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Original Article

Shifts That May Appear in Climate Classifications in Bursa Due to Global Climate Change

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ABSTRACT

Global climate change (GCC) is defined as a process that is considered the most crucial problem of the current century and will affect all living things and ecosystems in the world. In order to specify the potential impacts of this phenomenon, which does not seem possible to stop, it is necessary first to predict the change in climate types. Therefore, the current study aimed to define the shift of climate classifications (according to De Martonne, Erinç, and Emberger climate category) in 2040, 2060, 2080, and 2100 for Bursa, one of the largest cities in Türkiye, according to the SSPs 245 and SSPs585 scenarios, and compare it with its current situation. As a result, it was determined that the climate types in Bursa province would change significantly and primarily manifest as a shift into arid climate types. It is recommended to take precautions on a sectoral basis to avoid the devastating effects of GCC.

Keywords: De Martonne, Emberger, Erinç, SSPs585, SSPs245

Introduction

Developments in the field of industry over the last century have brought many problems, especially pollution, around the world (Ucun Ozel et al., 2019). In this past century, there have been notable changes in the structure of the atmosphere due to anthropogenic factors, especially industrial activities (Yayla et al., 2022). These changes have led to a significant decrease in air quality and elevated levels of pollution factors, such as heavy metals, which can be extremely dangerous and fatal for all living things, especially humans (Aricak et al., 2019; Kuzmina et al., 2023). It is claimed that today, roughly 90% of the world's population breathes polluted air (Cesur et al., 2022). Studies reveal that about 7 million human deaths and more than 4 million premature births every year worldwide are associated with air pollution (Ghoma et al., 2022). According to the data from the European Environment Agency, air pollution is seen as the single biggest environmental problem in Europe (Cobanoglu et al., 2023a). In addition, the concentration of CO_2, a component of air pollution, has increased enormously as a result of the increase in fossil fuel consumption and the spatial reduction of forests, which are carbon sinks, and this increase has emerged as the main responsible for global climate change (GCC) (Key et al., 2022).

It is known that, in addition to changing the composition of the air, one of the most critical effects of industrial activities is on population density. The world population, which was just over 700 million about 250 years ago, has reached almost 8 billion nowadays. Furthermore, the urbanization ratio, which was <10% in the 1900s, is approximately 50% today and projected to reach 90% by the year 2030. Given the authorized data, the urbanization ratio in Türkiye reached 92.5% (Dogan et al., 2022; Isinkaralar et al., 2022).

These developments in the industrial field have caused substantial transitions in population projections and have fundamentally affected some balances in the ecosystem. Therefore, urbanization, which occurs due to the concentration of the population in urban regions (Zeren Cetin et al., 2023), and GCC, which occurs due to differences in the composition of the atmosphere (Tekin et al., 2022), have become irreversible concerns of the world (Koc et al., 2023).

Since all living things on Earth depend directly or indirectly on plants, GCC is seen as a process that will affect all living things (Koç & Nzokou, 2022; Tandogan et al., 2023). Because all phenotypic characteristics of living things are affected by their genetic structures (Hrivnák et al., 2023) and environmental factors (Özel et al., 2022).

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Although the genetic structures of living things can tolerate changes that may occur in environmental factors to a certain level, changes in environmental factors above a certain level affect the morphological, anatomical, and physiological characteristics of living things (Yigit et al., 2021; Yucedag et al., 2019). Among the environmental factors, climatic parameters, predominantly temperature, and resulting drought, which are shown to be the most prominent effects of GCC, are the most critical parameters that determine the living conditions of living things (Bouabdelli et al., 2022; Feng et al., 2022). It is very difficult for living things to tolerate permanent changes in temperature (Ati et al., 2022; Koç, 2021a). Animals can tolerate climatic changes through migration and quickly settle in areas with suitable climatic conditions (Ozkazanc et al., 2019; Kubelka et al., 2022). However, since plants do not have an effective migration tool, it is much more challenging for them to adapt to climatic shifts (Varol et al., 2021). The ability of plants to continue their vitality, growth, and development is shaped by the influence of environmental factors and, especially, the climate (Key et al., 2023; Koc et al., 2023). Therefore, shifts in climate parameters will significantly affect plants, which are the food source of all living things and, therefore, food resources.

In addition, changes in climatic parameters may affect all ecosystems as well as humans. They may radically change living things, habitats, behaviors, and food habits (Varol et al., 2022a; 2022b). It is said that the impact of GCC on forests may be devastating, and as a result, significant individual, species, and population losses may occur (Tekin et al., 2022). The fact that the effects of GCC will be witnessed in almost every area has obliged scientists to define these outcomes in their own fields and to determine the measures that can be taken by calculating the possible consequences. Starting from this point, Bursa is chosen for this study because it is one of the biggest industrial and agricultural cities of Türkiye, and its population is constantly increasing. This study is aimed to determine the current (2023) climate types in Bursa, the fourth largest in Türkiye, according to different climate scenarios until 2040, 2060, 2080, and 2100.

Material and Methods

The current study was conducted in Bursa, one of the largest and most developed provinces of Türkiye. Changes in climate categories were defined according to De Martonne, Emberger, and Lang climate classes according to SSPs 245 and SSPs 585 scenarios throughout the Bursa province. The selected climate classifications are among the most preferred scientific studies and are frequently used in studies on GCC (Beloiu et al., 2022; Koç, 2021a; 2021b).

In this study, climate parameters and climate class change predictions in four different periods (2040, 2060, 2080, and 2100) within two selected SSPs 245 (4.5 W/m^2—an intermediate) and SSPs 585 (8.5 W/m^2—the most extreme) scenarios were determined. These scenarios represent the concentration of greenhouse gases and pollutants resulting from human activities.

The first of the three different climate classifications preferred within the scope of the study is the De Martonne climate classification. De Martonne climate classification (1929), annual average temperature, annual total average precipitation, the highest temperature averages, and lowest temperature averages seen in January and July, respectively, are based on the difference of these averages. The amount of annual precipitation distinguishes between wet and dry climates. Drought is related to the temperature, which appears as an evaporation factor, and the amount of precipitation. De Martonne classification formulas used within the scope of the study are given below (Akman, 1990).

De Martonne formula: $\mathrm{IM} = P/(T+10)$ (1)

P—annual average total precipitation and T—annual average temperature (°C).

According to De Martonne climate index values, climate formulas were applied with ArcGIS 10.5 software, one of the Geographic Information Systems programs, and climate model index values were calculated throughout Bursa. The reclassification process was applied according to the calculated climate model index values (Table 1), and maps were created according to the climate classification indices.

The second climate classification used in the study, the Emberger climate classification (Table 2), was created by the French phytogeographer and botanist Emberger (1933), and is ecophysiologically based. Emberger focused mainly on the Mediterranean climate and the climatic problems of these regions. He defined the Mediterranean climate according to photoperiodism, the amount of summer precipitation, the duration of the dry season, whether there are showers or infrequent precipitation in the rainy season, and the annual and monthly variability in precipitation amounts (Akman, 1990).

Emberger formula (°C): $\mathrm{IE} = [(100 \cdot P)/(M^2 - m^2)]$ (2)

Table 1.
De Martonne Climate Indices

Calculated Value	Climate Class
0–10	Arid
10.1–20	Semiarid
20.1–24	Mediterranean climate
24.1–28	Subhumid
28.1–35	Humid
35.1–55	Very humid
>55	Extremely humid

Table 2.
Emberger Climate Indices

Calculated Value	Climate Class
<30	Arid
30–50	Semiarid
50–90	Subhumid
>90	Humid

Table 3.
Lang Climate Indices

Calculated Value	Climate Class
0–20	Desert
20.1–40	Arid
40.1–60	Semiarid
60.1–100	Subhumid
100.1–160	Humid

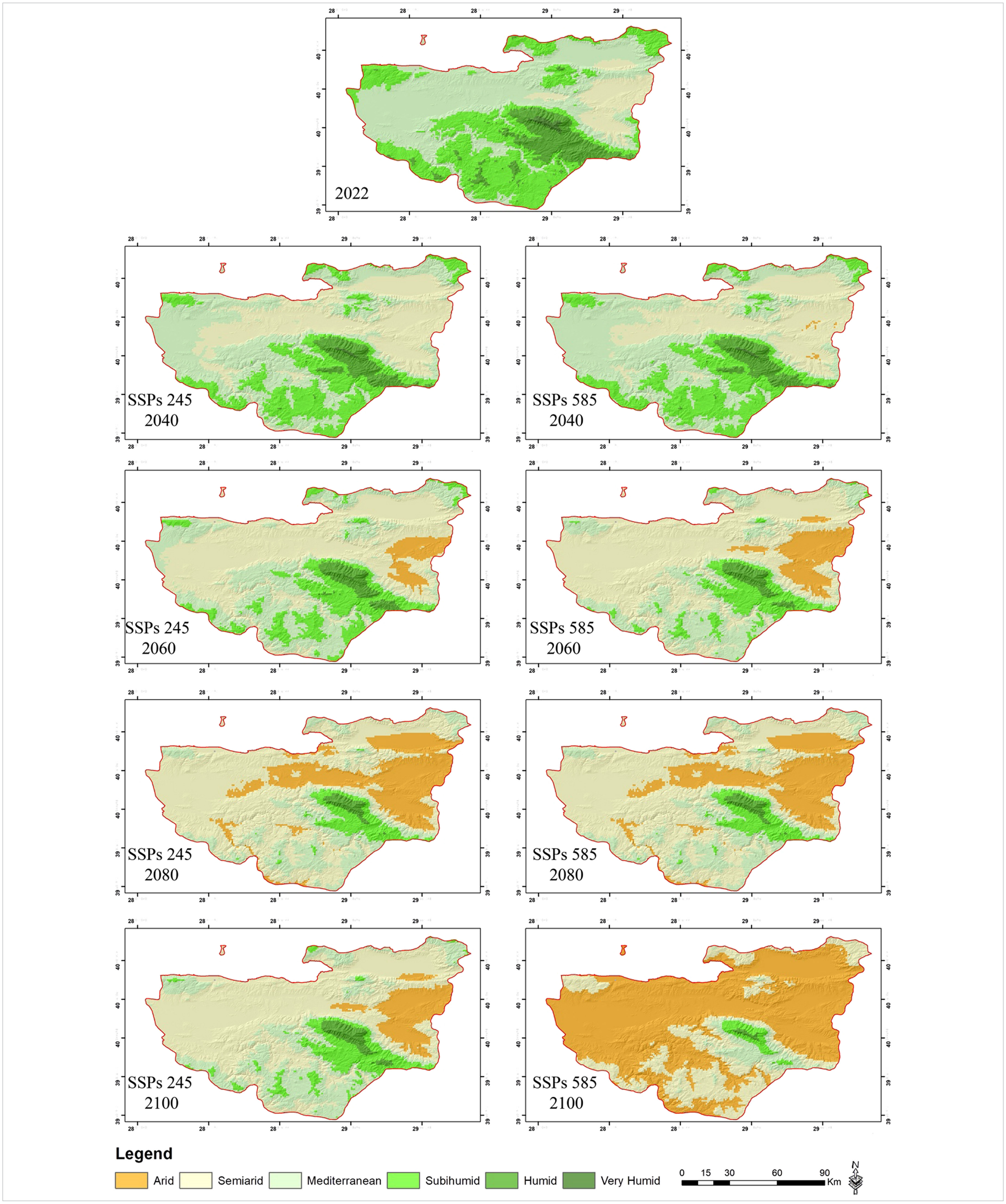

Figure 1.
Alteration of Climate Types Based on the De Martonne Climate Classes.

Table 4.
Areal Alteration of Climate Categories Based on the De Martonne Climate Classes

Climate Type	Today (2022)	SSPs 245				SSPs 585			
		2040	2060	2080	2100	2040	2060	2080	2100
Arid	0	0	4.66	23.19	10.12	0.24	9.28	23.19	69.17
Semiarid	9.82	33.35	46.47	53.36	55.32	30.94	54.93	53.36	23.13
Mediterranean	45.9	39.21	29.54	16.26	21.98	40.83	23.05	16.26	5.3
Subhumid	33.45	21.71	15.5	5.68	10.02	22.35	10.03	5.68	2.07
Humid	10.21	5.56	3.8	1.51	2.56	5.47	2.71	1.51	0.33
Very humid	0.62	0.17	0.03	0	0	0.17	0	0	0

where *M*—average highest temperature of the hottest month, *m*—average lowest temperature of the coldest month, and *P*—annual average total precipitation.

The third climate classification method applied within the scope of this study is the Lang (Erinç) Precipitation Efficiency formula (Erinç, 1969) (Table 3). This method is based on the parameters of annual precipitation amount and annual maximum temperature average. Erinç obtained rainfall efficiency classes by controlling these index results with the distribution areas of vegetation formations (Erinç, 1984).

Lang Climate Classification Formula: $L = P/\text{Ta}$ (3)

where *P*—annual average total precipitation and Ta—annual average temperature (°C).

After determining the possible changes in the climate class, the climate change throughout the province was evaluated, and the obtained data were tabulated and interpreted.

Results

In accordance with the scenarios subject to the study, visual (Figure 1) and spatial changes of the climate types of Bursa province between today and 2100, according to De Martonne climate classes in 20-year periods, are given in Table 4.

In accordance with the De Martonne climate classes, the Mediterranean climate type prevails in about 45.9% of the province of Bursa, the subhumid climate type prevails in 33.45%, the humid climate type prevails in 10.21%, and the semiarid climate type prevails in 9.82%. In contrast, approximately 0.62% of the province has a very humid climate type.

According to the SSPs 245 scenario, it is predicted that there will be aridity throughout the province by 2100; arid areas, that do not exist nowadays, will be formed as of 2060 and will be effective in approximately 23.19% of the province by 2080. On the other hand, very humid areas will not be seen by 2080, and the areas where the humid climate type prevails in more than 10% of the province today will decrease to 1.51% by 2080. It is predicted that the arid or semiarid climate type will dominate at least 65% of the province by 2080.

According to the SSPs 585 scenario, a much faster aridification is predicted. Under this scenario, areas with an arid climate type, which do not exist today, are projected to prevail in 23.19% of the province by 2080 and 69.17% by 2100. Additionally, it is anticipated that arid or semiarid climate types will prevail in more than 75% of the province by 2080 and more than 93% by 2100.

When Figure 1 is examined, it is predicted that the arid climate type will begin to be seen in the middle eastern part of the province and will gradually spread toward the west. It is estimated that the humid climate categories prevailing in the northern, southern, and western parts of the province will disappear quickly. According to Emberger climate classes, the alteration in climate over the period is presented in Figure 2, and the areal shift of climate types is given in Table 5.

In accordance with the Emberger climate classes, the humid climate type prevails in approximately 30.92% of Bursa province, and the subhumid climate type prevails in 69.08%. There are no arid or semiarid areas along the city. However, by 2100, according to the SSPs 245 scenario, the semiarid climate type will dominate approximately 28.23% of the province, and according to the SSPs 585 scenario, arid climate type will dominate approximately 5.8% of the province, and semiarid climate type will dominate in 82.65%. Especially according to the SSPs 585 scenario, it is forecasted that the semiarid climate type will dominate in more than half of the province by 2080. Upon evaluating Figure 2, it can be observed that the area with the highest drought risk is the center of the eastern part of the province. According to Erinç climate classes, the climate change during the process is presented in Figure 3, and the areal shift of climate types is given in Table 6.

According to the Erinç climate classification, while most of Bursa province (72.9%) shows a semiarid climate class type, only 3.74% has an arid one. According to the SSPs 245 scenario, the arid climate type will prevail in more than half of the province by 2060, and the arid climate type will prevail in more than 65% of the province by 2100. On the other hand, according to the SSPs 585 scenario, an arid climate type will be observed in approximately 93.45% of the province by 2100. According to this scenario, the semiarid climate type will be confined to only a small part of the province near the central areas in 2100.

Discussion

The current study results reveal that there will be noteworthy changes in climate types along Bursa province in the future. This change will occur in the form of climate types turning into arid climate types. This change in the climate types of the province is expected to have different effects on almost every field, from the change in the distribution zones of plant species to the energy needs of the province. As is known, climate not only shapes people's physical environment but also affects human life, all kinds of social and economic activities, and the formation of habitats for all living things. The effect of climate is seen in

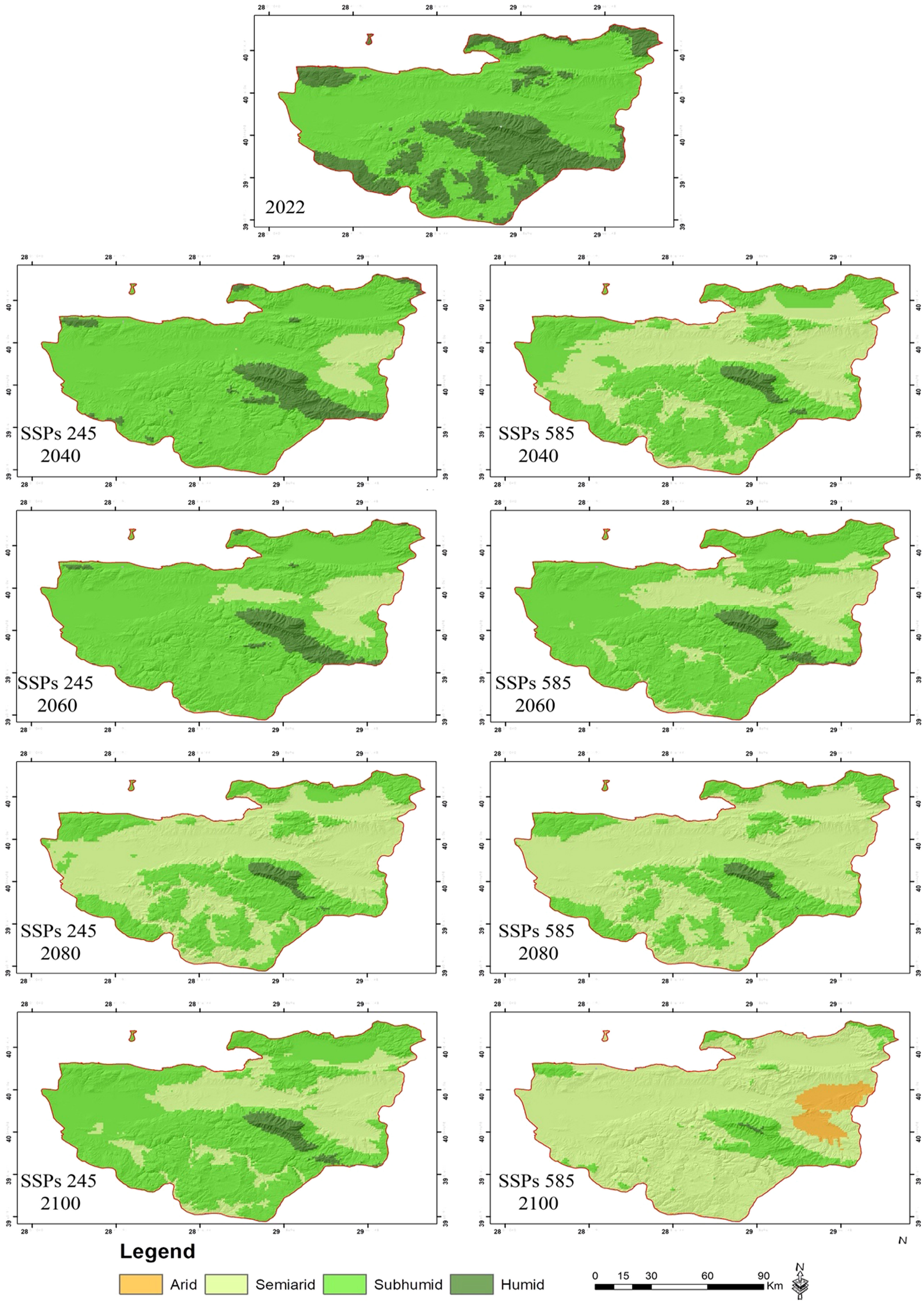

Figure 2.
Alteration of Climate Categories Based on the Emberger Climate Classes.

Table 5.
Areal Alteration of Climate Categories Based on the Emberger Climate Classes

Climate Type	Today (2022)	SSPs 245				SSPs 585			
		40	60	80	2100	40	60	80	2100
Arid	0	0	0	0	0	0	0	0	5.8
Semiarid	0	6.7	11.02	56.62	28.23	45.06	23.75	63.35	82.65
Subhumid	69.08	84.07	82.49	41.44	68.6	52.52	72.41	34.95	11.36
Humid	30.92	9.23	6.49	1.94	3.17	2.42	3.84	1.7	0.19

many areas, from people's clothing preferences to all kinds of economic processes to societies' language and cultural development. It is even stated that the climate significantly affects people's psychological states (Canturk & Kulaç, 2021; Dogan et al., 2022; Koç, 2022; Sevik et al., 2021).

The fact that climate is a factor that affects all living things on Earth makes climatic changes also important. It is known that the structure of the atmosphere has changed in the last century due to the influence of various anthropogenic factors, especially industrial activities (Savas et al., 2021), and the rate of gases such as CO_2 and methane (Elsunousi et al., 2021; Isinkaralar, 2023a; 2023b), as well as various elements in the atmosphere has increased (Karacocuk et al., 2022). This change has caused climate change on a global scale, and urbanization and climate change due to industrial activities have become irreversible problems worldwide (Ghoma et al., 2023; Key et al., 2023).

At this stage, it is emphasized that GCC must be confronted and that possible changes in every field must be identified, and measures must be taken to reduce the destructive effects of the process (Varol et al., 2022a,b). For this purpose, it is necessary first to determine the effects of the process and climatic changes. As revealed by this study, climates across Bursa will rapidly shift towards arid climate types. Similar outcomes were achieved in various projects conducted in different provinces on the topic. Cetin (2020) stated that in Mersin, according to the RCP 8.5 scenario in 2070, the arid climate type will dominate in approximately 0.44% of the province, and the semiarid climate type will dominate in 80.5%. Similar results were found in reports conducted in dissimilar provinces in Türkiye, such as Muğla (Cetin et al., 2023), Düzce (Koç, 2021a), and Bolu (Koç, 2021b).

Our country, Türkiye, is one of the nations that will be most influenced by GCC. T is among the "countries at risk," with claims that the temperature will rise until 2100, and this escalation may extend 6ºC (Turan, 2018). This situation will have an impact on many regions. For example, as a result of a study conducted in Mugla, it was reported that biocomfort areas would change significantly. In this study, it was revealed that according to the SSPs 585 scenario, cold and cool areas, which currently cover approximately 46.09% of the province, will completely disappear in 2100, and approximately 68.78% of the province will be located in hot areas (Cetin et al., 2023).

It is stated that climate change will impact almost every area and may cause momentous and devastating alterations worldwide (Tekin et al., 2022). The living group that will be most affected by this process is shown to be plants. Because plants' development and all their phenotypic characteristics are formed by the interaction of their genetic structure (Hrivnák et al., 2017; Kurz et al., 2023) and environmental situations (Erdem et al., 2023a; 2023b; Tandogan et al., 2023). Therefore, environmental factors mainly influence plant development (Cobanoglu et al., 2023b; Sulhan et al., 2022; Yigit et al., 2023). Not having an effective movement and migration apparatus makes trees vulnerable to shifts that will appear due to GCC (Varol et al., 2021). For this reason, it is indicated that the most devastating impacts of climate change will show themselves on plants with long life cycles.

It is noted that the primary cause of GCC is human-induced alterations in the atmospheric structure, especially industrial actions (Isinkaralar et al., 2023a; 2023b). Many studies emphasize that the concentrations of atmospheric pollutants such as CO_2, heavy metals, and particulate matter have increased significantly in recent years (Elsunousi et al., 2021; Istanbullu et al., 2023; Koç et al., 2023; Sevik et al., 2015). Therefore, to diminish the consequences of GCC, it is vital first to reduce the cause, and the first step to be taken for this is to reduce fossil fuel consumption. However, this does not seem possible because the world's energy need is continuously growing, and worldwide energy consumption in 2030 is estimated to be 60% more than now (Kilicoglu et al., 2021). For this reason, numerous scientists stated that the potential outcomes of GCC should be defined, and protections should be taken (Varol et al., 2021).

It is known that the most devastating outcomes of GCC will be on plants. Therefore, it is emphasized that priority should be given to studies in the field of forestry, possible suitable distribution area changes should be determined in advance, and the migration mechanism needed by the species should be provided by human hands (Ning et al., 2021; Tekin et al., 2022). Agricultural product options suitable for new climate types should be evaluated in agricultural areas. Apart from this, the trees' response to environmental parameters is closely connected to the genetic makeup of the tree species, and because tree species of the same species have diverse genetic assemblies, they can respond to similar growth surroundings and stress situations at altered levels (Ozel et al., 2021a; 2021b; Yigit et al., 2016). Hence, determining the origins that best resist and adapt to the stress reasons that will appear due to drought and, using them in afforestation activities and choosing these origins in agricultural products is extremely important in terms of adaptation to GCC.

Recommendations

In conclusion, it is predicted that arid climate types will begin to be seen in the middle eastern part of the province according to all three climate types and will gradually spread toward the west. The humid climate types prevailing in the province's northern, southern, and western parts are estimated to disappear quickly. Therefore, climates throughout Bursa will rapidly shift toward arid climate types. This situation will significantly affect agricultural and forest areas. It is recommended that the relevant institutions consider the study's results and that necessary precautions be taken in agricultural and forest areas.

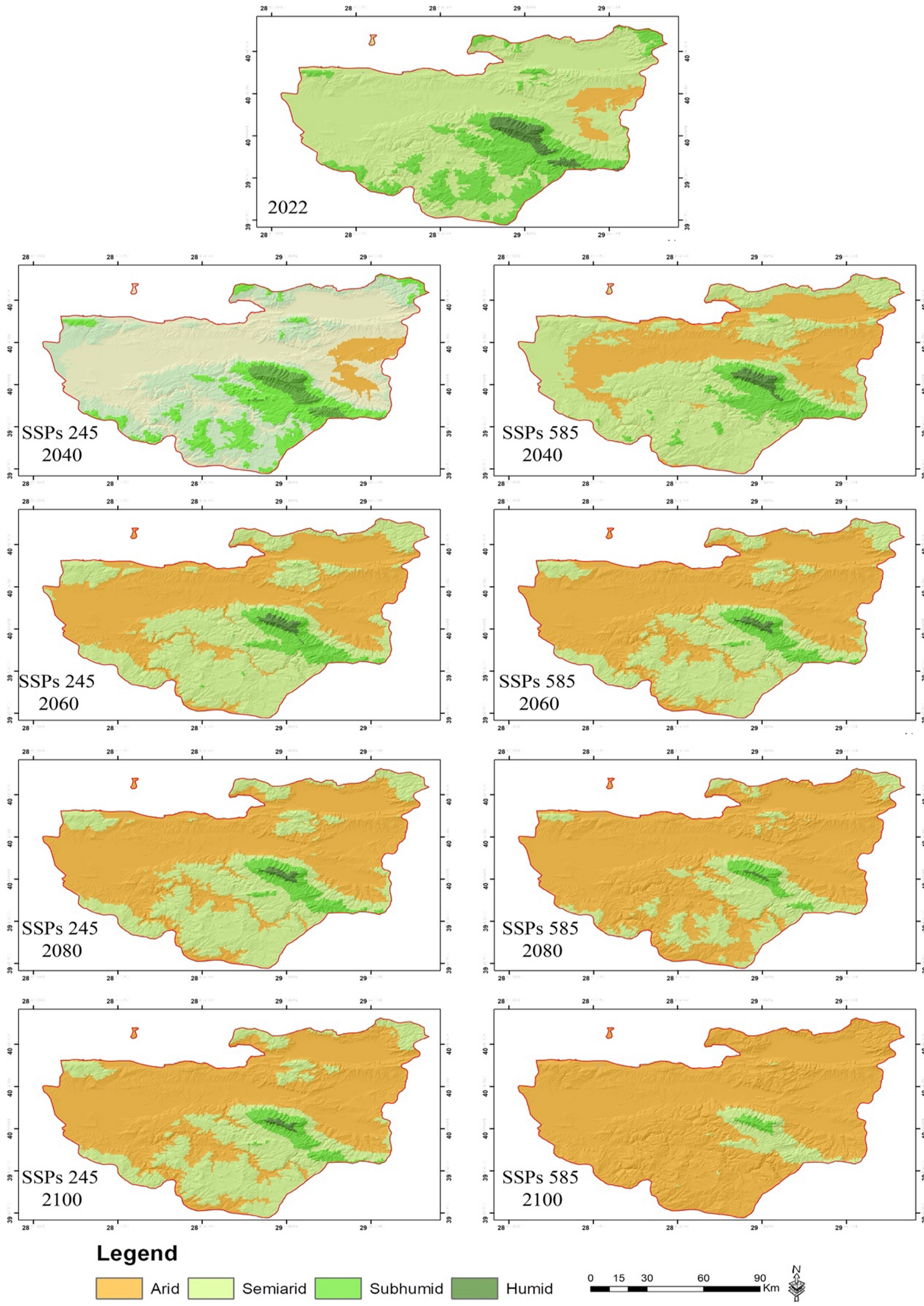

Figure 3.
Alteration of Climate Classification Based on the Erinç Climate Classes.

Table 6.
Areal Alteration of Climate Categories Based on the Erinç Climate Classes

Climate Type	Today (2022)	SSPs 245 40	SSPs 245 60	SSPs 245 80	SSPs 245 2100	SSPs 585 40	SSPs 585 60	SSPs 585 80	SSPs 585 2100
Arid	3.74	34.81	50.98	59.85	65.07	35.41	62.28	78.21	93.45
Semiarid	72.9	55.11	42.25	35.01	30.77	54.88	32.74	19.25	5.75
Sub-humid	20.44	8.68	5.87	4.56	3.75	8.42	4.38	2.38	0.8
Humid	2.92	1.4	0.9	0.58	0.41	1.29	0.6	0.16	0

It is impossible to stop GCC under present environments, and it is estimated that this alteration will impact almost every area. For this cause, stakeholders from different sectors need to prepare strategies and take precautions to contribute to the process and be affected at the least level. Some of these recommendations include providing energy needs from renewable energy sources, economical use of natural resources, especially water, choosing plant genotypes with lower water demands in forestry and agriculture, including process-related projections in forestry studies in management policies and plans, and using drought-resistant plant species and varieties adapting to new climate types in agricultural areas. These recommendations should be combined with the study results, and implementation plans should be created. For example, it is recommended to carry out afforestation activities in forest areas with species compatible with drought and the soil structure of the region and to start planting agricultural products that are more drought-resistant, at least on a trial basis.

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References

- Akman, Y. (1990). *İklim ve biyoiklim* (pp. 186–193). Palme Yayınları.
- Aricak, B., Cetin, M., Erdem, R., Sevik, H., & Cometen, H. (2019). The change of some heavy metal concentrations in Scotch pine (Pinus sylvestris) depending on traffic density, organelle and washing. *Applied Ecology and Environmental Research*, *17*(3), 6723–6734. [CrossRef]
- Ati, O. F., Aremu, K., Olatunde, A. F., Abaje, I. B., and Oladipo, E. O. (2022). Meteorological drought and temperature in sudanosahelian region of Nigeria under increasing global warming. In: Stuart Harris (Ed). The Nature, Causes, Effects and Mitigation of Climate Change on the Environment, (pp: 201-216) Chapter 12, IntechOpen Book Series, London. [CrossRef]
- Beloiu, M., Poursanidis, D., Tsakirakis, A., Chrysoulakis, N., Hoffmann, S., Lymberakis, P., Barnias, A., Kienle, D., & Beierkuhnlein, C. (2022). No treeline shift despite climate change over the last 70 years. *Forest Ecosystems*, *9*, 100002. [CrossRef]
- Bouabdelli, S., Zeroual, A., Meddi, M., & Assani, A. (2022). Impact of temperature on agricultural drought occurrence under the effects of climate change. *Theoretical and Applied Climatology*, *148*(1–2), 191–209. [CrossRef]
- Canturk, U., & Kulaç, Ş. (2021). The effects of climate change scenarios on Tilia ssp. in Turkey. *Environmental Monitoring and Assessment*, *193*(12), 771. [CrossRef]
- Cesur, A., Zeren Cetin, I., Cetin, M., Sevik, H., & Ozel, H. B. (2022). The Use of *Cupressus arizonica* as a biomonitor of Li, Fe, and Cr Pollution in Kastamonu. *Water, Air, and Soil Pollution*, *233*(6), 193. [CrossRef]
- Cetin, M. (2020). The changing of important factors in the landscape planning occur due to global climate change in temperature, Rain and climate types: A case study of Mersin City. *Turkish Journal of Agriculture – Food Science and Technology*, *8*(12), 2695–2701. [CrossRef]
- Cetin, M., Sevik, H., Koc, I., & Zeren Cetin, I. Z. (2023). The change in biocomfort zones in the area of Muğla province in near future due to the global climate change scenarios. *Journal of Thermal Biology*, *112*, 103434. [CrossRef]
- Cobanoglu, H., Sevik, H., & Koç, İ. (2023a). Do annual rings really reveal Cd, Ni, and Zn pollution in the air related to traffic density? An example of the cedar tree. *Water, Air, and Soil Pollution*, *234*(2), 65. [CrossRef]
- Cobanoglu, H., Canturk, U., Koç, I., Kulac, S., & Sevik, H. (2023b). Climate change effect on potential distribution of Anatolian chestnut (*Castanea sativa mill.*) in the upcoming century in Türkiye. *Forestist*, *73*(3), 247–256. [CrossRef]
- Dogan, S., Kilicoglu, C., Akinci, H., Sevik, H., & Cetin, M. (2022). Determining the suitable settlement areas in Alanya with GISbased site selection analyses. *Environmental Science and Pollution Research*. [CrossRef]
- Elsunousi, A. A. M., Sevik, H., Cetin, M., Ozel, H. B., & Ozel, H. U. (2021). Periodical and regional change of particulate matter and CO_2 concentration in Misurata. *Environmental Monitoring and Assessment*, *193*(11), 707. [CrossRef]
- Erdem, R., Cetin, M., Aricak, B., & Sevik, H. (2023a). The change of the concentrations of boron and sodium in some forest soils depending on plant species. *Forestist*, *73*(2), 207–212. [CrossRef]
- Erdem, R., Aricak, B., Cetin, M., & Sevik, H. (2023b). Change in some heavy metal concentrations in forest trees by species, organ, and soil depth. *Forestist*, *73*(3), 257–263. [CrossRef]
- Erinc, S. (1969). *Klimatoloji ve metodları*. Üniversitesi, Coğrafya Enstitüsü.
- Erinç, S. (1984). *Klimatoloji ve Metotları* (3. Baskı). İstanbul Üniversitesi Deniz Bilimleri ve Coğrafya Enstitüsü Yayınları.
- Feng, S., Hao, Z., Zhang, X., Wu, L., Zhang, Y., & Hao, F. (2022). Climate change impacts on concurrences of hydrological droughts and high temperature extremes in a semi-arid river basin of China. *Journal of Arid Environments*, *202*, 104768. [CrossRef]
- Ghoma, W. E. O., Sevik, H., & Isinkaralar, K. (2022). Using indoor plants as biomonitors for detection of toxic metals by tobacco smoke. *Air Quality, Atmosphere and Health*, *15*(3), 415–424. [CrossRef]
- Ghoma, W. E. O., Sevik, H., & Isinkaralar, K. (2023). Comparison of the rate of certain trace metals accumulation in indoor plants for smoking and non-smoking areas. *Environmental Science and Pollution Research International*, *30*(30), 75768–75776. [CrossRef]
- Hrivnák, M., Krajmerová, D., Paule, L., Zhelev, P., Sevik, H., Ivanković, M., Goginashvili, N., Paule, J., & Gömöry, D. (2023). Are there hybrid zones in *Fagus sylvatica* L. sensu lato? *European Journal of Forest Research*. [CrossRef]
- Hrivnák, M., Paule, L., Krajmerová, D., Kulaç, Ş., Şevik, H., Turna, İ., Tvauri, I., & Gömöry, D. (2017). Genetic variation in tertiary relics: The case of eastern-Mediterranean Abies (Pinaceae). *Ecology and Evolution*, *7*(23), 10018–10030. [CrossRef]
- Isinkaralar, K., Koc, I., Erdem, R., & Sevik, H. (2022). Atmospheric Cd, Cr, and Zn deposition in several landscape plants in Mersin, Türkiye. *Water, Air, and Soil Pollution*, *233*(4). [CrossRef]
- Isinkaralar, K., Isinkaralar, O., Koç, İ., Özel, H. B., & Şevik, H. (2023a). Assessing the possibility of airborne bismuth accumulation and spatial distribution in an urban area by tree bark: A case study in Düzce, Türkiye. *Biomass Conversion and Biorefinery*, 1–12. [CrossRef]
- Isinkaralar, O., Isinkaralar, K., Sevik, H., & Kucuk, O. (2023b). Spatial modeling the climate change risk of river basins via climate classification: A scenario-based prediction approach for Türkiye. *Natural Hazards*, 1–18.
- Istanbullu, S. N., Sevik, H., Isinkaralar, K., & Isinkaralar, O. (2023). Spatial distribution of heavy metal contamination in road dust samples from an urban environment in Samsun, Türkiye. *Bulletin of Environmental Contamination and Toxicology*, *110*(4), 78. [CrossRef]
- Karacocuk, T., Sevik, H., Isinkaralar, K., Turkyilmaz, A., & Cetin, M. (2022). The change of Cr and Mn concentrations in selected plants in Samsun city center depending on traffic density. *Landscape and Ecological Engineering*, *18*(1), 75–83. [CrossRef]
- Key, K., Kulaç, Ş., Koç, İ., & Sevik, H. (2022). Determining the 180-year change of Cd, Fe, and Al concentrations in the air by using annual rings of *Corylus colurna* L. *Water, Air, and Soil Pollution*, *233*(7), 1–13. [CrossRef]
- Key, K., Kulaç, Ş., Koç, İ., & Sevik, H. (2023). Proof of concept to characterize historical heavy metal concentrations in atmosphere in North Turkey: Determining the variations of Ni, Co and Mn concentrations in 180-year-old *Corylus colurna* L. (Turkish hazelnut) annual rings. *Acta Physiologiae Plantarum*, *45*(10), 1–13. [CrossRef]
- Kilicoglu, C., Cetin, M., Aricak, B., & Sevik, H. (2021). Integrating multicriteria decision-making analysis for a GIS-based settlement area in the district of Atakum, Samsun, Turkey. *Theoretical and Applied Climatology*, *143*(1–2), 379–388. [CrossRef]
- Koç, İ. (2021a). Changes that may occur in temperature, rain, and climate types due to global climate change: The example of Düzce. *Turkish Journal of Agriculture – Food Science and Technology*, *9*(8), 1545–1554. [CrossRef]
- Koç, I. (2021b). The effect of global climate change on some climate parameters and climate types in Bolu. *Journal of Bartin Faculty of Forestry*, *23*(2), 706–719.
- Koc, I. (2022). Determining the near-future biocomfort zones in Samsun Province by the global climate change scenarios. *Kastamonu University Journal of Forestry Faculty*, *22*(2), 181–192.

- Koc, I., Cobanoglu, H., Canturk, U., Key, K., Kulac, S., & Sevik, H. (2023). Change of Cr concentration from past to present in areas with elevated air pollution. *International Journal of Environmental Science and Technology*, 1–12.
- Koc, I., & Nzokou, P. (2022). Do various conifers respond differently to water stress? A comparative study of white pine, concolor and balsam fir. *Kastamonu University Journal of Forest Faculty*, *22*(1), 1–16.
- Kubelka, V., Sandercock, B. K., Székely, T., & Freckleton, R. P. (2022). Animal migration to northern latitudes: Environmental changes and increasing threats. *Trends in Ecology and Evolution*, *37*(1), 30–41. [CrossRef]
- Kurz, M., Kölz, A., Gorges, J., Pablo Carmona, B., Brang, P., Vitasse, Y., Kohler, M., Rezzonico, F., Smits, T. H. M., Bauhus, J., Rudow, A., Kim Hansen, O., Vatanparast, M., Sevik, H., Zhelev, P., Gömöry, D., Paule, L., Sperisen, C., & Csilléry, K. (2023). Tracing the origin of Oriental beech stands across Western Europe and reporting hybridization with European beech–Implications for assisted gene flow. *Forest Ecology and Management*, *531*, 120801. [CrossRef]
- Kuzmina, N., Menshchikov, S., Mohnachev, P., Zavyalov, K., Petrova, I., Ozel, H. B., Aricak, B., Onat, S. M., & Sevik, H. (2023). Change of aluminum concentrations in specific plants by species, organ, washing, and traffic density. *BioResources*, *18*(1), 792–803. [CrossRef]
- Ning, H., Ling, L., Sun, X., Kang, X., & Chen, H. (2021). Predicting the future redistribution of Chinese White pine Pinus armandii Franch. under climate change scenarios in China using species distribution models. *Global Ecology and Conservation*, *25*, e01420. [CrossRef]
- Ozel, H. B., Cetin, M., Sevik, H., Varol, T., Isik, B., & Yaman, B. (2021a). The effects of base station as an electromagnetic radiation source on flower and cone yield and germination percentage in Pinus brutia Ten. *Biologia Futura*, *72*(3), 359–365. [CrossRef]
- Ozel, H. B., Abo Aisha, A. E. S., Cetin, M., Sevik, H., & Zeren Cetin, I. (2021b). The effects of increased exposure time to UV-B radiation on germination and seedling development of Anatolian Black pine seeds. *Environmental Monitoring and Assessment*, *193*(7), 388. [CrossRef]
- Özel, H. B., Şevik, H., Onat, S. M., & Yiğit, N. (2022). The effect of geographic location and seed storage time on the content of fatty acids in stone pine (Pinus pinea L.) seeds. *BioResources*, *17*(3), 5038–5048. [CrossRef]
- Ozkazanc, N. K., Ozay, E., Ozel, H. B., Cetin, M., & Sevik, H. (2019). The habitat, ecological life conditions, and usage characteristics of the otter (Lutra lutra L. 1758) in the Balikdami Wildlife Development Area. *Environmental Monitoring and Assessment*, *191*(11), 645. [CrossRef]
- Savas, D. S., Sevik, H., Isinkaralar, K., Turkyilmaz, A., & Cetin, M. (2021). The potential of using *Cedrus atlantica* as a biomonitor in the concentrations of Cr and Mn. *Environmental Science and Pollution Research International*, *28*(39), 55446–55453. [CrossRef]
- Şevik, H., Cetin, M., & Belkayalı, N. (2015). Effects of forests on amounts of CO2: Case study of Kastamonu and Ilgaz Mountain National Parks. *Polish Journal of Environmental Studies*, *24*(1), 253–256. [CrossRef]
- Sevik, H., Cetin, M., Ozel, H. B., Erbek, A., & Zeren Cetin, I. (2021). The effect of climate on leaf micromorphological characteristics in some broad-leaved species. *Environment, Development and Sustainability*, *23*(4), 6395–6407. [CrossRef]
- Sulhan, O. F., Sevik, H., & Isinkaralar, K. (2022). Assessment of Cr and Zn deposition on Picea pungens Engelm. in urban air of Ankara, Türkiye. *Environment, Development and Sustainability*. [CrossRef]
- Tandoğan, M., Özel, H. B., Gözet, F. T., & Şevik, H. (2023). Determining the Taxol contents of yew tree populations in western Black Sea and Marmara regions and analyzing some forest stand characteristics. *BioResources*, *18*(2), 3496–3508. [CrossRef]
- Tekin, O., Cetin, M., Varol, T., Ozel, H. B., Sevik, H., & Zeren Cetin, I. (2022). Altitudinal migration of species of fir (*Abies spp.*) in adaptation to climate change. *Water, Air, and Soil Pollution*, *233*(9), 385. [CrossRef]
- Turan, E. S. (2018). Turkey's drought status associated with climate change. Artvin Çoruh university natural hazards application and research center. *Journal Natural Hazards Environment*, *4*(1), 63–69.
- Ucun Ozel, H., Ozel, H. B., Cetin, M., Sevik, H., Gemici, B. T., & Varol, T. (2019). Base alteration of some heavy metal concentrations on local and seasonal in Bartin River. *Environmental Monitoring and Assessment*, *191*(9), 594. [CrossRef]
- Varol, T., Canturk, U., Cetin, M., Ozel, H. B., & Sevik, H. (2021). Impacts of climate change scenarios on European ash tree (*Fraxinus excelsior* L.) in Turkey. *Forest Ecology and Management*, *491*, 119199. (doi: [CrossRef])
- Varol, T., Cetin, M., Ozel, H. B., Sevik, H., & Zeren Cetin, I. (2022a). The Effects of Climate Change Scenarios on Carpinus betulus and *Carpinus orientalis* in Europe. *Water, Air, and Soil Pollution*, *233*(2), 45. [CrossRef]
- Varol, T., Canturk, U., Cetin, M., Ozel, H. B., Sevik, H., & Zeren Cetin, I. (2022b). Identifying the suitable habitats for Anatolian boxwood (*Buxus sempervirens* L.) for the future regarding the climate change. *Theoretical and Applied Climatology*, *150*(1–2), 637–647. [CrossRef]
- Yigit, N., Mutevelli, Z., Sevik, H., Onat, S. M., Ozel, H. B., Cetin, M., & Olgun, C. (2021). Identification of some fiber characteristics in Rosa sp. and nerium oleander L. wood grown under different ecological conditions. *BioResources*, *16*(3), 5862–5874. [CrossRef]
- Yigit, N., Öztürk, A., Sevik, H., Özel, H. B., Kshkush, F. E. R., & Işık, B. (2023). Clonal variation based on some morphological and micromorphological characteristics in the Boyabat (Sinop/Turkey) black pine (*Pinus nigra* subsp. *pallasiana* (Lamb.) Holmboe) seed orchard. *BioResources*, *18*(3), 4850–4865. [CrossRef]
- Yigit, N., Sevik, H., Cetin, M., & Kaya, N. (2016). Determination of the effect of drought stress on the seed germination in some plant species. *Water Stress in Plants*, 43–62.
- Yucedag, C., Ozel, H. B., Cetin, M., & Sevik, H. (2019). Variability in morphological traits of seedlings from five Euonymus japonicus cultivars. *Environmental Monitoring and Assessment*, *191*(5), 285. [CrossRef]
- Zeren Cetin, I., Varol, T., Ozel, H. B., & Sevik, H. (2023). The effects of climate on land use/cover: A case study in Turkey by using remote sensing data. *Environmental Science and Pollution Research International*, *30*(3), 5688–5699. [CrossRef]