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Changes That May Occur in Temperature, Rain, and Climate Types Due to Global Climate Change: The Example of Düzce

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ARTICLE INFO	ABSTRACT
	Global climate change is defined as a process that affects all living things and ecosystems globally and is claimed as the most critical problem of the current century. Turkey, which is shown as one of the most affected countries by this process, is among the "countries at risk." It is stated that the temperature will increase throughout the country until 2100, and this increase may reach 6 ºC. In order to determine the possible effects of global climate change, it is necessary to predict how the climate structure and basic parameters may change. From this point of view, this study is aimed to determine the change of temperature and precipitation, climate types (according to De Martonne, Lang, and Emberger climate classification) which are the most critical climate parameters until 2050 and 2070 in Düzce, one of the important cities of our country. The current situation and possible changes in 2050 and 2070 have been compared using RCP 4.5 and RCP 8.5 scenarios. As a result of the study, the temperature, precipitation, and related climate types would change significantly throughout the province of Düzce, and this change will show itself as a significant temperature increase and change in precipitation regime. In addition, a shift in climate types towards continental climate types is predicted until 2070. In order to avoid the destructive effects of global climate change, it is recommended to take measures on a sectoral basis.

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Introduction

The world has experienced perhaps the most severe and rigid changes in its history in the last century, and the world population has increased significantly in a short period and concentrated in urban areas (Kilicoglu et al., 2020; Turkyilmaz et al., 2020). Today, the estimated world population exceeds 7.8 billion, and the population in urban areas has increased to 56%; it may exceed 8.5 billion by 2030, and the population rate in urban areas may reach 90% (Sevik, 2021).

In addition to the increase in population, the densification of the population in urban areas, the developments in the technological field together with the industrial revolution have caused the increasingly diverse demands and needs of people. The production activities carried out to meet these demands and needs have also caused the mineral resources underground to be extracted and used as raw materials in the industry (Shahid et al., 2017; Kaplan et al., 2021; Koç, 2021). In this process, the release of various elements forming the raw material of industrial activities is air (Turkyilmaz et al., 2018a, b; Aricak et al., 2020; Cetin et al., 2020), water (Emin et al.,

2020; Ucun Ozel et al., 2020; Tokatli et al., 2021) and soil (Bayraktar, 2020a, b) pollution, and the use of fossil fuels in order to meet energy needs caused a significant increase in the atmospheric CO_2 concentration (Cetin et al., 2019; Cesur et al., 2021).

The increase in the concentration of CO_2, greenhouse gases, and particulate matter in the atmosphere due to human and industrial activities and the use of fossil fuels destroyed the natural environment, and the depletion of the ozone layer causes an increase in global temperature (Demirbaş and Aydın, 2020; Gür and Palta, 2021; Ertugrul et al., 2021). The global climate change that emerged from this is seen as the most crucial threat today (Demirbaş and Aydın, 2020). This is because it is predicted that global climate change will affect almost all living things and ecosystems directly or indirectly and will have destructive and irreversible effects on ecosystems (Gustavsson et al., 2017; Meli et al., 2017; Varol et al., 2021). In this process, it is predicted that natural disasters such as forest fires, drought, floods, desertification, and erosion will increase the frequency and intensity of natural disasters and

ecological degradation, and the most important effects will be the increase in temperature and decrease in water resources (Ertugrul et al., 2019; Lee et al., 2019; Cetin, 2020).

The fact that global climate change will be seen in almost every field has forced the researchers to determine these effects and determine the precautions taken by calculating the possible outcomes. Therefore, many studies are carried out on the effects of global climate change in many areas such as forests (Grainger, 2020; Ellis and Eaton, 2021), agricultural lands (Ampaire et al., 2020; Zilli et al., 2020), insects (Johansson et al., 2020; Halsch et al., 2021). However, to determine the impact of global climate change in all areas, it is necessary to determine how the climate structure and basic parameters can change initially. From this point of view, this study aimed to determine the most critical climate parameters, temperature and precipitation, and the changes in the climate structure according to different climate scenarios.

Material and Method

This study was carried out in the ever-developing city of Düzce, located in the northwest of Turkey. The basis of the study was the RCP 4.5 and RCP 8.5 scenarios produced within the HadGEM2-ES Global Roaming Model group prepared for the 5th Assessment Report of the International Panel on Climate Change (IPCC). Representative Concentration Pathways (RCPs), the climate change scenarios used by the IPCC in the IPCC 5th Assessment Report, were evaluated by experts in 2007; four RCP's have been determined under the new emission/concentration scenarios. RCP 4.5, the first scenario is based on that the CO_2 concentration in the atmosphere will be around 650 ppm in 2100 and the greenhouse gas emissions specified in the Kyoto Protocol will decrease from the second half of the century. In the RCP 8.5 scenario, it is estimated that the CO_2 concentration in the atmosphere in 2100 will almost double (1370 ppm) compared to RCP 4.5, and this increase in greenhouse gas emissions will continue until 2100 according to the Kyoto Protocol (Demircan et al., 2014).

Within the scope of the study, climate types were determined according to De Martone, Emberger, and Erinç climate classifications under the RCP 4.5 and RCP 8.5 scenarios by using the distribution of the temperature and precipitation situation estimated to occur in 2050 and 2070 and maps of the areas where these climate types will prevail were created. Therefore, climate types were evaluated for today, 2050, and 2070 according to De Martonne, Emberger, and Lang climate classes, which were formed by temperature and precipitation parameters. Thereby, it had been tried to predict how the temperature, precipitation, and climate in Düzce will change within the specified years.

Results

According to the scenarios subject to study, the current state of the average annual temperature in Düzce and the change in 2050 and 2070 are given in Figure 1. When the temperature change in Düzce is examined, it is seen that the average temperature of the province today varies between 5.73° C and 13.0°C. The temperature in Düzce province is approximately 1.10% below 6.5°C. The average temperature in 4.57, 5.96, 9.43, 15.13, 21.58, 24.04, and 18.19% of the province's area are between 6.5-7.5, 7.5-8.5, 8.5-9.5, 9.5-10.5, 10.5-11.5, 11.5-12.5, and 12.5-13.5°C, respectively. There is no area above 13.5°C throughout the province.

According to the RCP 4.5 scenario, it is estimated that the temperature across the province will vary between 8.7°C and 16.0°C in 2050. According to the RCP 4.5 scenario results of calculation, it is predicted that the average temperature would be below 9.5°C in only 0.89% of the province in 2050, whereas it will be above 15.5°C in approximately 17.59% of the province. Apart from that, the average temperature is between 9.5-10.5, 10.5-11.5, 11.5-12.5, 12.5-13.5, 13.5-14.5, 14.5-15.5°C at 4.57, 5.46, 8.88, 14.74, 21.71, 26.16% of the area of province, respectively.

According to the RCP 8.5 scenario, the situation in 2050 is worse. According to this scenario, it is estimated that the temperature in Düzce will vary between 9.3°C and 16.6°C in 2050. Moreover, the average temperature will be below 9.5°C in only 0.08% and above 15.5°C in 35.25% of the province. In addition, it is estimated that the average temperature is between 9.5-10.5, 10.5-11.5, 11.5-12.5, 12.5-13.5, 13.5-14.5, 14.5-15.5°C at 1.93, 5.07, 6.48, 10.58, 17.74, 22.86% of the province, respectively.

According to the RCP 4.5 scenario calculation results, the temperature throughout the province will increase even more in 2070. Also, the average temperature in Düzce will vary between 9.3°C and 16.6°C, and the average temperature will be below 9.5°C in only 0.08%, whereas it will be above 15.5°C is approximately 34.99% of the province is foreseen. Moreover, it is estimated that the average temperature is between 9.5-10.5, 10.5-11.5, 11.5-12.5, 12.5-13.5, 13.5-14.5, 14.5-15.5°C at 2.01, 5.25, 6.45, 10.56, 18.16, 22.50% of the province, respectively.

According to the RCP 8.5 scenario calculation results, the temperature throughout the province will vary between 10.7°C and 18°C, and the average temperature will be below 9.5°C in only 0.76%, whereas it will be above 16.5°C is approximately 44.19% is estimated. Also, it is estimated that the average temperature is between 11.5-12.5, 12.5-13.5, 13.5-14.5, 14.5-15.5, 15.5-16.5°C at 4.36, 5.57, 8.86, 14.32, 21.95% of the province, respectively.

According to the study scenarios, the precipitation changes in 2050 and 2070 in Düzce are given in Figure 2. It has been calculated that the average annual precipitation in Düzce varies between 584 mm and 991 mm today. According to the calculations, annual precipitation is below 650 mm at approximately 31.20%, while it is over 950 mm at 4.39% of the province. The total annual precipitation is about 650-700, 700-750, 750-800, 800-850, 850-900, and 900-950 mm at 10.58, 11.39, 11.26, 17.40, 9.30, and 4.47% of the province, respectively.

According to the RCP 4.5 scenario, it is estimated that the average annual precipitation across the province will vary between 608 mm and 987 mm in 2050. According to the RCP 4.5 scenario calculation results, the total annual precipitation is below 650, between 650-700, 700-750, 750-800, 800-850, 850-900, 900-950, and over 950 mm at approximately 5.57, 19.07, 18.21, 18.55, 22.97, 7.39, 4.70, and 3.53% of the province, respectively. According to the RCP 8.5 scenario, the amount of precipitation will vary

between 617 mm and 1010 mm in 2050, and the precipitation will be below 650 mm and above 950 mm, represents 3.14 and 5.33% of the province, respectively. Also, the amount of precipitation is between 650-700, 700-750, 750-800, 800-850, 850-900, 900-950 mm at 17.38, 16.91, 17.48, 21.43, 13.77, 4.57% of the province, respectively.

According to the RCP 4.5 scenario, the average annual precipitation across the province will vary between 592 mm and 958 mm in 2070. In addition, the total annual precipitation is below 650, between 650-700, 700-750,

750-800, 800-850, 850-900, 900-950, and over 950 mm at approximately 11.81, 19.52, 18.63, 22.79, 16.57, 5.71, 5.07, and 0.44% of the province, respectively. According to the RCP 8.5 scenario, the amount of precipitation will vary between 602 mm and 997 mm in 2070, and the precipitation will be below 650 mm at 5.57% of the province. Also, it is expected that the amount of precipitation is between 650-700, 700-750, 750-800, 800-850, 850-900, 900-950, 950-100 mm at 18.55, 17.12, 16.67, 22.47, 10.56, 4.57, 4.49% of the province, respectively.
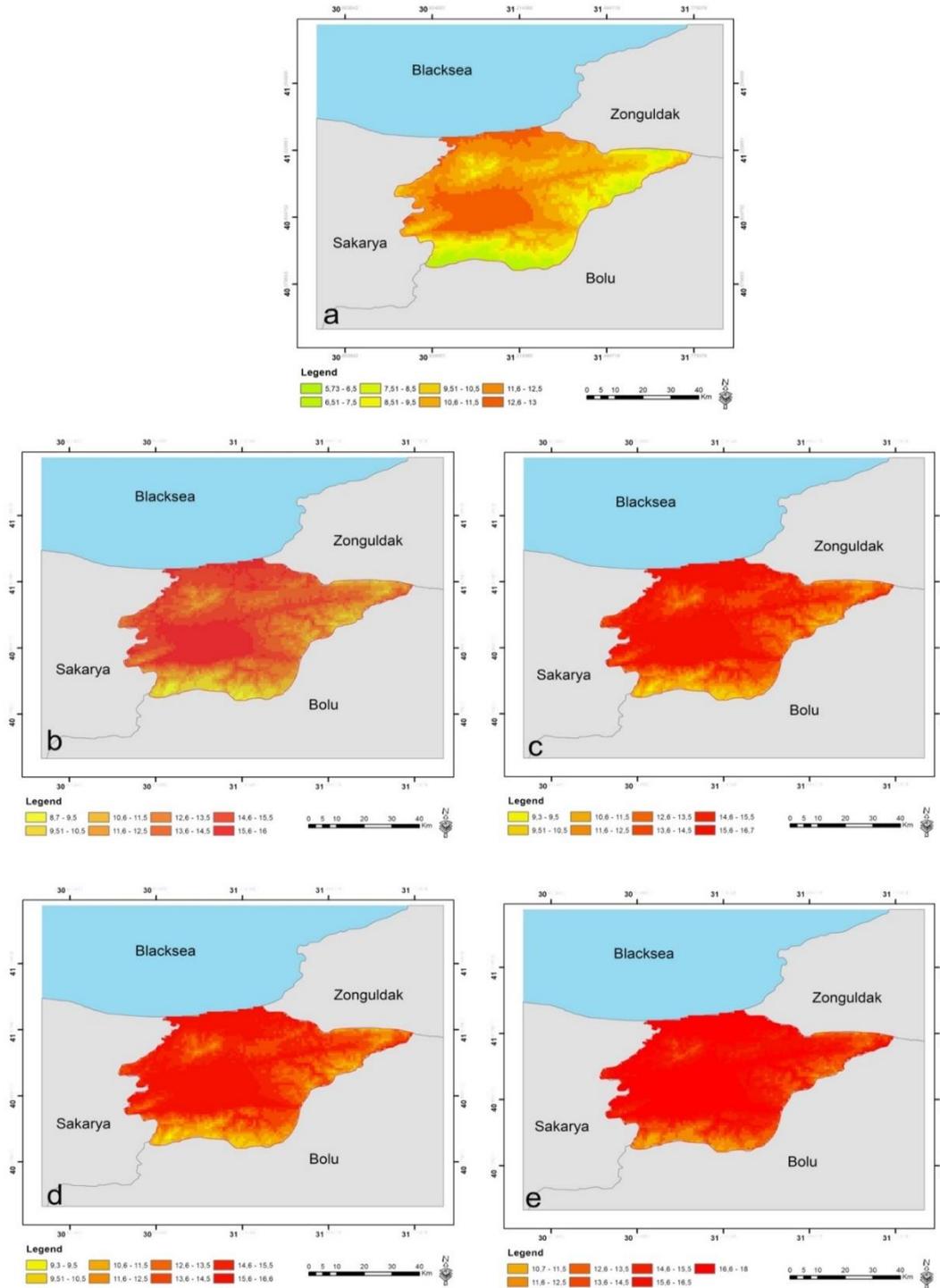

Figure 1. Temperature changes a) Today, b) RCP 4.5 scenario in 2050 c) RCP 8.5 scenario in 2050 d) RCP 4.5 scenario in 2070 e) RCP 8.5 scenario in 2070
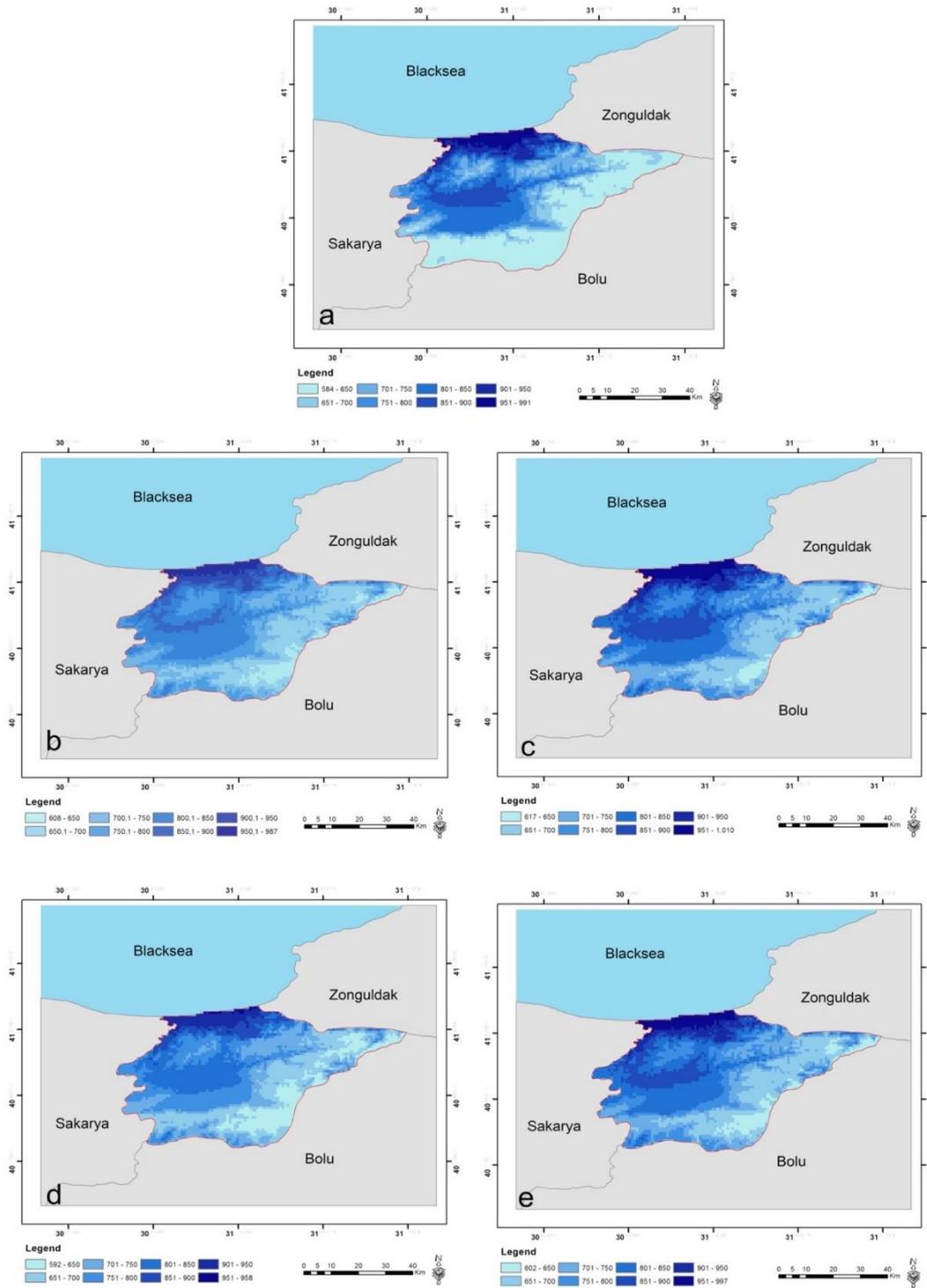
Figure 2. Precipitation change a) Today, b) RCP 4.5 scenario in 2050 c) RCP 8.5 scenario in 2050 d) RCP 4.5 scenario in 2070 e) RCP 8.5 scenario in 2070

According to the study scenarios, the climate classes of the Düzce province were determined in terms of temperature and precipitation for the present and in the years 2050 and 2070, and the change of climate in the process according to De Martonne climate classes is given in Figure 3. According to the De Martonne climate classification, humid and extremely humid climate prevails in approximately 47.22 and 52.78% of Düzce province. It is predicted that there will be some changes in the climate in 2050. The humid climate will prevail in Düzce province in 2050, according to the RCP 4.5 scenario (approximately 74.92% of the province). In addition, it is predicted that the areas where the semi-humid climate will prevail will emerge, and this rate will be 6.58%, and the areas with very humid climates will decrease significantly to 18.50% of the province. According to the RCP 8.5 scenario, the semi-humid climate areas will prevail 8.78% of the province, and the humid and very humid climate will prevail in approximately 74.39% and 16.83% of the province, respectively.
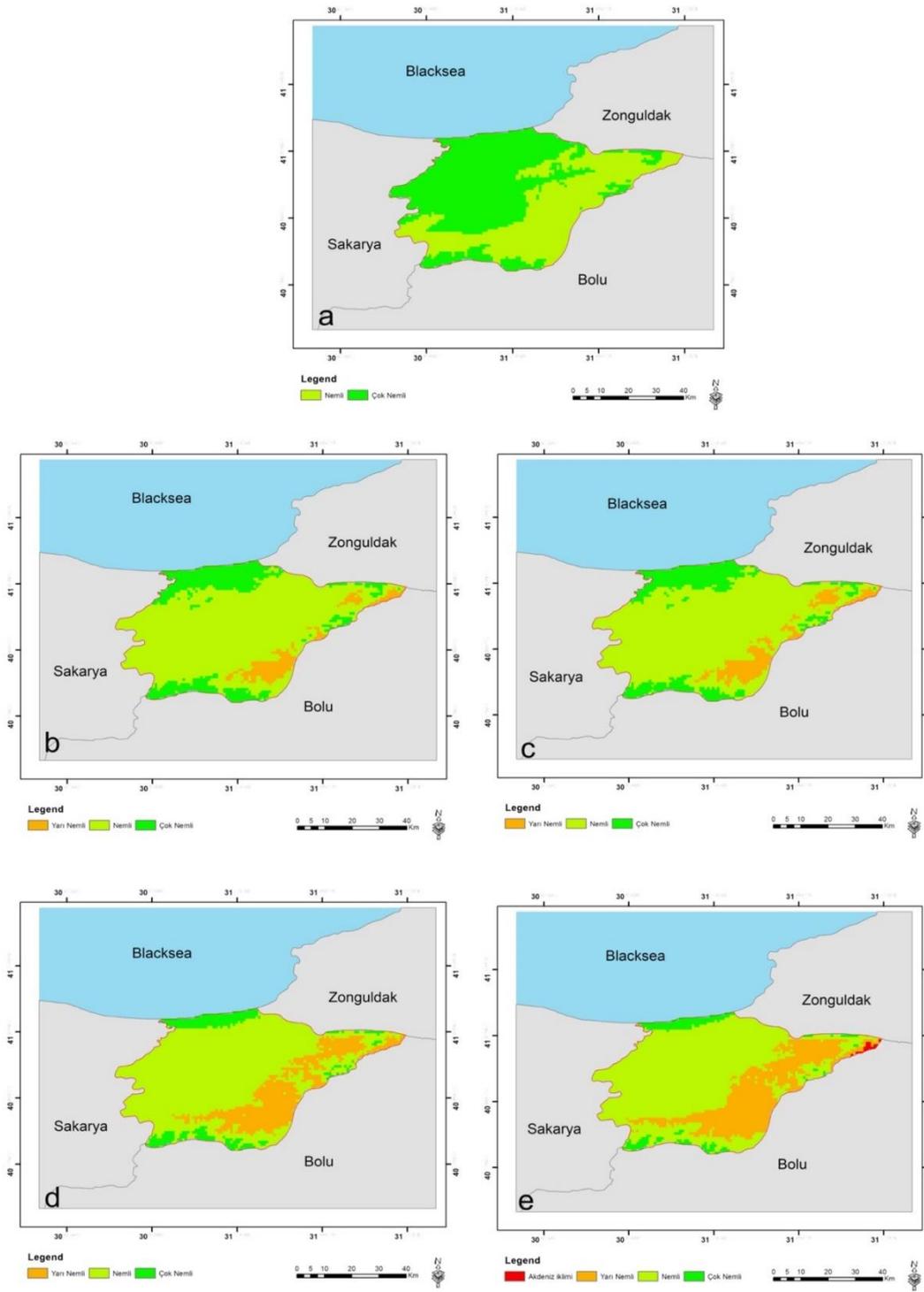
Figure 3. Change of climate classes according to De Martonne climate classification a) Today, b) RCP 4.5 scenario in 2050 c) RCP 8.5 scenario in 2050 d) RCP 4.5 scenario in 2070 e) RCP 8.5 scenario in 2070

In 2070, the situation will get more severe, and the Mediterranean climate will prevail on 0.47% of the province according to the RCP 8.5 scenario, while there is no Mediterranean climate in the province according to the RCP 4.5 scenario. According to the RCP 4.5 scenario, approximately 19.94% of the province will be under the influence of the semi-humid climate, 71.10% of the humid climate, and 8.96% of the very humid climate. According to the RCP 8.5 scenario, the semi-humid climate areas will prevail 8.78% of the province, and the humid and very

humid climate will prevail in approximately 74.39% and 16.83% of the province, respectively.

The change of climate in the process according to Emberger's climate classes is given in Figure 4. According to the Emberger climate classification, when the change of climate classes is examined, it is understood more clearly how severe the change that is predicted to occur in the process and how serious the situation will be. According to the Emberger climate classification, while humid climate prevails in the whole of Düzce today, according to the RCP

4.5 scenario, approximately 61.41% and 38.59% of the province will have a semi-humid and humid climate, respectively. According to the RCP 8.5 scenario, the semi-humid areas will prevail approximately 65.74%, and the humid climate will prevail 34.26% of the province.

In 2070, the situation will get much worse, and the semi-humid areas will prevail approximately 76.74%, and the humid areas will prevail 23.26% of the province according to the RCP 4.5 scenario. According to the RCP

8.5 scenario, 89.63% of the province will continue to have a semi-humid and 10.37% humid climate.

According to Lang's climate classes, the change of climate in the process is given in Figure 5. When the change of climate classes is examined according to Lang's climate classification, it is understood more clearly how severe the change may occur in the process and how critical the situation will be.
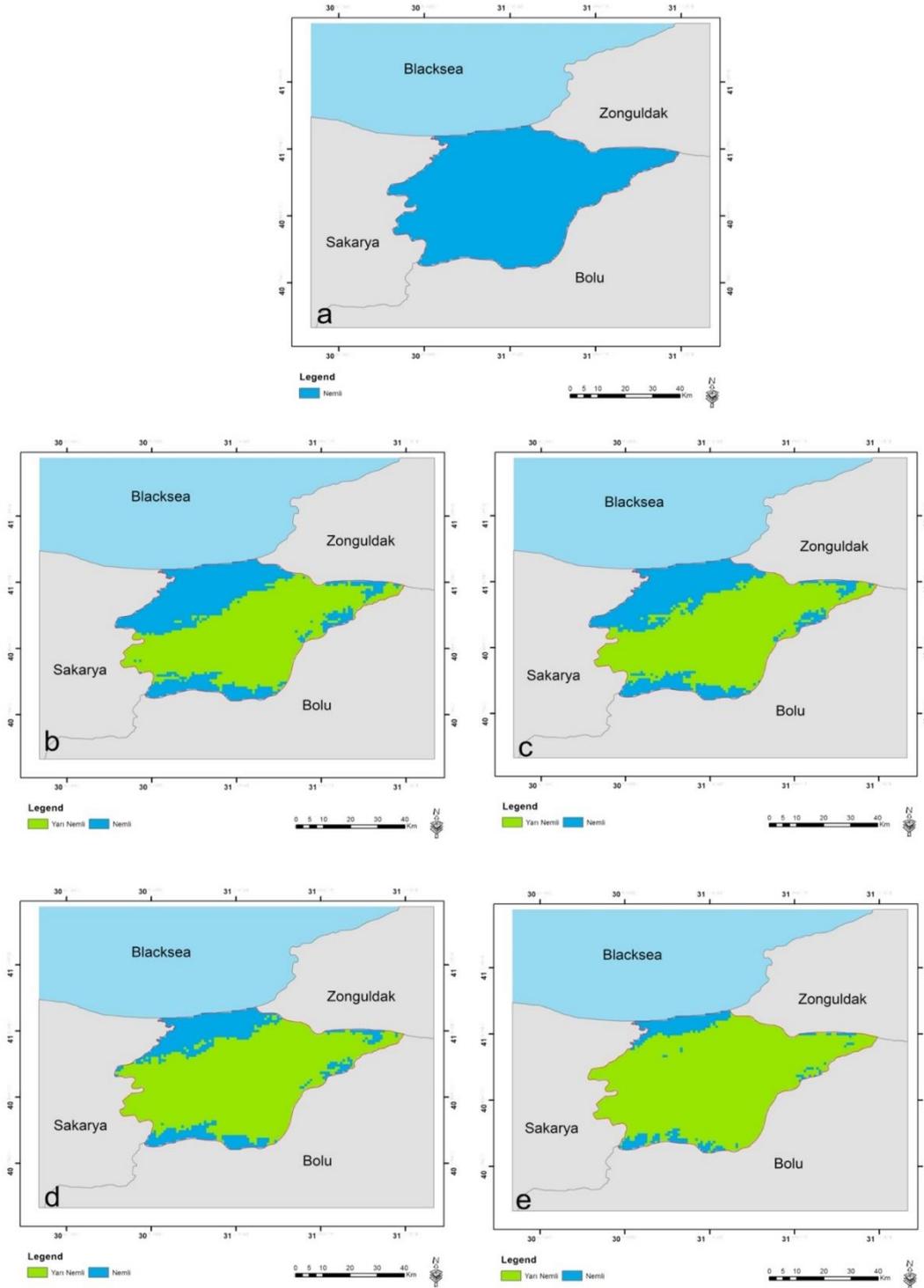

Figure 4. Change of climate classes according to Emberger climate classification a) Today, b) RCP 4.5 scenario in 2050 c) RCP 8.5 scenario in 2050 d) RCP 4.5 scenario in 2070 e) RCP 8.5 scenario in 2070

According to Lang's climate classification, while semi-arid, semi-humid, and humid climate prevails in 3.63, 95.82, and 0.55% of Düzce nowadays, respectively. There are no arid climatic areas throughout the province today. In 2050, according to the RCP 4.5 scenario, there will be no humid climatic areas throughout the province, and semi-arid climate will prevail in approximately 80.25% and semi-humid climate in 19.75%. According to the RCP 8.5

scenario, approximately 85.84% and 14.16% of the province will have semi-arid and semi-humid climates.

In 2070, the situation will get much worse, and according to the RCP 4.5 scenario, approximately 91.64% and 8.36% of the province will have semi-arid and semi-humid climates. According to the RCP 8.5 scenario, the arid climate will emerge for the first time in 0.84% of the province. The semi-arid and semi-humid climate will prevail in 94.15% and 5.02% of the province.
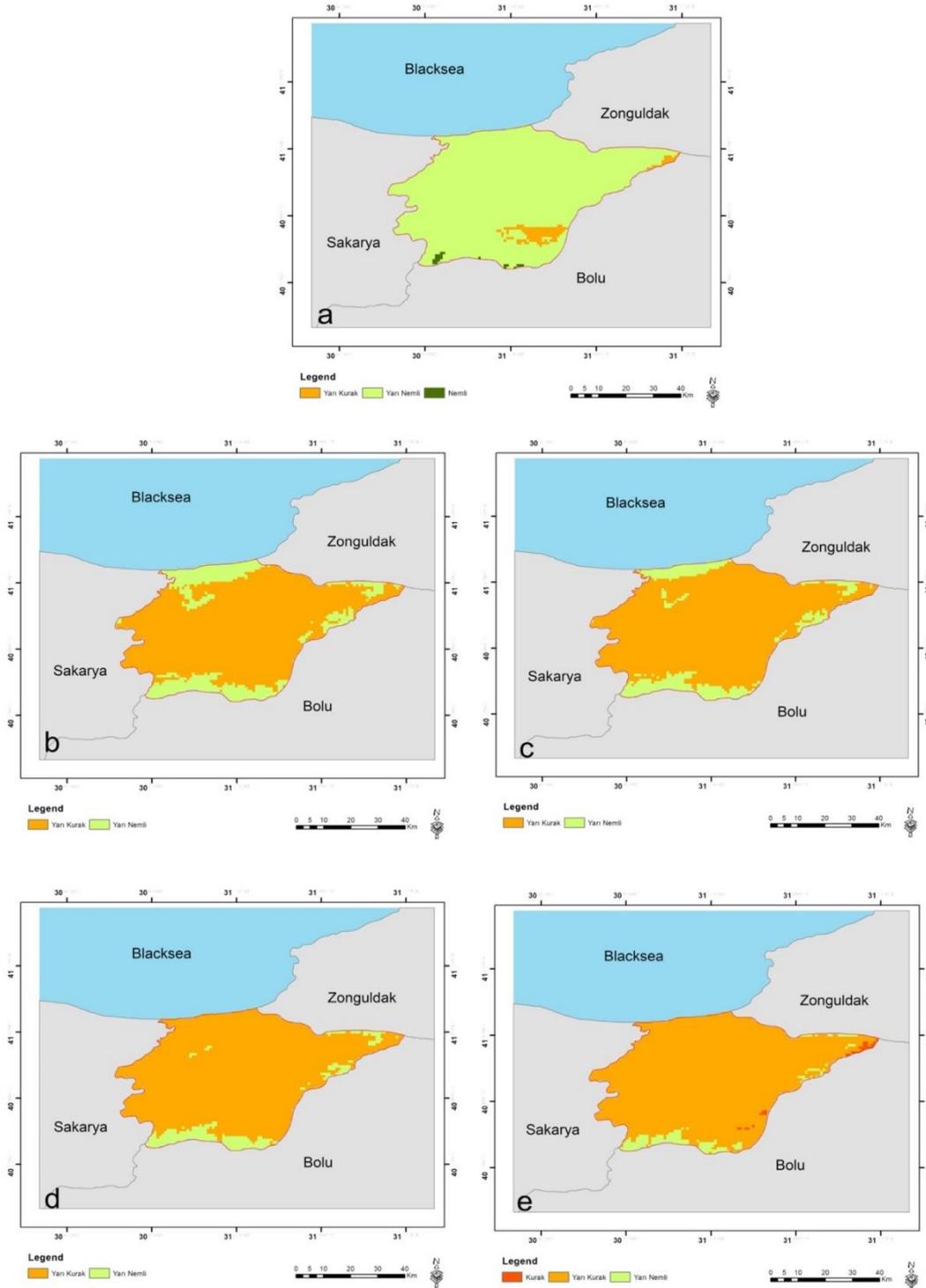

Figure 5. Change of climate classes according to Lang climate classification a) Today, b) RCP 4.5 scenario in 2050 c) RCP 8.5 scenario in 2050 d) RCP 4.5 scenario in 2070 e) RCP 8.5 scenario in 2070

Discussion and Conclusion

The study results show that there will be a significant change in temperature, rainfall, and related climate classes throughout the province of Düzce in the coming years. It is predicted that this change will occur, especially in temperature increases, and this situation will cause very drastic changes in the climate type. For example, according to the De Martonne climate classification, while the humid climate prevails in approximately 47.22% and extremely humid climate in 52.78% of the province today, according to the RCP 4.5 scenario in 2070, approximately 19.94, 71.10, and 8.96% of the province have a semi-humid, humid and very humid climate, respectively. A similar situation occurs in other climate scenarios.

Similar results were obtained in studies conducted in different regions on the subject. In 2070, there will be an increase of around 5°C in the temperature change range in Mersin, according to the RCP 8.5 scenario (Cetin, 2020). According to the Emberger climate classification, while the humid or very humid climate type prevails in the whole of Mersin today, it is stated that approximately 0.44% and 80.5% of the province will be arid and semi-arid climates, respectively (Cetin, 2020). Aktaş (2020) states that drought will reach severe levels in Konya in 2070, and even desert areas that do not exist today are expected to occur across the city. It is estimated that our country will be one of the countries most affected by the global climate change process, and the temperature increase across the country may reach 6°C according to the RCP 8.5 scenario (Demircan et al., 2014; Turan, 2018).

It is stated that the effect of climate change can be seen in almost every field and can cause significant and destructive changes worldwide (Bouras et al., 2019; Clarke et al., 2019; Piao et al., 2019). The plants will be most affected by this process in the terrestrial ecosystem. The development of plants and all their phenotypic characters are shaped by the interaction of genetic structures (Hrivnak et al., 2017; Yigit et al., 2019; Imren et al., 2020) and environmental conditions (Cetin et al., 2018a, b; Ozel et al., 2020; Sevik et al., 2020a). In addition, plant growth is mainly under the influence of environmental factors (Ozkazanc et al., 2019; Yucedag et al., 2019; Sevik et al., 2021a, b), and their lack of an effective motion and migration mechanism makes plants vulnerable to changes that may occur due to global climate change. (Varol et al., 2021). Therefore, it is stated that the most destructive effects of climate change will appear in agriculture (Dellal, 2014; Aktaş, 2020) and the forestry sector (Gomez-Pineda et al., 2021; Ning et al., 2021; Varol et al., 2021).

In order to prevent or at least mitigate the possible destructive effects of global climate change, the causes of climate change must first be eliminated. It is stated that the main reason for global climate change is human-induced changes in the structure of the atmosphere, especially industrial activities (Turkyilmaz et al., 2018a, b; Demirbaş and Aydın, 2020). Many studies emphasize that pollutants such as CO_2, particulate matter, and heavy metals in the atmosphere have increased significantly in recent years (Aricak et al., 2019). Therefore, to reduce the effects of global climate change, it is necessary to eliminate the reason first. However, this option does not seem feasible in the current situation. Because the world's energy need is constantly increasing and it is estimated that the energy consumption in the world in 2030 will be 60% more than today (Kilicoglu et al., 2021). Therefore, it is currently planned to establish many new thermal power plants (Akyüz and Tezel, 2017).

Global climate change is seen as an irreversible problem (Cetin, 2020). Therefore, many researchers state that the possible consequences of global climate change should be determined, and precautions should be taken (Aktaş, 2020; Varol et al., 2021). Possible precautions should be determined based on different sectors, and studies should be carried out in this direction. For example, the use of genotypes with fewer water requirements in the agricultural field, the preference of irrigation systems such as drip irrigation systems that ensure the sparing use of water, the choice of products according to changing climate conditions, and keeping the principle of sustainability in the forefront are some of these strategies (Çaltı and Somuncu, 2018; Aktaş, 2020; Kalayci Onac et al., 2021; Xia et al., 2021).

Aside from this, the plant's response to environmental factors is closely related to the genetic structure of the plant, and since plants belonging to the same species have different genetic structures, they can react to the same growing conditions and stress conditions at different levels (Yigit et al., 2016; Koç, 2019; Sevik et al., 2019; Ozel et al., 2021a, b; Savas et al., 2021). It is predicted that the most significant effect of the global climate change process will demonstrate itself in temperature increase and decrease in precipitation, and these factors are the main factors restricting the distribution of many tree species (Ning et al., 2021). Therefore, since the origins that are the best resistant and adaptable to the stress factors that may occur due to these factors have a higher chance of survival, determining drought-resistant origins in breeding studies and using them in afforestation studies may help to reduce the effects of global climate change.

Suggestions

The study results show that the average temperature in the province of Düzce may increase significantly, the precipitation regime may change, and the climate types may shift towards arid climate types in the coming years. Almost all living things and ecosystems will be significantly affected by this process. In order to minimize this effect, possible future changes should be predicted from now. Therefore, it is recommended that similar studies on the subject be carried out in detail in all our provinces.

The effects of global climate change will be seen worldwide and may affect all living things directly or indirectly. This destructive effect can be minimized by taking global precautions. For this, the importance and possible effects of the issue should be revealed by high-level and pluralist approach studies on the subject and then effectively shared with the public.

It is unlikely that global climate change can be stopped under current conditions, and it is predicted that this change will affect almost every field. For this reason, all sectors need to make plans and take measures to contribute to the process at the minimum level and be affected by the process at the least level. Some of these measures include

meeting energy needs from renewable energy sources, using natural resources economically, especially water, preferring genotypes with lower water needs in agriculture and forestry, including process predictions in forestry management plans.

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