498,254.14	482,983.96	463,625.39	443,879.91	451,076.50	473,246.64	454,081.53	409,251.17	399,810.48
200–400	207,230.80	204,058.11	197,519.28	197,235.54	200,962.80	204,457.92	200,446.92	189,987.36	190,038.95
400–600	155,216.75	153,772.27	146,034	144,254.2	143,751.21	153,320.87	146,743.34	134,529.78	130,067.38
600–800	79,188.27	78,801.36	72,120.65	71,204.96	69,657.30	79,226.96	71,965.89	60,925.96	58,875.32
800–1000	51,511.07	50,608.27	46,532.78	46,842.31	43,979.15	50,904.9	45,526.81	37,659.57	39,439.37
1000–1200	34,486.88	35,879.77	32,023.53	32,823.15	30,205.04	34,203.14	30,978.86	25,910.3	27,341.88
1200–1400	19,216.70	21,306.03	17,643.25	18,997.45	16,792.04	18,649.22	16,804.94	13,541.97	15,347.56
1400–1600	11,117.31	12,793.94	9827.6	10,846.47	9582.55	10,872.27	9247.23	7673.78	9260.13
1600–1800	5068.57	6435.66	4797.73	5262.02	4810.62	4900.9	4294.74	3778.85	5468.38
1800–2000	1779.80	2502.04	1573.45	1779.8	1599.24	1625.04	1405.79	1122.05	2256.99
2000–2200	412.71	619.06	335.32	425.6	374.02	348.22	283.74	257.94	735.14
2200+	25.79	116.07	51.59	51.59	25.79	25.79	38.69	25.79	322.43

Table 2 Relative changes in *Carpinus betulus* distribution areas depending on the global climate change and by the altitude

Altitude (m)	2020	SSPs 245				SSPs 585			
		2040	2060	2080	2100	2040	2060	2080	2100
0–200	100	96.9	93.0	89.1	90.5	95.0	91.1	82.1	80.2
200–400	100	98.5	95.3	95.2	97.0	98.7	96.7	91.7	91.7
400–600	100	99.1	94.1	92.9	92.6	98.8	94.5	86.7	83.8
600–800	100	99.5	91.1	89.9	88.0	100.0	90.9	76.9	74.3
800–1000	100	98.2	90.3	90.9	85.4	98.8	88.4	73.1	76.6
1000–1200	100	104.0	92.9	95.2	87.6	99.2	89.8	75.1	79.3
1200–1400	100	110.9	91.8	98.9	87.4	97.0	87.4	70.5	79.9
1400–1600	100	115.1	88.4	97.6	86.2	97.8	83.2	69.0	83.3
1600–1800	100	127.0	94.7	103.8	94.9	96.7	84.7	74.6	107.9
1800–2000	100	140.6	88.4	100	89.9	91.3	79.0	63.0	126.8
2000–2200	100	150.0	81.2	103.1	90.6	84.4	68.8	62.5	178.1
2200+	100	450.1	200.0	200.0	100.0	100.0	150.0	100.0	1250.2

585 that, as of the year 2100, the appropriate distribution areas will increase at the altitudes higher than 1600 m. Taking the current appropriate distribution areas of *C. betulus* as 100%, the changes by the altitude according to SSP245 and SSP585 are presented in Table 2.

Given the rational change in *C. betulus* by the altitude, it is estimated that, according to SSP 245 scenario, the gradually rising and reaching 50% increases will occur at the altitudes higher than 1000 m until year 2040 (since there are very limited appropriate distribution areas at the altitudes higher than 2200 m, it is considered to not consider them) but then there will be decreases. It is estimated for the year 2100 that there will be significant decreases at all the altitudes according to the SSP245 scenario and at the altitudes below 1600 m according to the SSP585 scenario and that this decrease may exceed beyond 25% (25.7% at the altitudes between 600 and 800 m).

3.2 Changes in *Carpinus orientalis*

The validation value of the training data in ROC curve obtained as a result of the modeling for *Carpinus orientalis* was found to be 0.995 (Fig. 3). These findings suggest that the model has a high level of estimation power. According to the achievement table established using the Jackknife test for *Carpinus orientalis*, it was determined that three variables individually influencing the distribution of species at most were annual mean temperature [Bio1], min temperature of coldest month [Bio6], and mean temperature of coldest quarter [Bio11]. It suggests that this variety is significantly affected especially by the temperature regime.

According to the response curves, it can be seen that *Carpinus orientalis* might show distribution even at very low temperatures such as annual mean temperature between -5 and 15 °C and mean temperature of coldest quarter between 2 and 8 °C and even

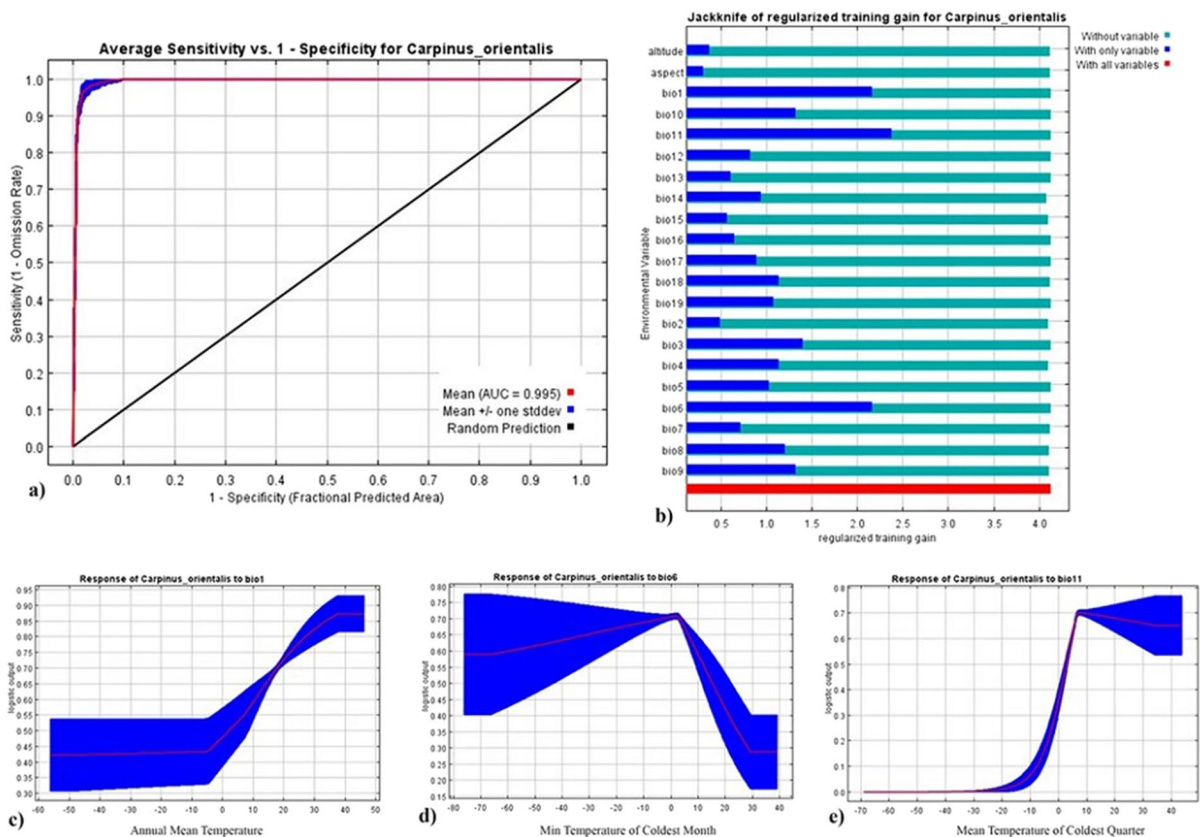


Fig. 3 ROC curve-AUC value of the model (a), impact of environmental variables (b), and response curves (c, d, e)

below $-10\text{ }^{\circ}\text{C}$ (Fig. 3). The current potential distribution areas of *Carpinus orientalis* and the appropriate distribution scenarios according to SSP245 and SSP585 for the future (2040, 2060, 2080, and 2100) are presented in Fig. 4.

Given the altitude changes in current and future potential distribution areas of *Carpinus orientalis* in Europe, it is projected that the potential distribution areas in Europe will shift toward higher altitudes and there will be losses in Italy, Bulgaria, and northern Turkey. It is estimated that the appropriate distribution areas in Greece will shift to higher altitudes and new appropriate distribution areas will occur in Spain and southern Turkey. The numerical results regarding the spatial changes in *Carpinus orientalis* by the global climate change and by the altitude are presented in Table 3.

Given the values presented in the table showing the numerical changes in the distribution areas of *Carpinus orientalis*, it can be seen that, similar to *Carpinus betulus*, the widest appropriate distribution areas in Europe at this moment range between the altitudes of 0 and 400 m and the area decreases as the altitude increases, such that it was determined that 43% of the appropriate distribution areas are located at altitudes below 400 m. However, it is estimated that, depending on the global climate change, significant decreases in appropriate distribution areas of *Carpinus orientalis* will be seen in the near future (2040–2060) and then decreases will occur. The alarming situation in the spatial change in the distribution areas of *Carpinus orientalis* by altitude is that there will be significant losses in appropriate distribution areas in the near future. These significant decreases will occur in years 2040 and 2060 for the areas with altitudes lower than 1000 m according to the SSP 245 scenario and in year 2040 according to the SSP 585 scenario. At certain altitudes, the loss will be higher than 30% (32.4% in year 2040 at the altitudes lower than 200 m according to the SSP 245 scenario) (Table 4). In the following years, significant increases are expected in the appropriate distribution areas. This increase will be more significant at high altitudes. In the year 2100, when compared to the current level, the appropriate distribution areas at the altitudes between 1000 and 2000 m will be 17.9–101.1% higher according to the SSP 245 scenario and 22.2–192.3% according to the SSP 585 scenario.

4 Results and Discussions

As a result of this study, it was determined that the appropriate distribution areas of both *Carpinus* varieties will decrease at low altitudes and increase in high altitudes. In other words, *Carpinus orientalis* and *Carpinus betulus* will have to migrate to higher altitudes.

The studies carried out on *Carpinus* varieties reported that significant population losses may occur in many regions depending on global climate change. Zhao et al. (2020) stated that *Carpinus* varieties having limited distribution in China, especially *Carpinus tientaiensis*, will have significant population losses. Similarly, there will be decreases in distribution areas of *Carpinus viminea* in northern India, southern Xizang, eastern Yunnan, and Zhejiang regions, and it is projected that the appropriate distribution areas of *Carpinus londoniana* in China will change (He et al., 2020). Although the distribution areas of *Carpinus* varieties will increase in the long term according to RCP 4.5 and RCP 8.5 scenarios (such as *Carpinus laxiflora* with increases by 1.05% and 1.11%) (Lee et al., 2021), the spatial change in the potential distribution areas should not be underestimated. It shows that the varieties will not be able to effectively migrate to the appropriate distribution areas and the population and variety losses will occur. For instance, in the present study, it is estimated that the appropriate distribution areas will expand toward the year 2100 for both varieties, whereas there will be important decreases in the appropriate distribution areas in the near future (2040–2080). Hence, the population losses will occur in the near future but, since the settlement of the varieties in the appropriate distribution areas to occur will not be fast enough, it will not compensate the population losses.

Global climate change is defined as an irreversible process that will directly or indirectly affect the entire organic life in the world (Cetin, 2020a, 2020b). It was reported that this process will show its main effect in form of increases in temperature and decreases in precipitation (Varol et al., 2021), that (according to the latest climate change scenario for Europe) the temperatures will increase by approx. $2\text{ }^{\circ}\text{C}$ in Ireland and the UK, approx. $3\text{ }^{\circ}\text{C}$ in Central Europe, and $4\text{--}5\text{ }^{\circ}\text{C}$ in northern Boreal and several regions of Mediterranean until the year 2100 (Lindner et al., 2010), and

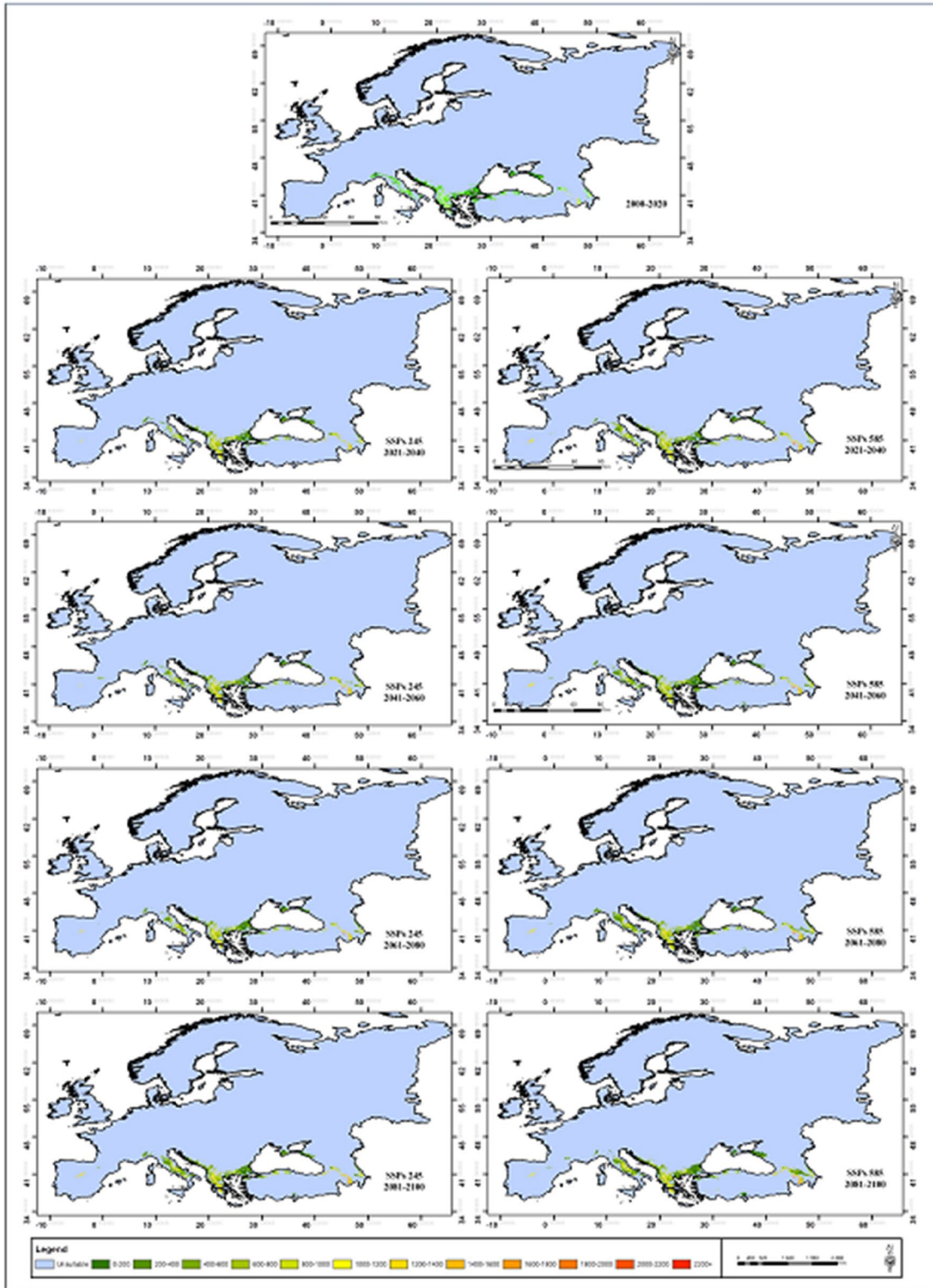


Fig. 4 Altitude changes in the potential distribution areas of *Carpinus orientalis* in Europe

Table 3 The spatial (km²) change in *Carpinus orientalis* distribution areas by the global climate change and altitude

Altitude (m)	2020	SSPs 245				SSPs 585			
		2040	2060	2080	2100	2040	2060	2080	2100
0–200	42,805.52	36,650.06	28,915.33	32,049.32	39,607.03	32,281.47	45,501.01	38,846.10	56,579.63
200–400	44,572.42	38,297.83	39,168.53	36,782.56	49,176.69	41,412.63	50,982.28	55,328.61	55,573.66
400–600	38,330.22	34,191.28	36,240.89	31,920.35	38,807.41	37,272.65	38,343.11	43,244.02	42,960.28
600–800	31,804.28	27,716.05	29,289.34	26,374.59	30,282.42	32,552.31	29,044.30	32,487.83	33,081.09
800–1000	22,066.96	20,352.56	19,603.61	18,120.44	21,628.46	23,743.58	19,358.57	21,602.66	22,853.68
1000–1200	12,071.70	12,898.97	12,097.49	11,736.37	14,238.41	14,973.55	11,607.40	13,361.41	14,754.30
1200–1400	6306.69	7067.40	7222.38	7441.63	9273.02	8886.11	7028.93	8589.48	9260.13
1400–1600	2953.44	2999.46	3946.52	4281.84	5390.99	4707.45	3585.40	4642.96	5042.77
1600–1800	1186.53	1441.80	1444.48	1508.96	2385.97	1831.39	1289.71	1947.46	2269.89
1800–2000	502.99	373.32	967.28	1070.46	1005.97	1251.02	1044.67	1379.99	1470.27
2000–2200	77.38	90.11	116.07	90.28	270.84	167.66	167.66	193.46	348.22
2200+	64.49	25.75	0	12.9	51.59	25.79	0	25.79	90.28

that this increase may locally reach 6 °C in Turkey (Dalfes et al., 2007).

The temperature and precipitation regime changes to occur depending on the global climate change will especially affect the plants to a significant extent because the leading one among the factors determining the plant development at most is the climate (Adiguzel et al., 2020, 2021; bozdogan Sert et al., 2021; Cetin, 2019, 2020a, 2020b; Cetin et al., 2018; Gungor et al., 2021; Savas et al., 2021; Yigit et al., 2021; Zeren Cetin & Sevik, 2020; Zeren Cetin et al., 2020). Thus, the changes to occur in the climatic parameters will have significant effects on plant development. This effect might be positive

from specific aspects. For instance, the productivity of Boreal forests is limited because of their short growing season, low summer temperatures, and insufficient nitrogen resources and the predicted temperature increase will prolong the growing season, accelerate the disintegration of organic matter in soil, and increase the nitrogen supply. As a result, a higher level of increase will be seen in the amount of biomass (Lindner et al., 2010). In this process, permanent changes will occur in the structure of forests; the distribution areas that are suitable for specific tree varieties will become suitable for other tree varieties. In a previous study, it was determined that, in Europe, there will be increases in the appropriate

Table 4 Relative changes in *Carpinus orientalis* distribution areas depending on the global climate change and by the altitude

Altitude (m)	2020	SSPs 245				SSPs 585			
		2040	2060	2080	2100	2040	2060	2080	2100
0–200	100	85.6	67.6	74.9	92.5	75.4	106.3	90.8	132.2
200–400	100	85.9	87.9	82.5	110.3	92.9	114.4	124.1	124.7
400–600	100	89.2	94.5	83.3	101.2	97.2	100.0	112.8	112.1
600–800	100	87.1	92.1	82.9	95.2	102.4	91.3	102.1	104.0
800–1000	100	92.2	88.8	82.1	98.0	107.6	87.7	97.9	103.6
1000–1200	100	106.9	100.2	97.2	117.9	124.0	96.2	110.7	122.2
1200–1400	100	112.1	114.5	118.0	147.0	140.9	111.5	136.2	146.8
1400–1600	100	101.6	133.6	145.0	182.5	159.4	121.4	157.2	170.7
1600–1800	100	121.5	121.7	127.2	201.1	154.3	108.7	164.1	191.3
1800–2000	100	74.2	192.3	212.8	200.0	248.7	207.7	274.4	292.3
2000–2200	100	116.5	150.0	116.7	350.0	216.7	216.7	250.0	450.0
2200+	100	39.9	0	20	80	40	0	40	140

distribution areas of *Abies alba*, *Fraxinus excelsior*, *Fagus sylvatica*, *Quercus robur*, and *Quercus petraea* and decreases in distribution areas of *Betula pendula*, *Picea abies*, *Larix decidua*, and *Pinus sylvestris* (Dyderski et al., 2018). However, it will be very difficult for the species to settle in appropriate distribution areas because the plants and especially the trees having long life-cycles (Lindner et al., 2010) have no effective movement and migration mechanism and especially the species having large seeds have a distribution area that is limited to the area around the main tree. Moreover, for almost all the species, geographical obstacles such as mountains and rivers further limit the opportunity of distribution (Ning et al., 2021). It makes the migration to appropriate distribution areas almost impossible for many species in the process of global climate change. In this case, species will inevitably experience population loss.

The results obtained here suggest that the appropriate distribution areas will shift from low altitudes toward high altitudes until the year 2100 and, moreover, new distribution areas will form in locations where *Carpinus* varieties do not currently have distribution area. However, since the altitudinal and regional migration of species (since the migration is upwards) and their establishment in new appropriate distribution areas to form will be impossible, remarkable losses will occur in the total distribution areas.

Similar results were also reported in different studies carried out on different tree species. It was reported that the decrease in potential distribution areas of *Fagus sylvatica* in Europe might reach 56% (Thurm et al., 2018), that habitat loss of specific species may reach 77% in mountainous areas in Mexico (Gómez-Pineda et al., 2020), that pure *Fraxinus excelsior* forests may be extinct, and that the populations that have limited distribution in many regions may completely disappear (Ning et al., 2021).

Global climate change will also have severe indirect effects on the forests. Increasing temperatures and a predicted decrease in precipitation will also increase the risk of drought, such that it was reported that even the ecosystems that have adapted to aridity will be affected by the drought (Rambal et al., 2003). Drought is one of the important stress factors influencing plant development (Topacoglu et al., 2016; Yigit et al., 2016) and increasing drought will cause declines in plant growth and productivity (Ogaya et al., 2003). Moreover, the stress factors to emerge

due to global climate change such as increase in UV-B might negatively affect the development and productivity of trees (Ozel et al., 2021).

Long-term droughts and hot periods to occur depending on global climate change will further increase the risk of forest fires. Forest fires will become a significant threat for the Mediterranean region, where the increase in temperature is predicted to be at a higher level (Moriondo et al., 2006). Increase in the frequency of forest fires (Ertugrul et al., 2021) might increase the soil erosion depending on the increase the hydrophobicity (Certini, 2005) and decrease in plant regeneration (Delitti et al., 2005) and desertification may accelerate in arid areas (Lindner et al., 2010; Peñuelas et al., 2018).

Due to global climate change, changes are expected in bug populations and mushroom distribution areas (Liu & Shi, 2020; Canelles et al., 2021). Moreover, highly thermophilic pathogen species will likely be more lethal and the pests that might highly develop on the trees having water stress might cause sudden deaths (Maresi et al., 2007). The damages that might arise due to the interaction between all these factors might result in species and population losses on large areas.

5 Conclusions

Previous studies showed that the point of no return has been passed for global climate change. For this reason, besides the studies on the reasons and results of global climate change and on stopping or (at least) decelerating the process, the studies should be carried out on minimizing the effects on organisms and ecosystem and measures should be taken. It can be stated that the most important point regarding the studies is to increase the consciousness level of societies on this subject and to raise awareness regarding this subject.

It is estimated that global climate change will show its effects on almost every field. For this reason, in order to make a minimum contribution to the process and to be affected by the process at the minimum level, all the sectors should make plans and take measures. In order to reduce the carbon emission, the need for energy should be met from renewable energy sources, natural sources including water should be used economically, the genotypes having low water need should be preferred in agricultural and forestry

areas, the projections on this process should be involved in the management plans in forestry studies, in situ and ex situ preservation strategies should be developed and implemented for endangered species and potentially endangered species, firm soils should be decreased and plant use should be increased in urban areas, and the use of roof gardens and terrace gardens should be popularized.

In forestry, this process should be properly analyzed and the effects should be determined in a multi-directional manner. Through the studies, action plans should be developed for each region and tree species. The measures to be taken might include preserving the composition and variety and genetic diversity in natural forests, using the drought-resistant species and origins in plantation efforts, considering the effects of global climate changes in reforestation of destroyed areas, and providing the migration mechanism, which the varieties will need, by the hands of men.

Acknowledgements The authors thank the support by the Republic of Turkey Ministry of Agriculture and Forestry, General Directorate of Forest Engineering, and the General Directorate of Meteorology for their prompt responses to our requests.

Author Contribution Halil, Tugrul, Hakan, and Ilknur designed the study and performed the experiments; and Tugrul, Ilknur, and Mehmet performed the experiments, analyzed the data, and wrote the manuscript.

Data Availability All data are given in the manuscript.

Declarations

Ethics Approval and Consent to Participate Not applicable.

Consent for Publication Not applicable.

Competing Interests The authors declare no competing interests.

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