HOW WILL CLIMATE CHANGE IMPACT THE PROTECTED AREA NETWORK IN TURKEY?

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ABSTRACT

HOW WILL CLIMATE CHANGE IMPACT THE PROTECTED AREA NETWORK IN TURKEY?

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Climate Change is a critical problem which might have irrecoverable effects on nature. Due to rising GHG concentrations in the atmosphere, and consequent global warming, global biodiversity is increasingly under threat. Protected areas are the most important tools to conserve biodiversity from destruction. That is why estimating future climatic conditions in protected areas plays a critical role in the prediction of possible changes in biota and ecosystems. Climate velocity is one such measurement that estimates the spatial change in climate over a certain period, which in turn can be used to assess how species or ecosystems will respond to climate change. Turkey will also be affected from climate change in this century. Therefore, to find out whether our protected area network will continue to be sufficient in in the future, and if movement of the biota inside towards newly climatically suitable areas will be possible, we will build a climate velocity surface for Turkey, estimate the positions of protected areas in the new climate space, and then assess whether they will be able to maintain their functions.

Keywords: Climate Change, Climate Velocity, Protected Areas, Climate Projections

ÖZ

İKLİM DEĞİŞİKLİĞİ TÜRKİYE'DEKİ KORUMA ALANLARI AĞINI NASIL ETKİLEYECEK?

Erol, Dudu
Yüksek Lisans, Yer Sistem Bilimleri
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Haziran 2021, 78 sayfa

İklim Değişikliği, doğa üzerinde geri dönüşü olmayan etkileri olabilecek kritik bir sorundur. Atmosferdeki yükselen sera gazı konsantrasyonları ve bunun sonucunda küresel ısınma nedeniyle küresel biyoçeşitlilik giderek daha fazla tehdit altında. Korunan alanlar, biyolojik çeşitliliği yıkımdan korumak için en önemli araçlardır. Korunan alanlarda gelecekteki iklim koşullarının tahmin edilmesinin, biyota ve ekosistemlerdeki olası değişikliklerin tahmin edilmesinde kritik bir rol oynamasının nedeni budur. İklim hızı, belirli bir süre boyunca iklimdeki mekansal değişimi tahmin eden bu türden bir ölçümdür; bu da, türlerin veya ekosistemlerin iklim değişikliğine nasıl tepki vereceğini değerlendirmek için kullanılabilir. Türkiye bu yüzyılda iklim değişikliğinden de etkilenecektir. Bu nedenle, korunan alan ağımızın gelecekte de yeterli olmaya devam edip edemeyeceğini ve yeni iklimlendirmeye uygun alanlara doğru içeride biyota hareketi yapılabileceğini öğrenmek için, Türkiye için bir iklim hızı yüzeyi oluşturacağız, Yeni iklim alanında korunan alanlar ve daha sonra bunların işlevlerini sürdürüp sürdüremeyeceğini değerlendirir.

Anahtar Kelimeler: İklim Değişikliği, İklim Hızı, İklim Projeksiyonları, Koruma Alanları

Eppur si muove…

-Galileo Galilei

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CHAPTER 1

INTRODUCTION

Humanity is increasingly facing climate change and its negative effects on Earth and all living things on it. In addition to climate change, human pressures resulting from urbanization and agriculture intensify the threats on natural areas and biodiversity. Especially after the Industrial Revolution, climate change started to pose a threat to integrity and viability of global biodiversity. Ecosystems and the living things associated with them are increasingly forced to either adapt, migrate or perish in the face of a fast shift in climatic patterns over time and space.

Protected areas are a major means for conservation of biodiversity and natural assets. But it has started to fall short against the effects of climate change because of shifting biota due to ongoing climatic change. In recent years, climate velocity has started to be used for climatic shift predictions. This study is aimed to search climate change impact on protected areas in Turkey by calculating climate velocity

1.1 Climate Change

The climate of the Earth has always been changing. Climate is influenced by changes in the Earth's orbit, seismic activities, the sun's energy supply, and other external and internal processes (Riedy, 2016). This kind of long-term change is considered natural climate change. After the Industrial Revolution, the increase in fossil fuel burning, deforestation and agricultural activities caused an intense release of human-induced greenhouse gas emissions and led to global warming, the main manifestation of climate change. As an outcome of climate change, higher temperatures, shifts in rainfall patterns, changes in the frequency and distribution of weather conditions such as droughts, hurricanes, flooding and heat waves, sea level rise, and consequent effects on human and natural environments have been widely observed. It is obvious that the consequences of climate change on natural and human environments will be catastrophic and that climate change constitutes an existential danger to ecosystems and biodiversity. From the organism to the biome, climate change's various elements are expected to have an effect on habitats at all stages.

According to IPCC Summary for Policy Makers Report, human activities are estimated to have induced around 1 degree Celsius of global warming over pre-industrial levels, with a possible range of 0.8 to 1.2 degree. Within the next 50 years, global warming is expected to hit the 1.5-degree mark if warming tends to rise at the present pace.

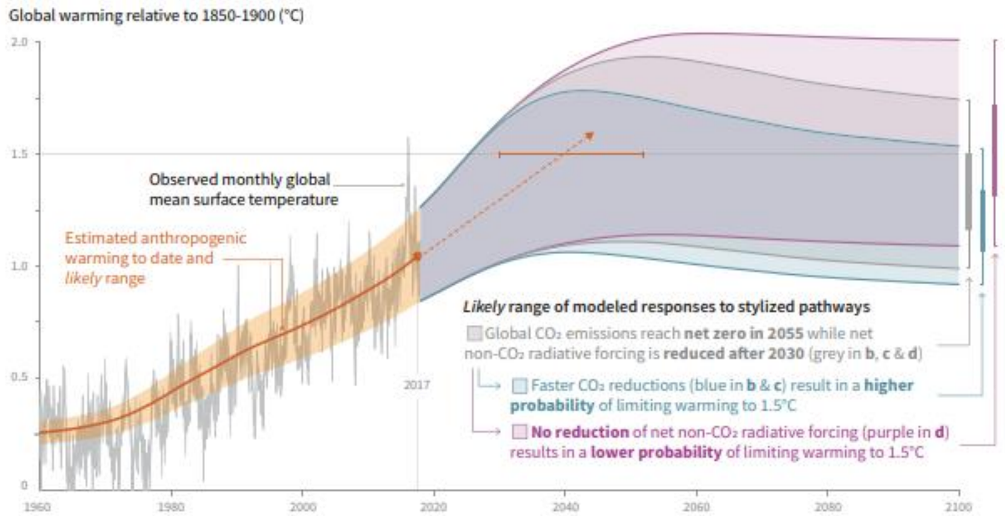


Figure 1.1. Observed global temperature change and modeled responses to stylized anthropogenic emission and forcing pathways (Source: IPCC Report)

Global climate change, also, will lead to an evolving relationship between the changing ranges of populations of plants and animals and the fixed limits of protected areas (Hannah 2008). Many protected areas are intended to reflect unique environmental structures, animals, and populations and aim to conserve them.

However, animals are migrating, plant and animal populations are being reassembled, and classic ecosystems are shifting or vanishing as temperature, precipitation, heat, and carbon dioxide (CO2) regimes alter. Current safe areas maybe some of the planet's most vulnerable regions to climate change. In the middle of degraded or established ecosystems, they are mostly tiny scattered fragments, and they often contain uncommon or unusual organisms and populations with narrow environmental tolerances.

1.1.1 Climate Change in Turkey

Climate change can vary from one location to another around the world. Turkey is one of the countries which is highly vulnerable to climate change. In Turkey, with the increase in population in the last 50 years, an increase of up to 3 times in temperature normal is observed. This demographic growth in favor of cities has drastic impacts on land-use structures, turns natural fields into concrete houses, and this, in turn, results in major changes in micro and mesoscale climatic conditions.

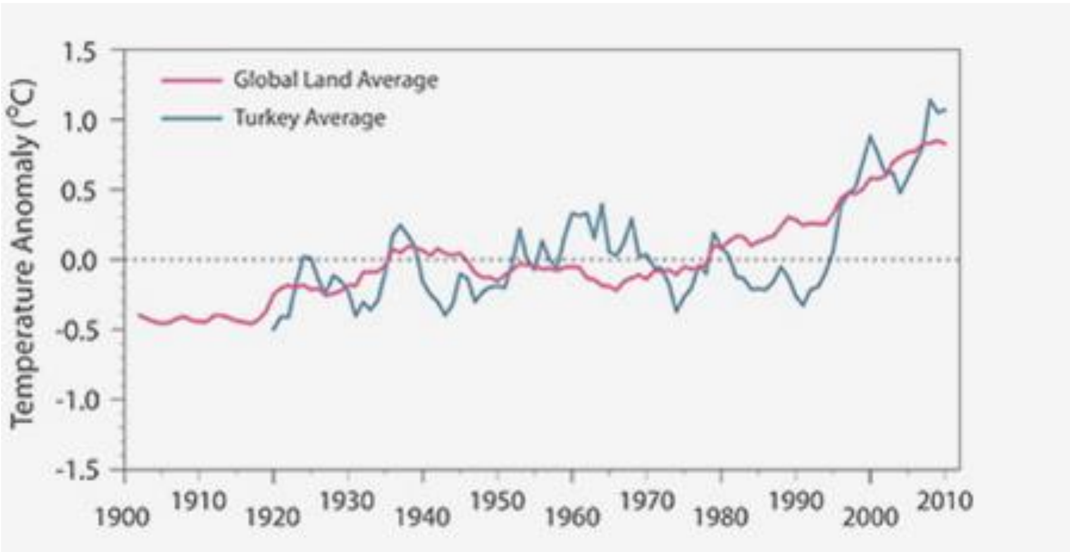


Figure 1.2. Temperature trend comparison between Turkey Average and Global Land Average since the year from 1900 (http://climatechangeinturkey.com/)

As shown in figure1.2, in the 1970s, warming trend began in Turkey and after the 1990s it follows above of global trend. When the annual average temperature trends of the 10-year periods from 1971 to the present in Turkey are examined, an increasing trend is observed in general. In a recent IPCC report, it was found that Turkey’s Mediterranean Region is one of the most sensitive areas that will be adversely affected by climate change due to the rise of temperatures by 1 to 2 degrees Celsius. It is also expected that aridity will spread across a larger area, and heatwaves and the number of extremely hot days will increase particularly in inland areas. Furthermore, significant variations in precipitation (extremely low or high) are expected and an increasing trend in average temperature is observed (IPCC, 2013).

Temperatures in Turkey are expected to rise by 2.5 to 4 degrees Celsius, rising up to 5°C in the interior and up to 4°C in the Aegean and Eastern Anatolia Regions (Turkey’s National Climate Change Adaptation Strategy and Action Plan, 2011). The IPCC study, as well as other national and international science modeling reports, shows that Turkey will get drier, hotter, and more erratic with regards to precipitation trends in the short run.

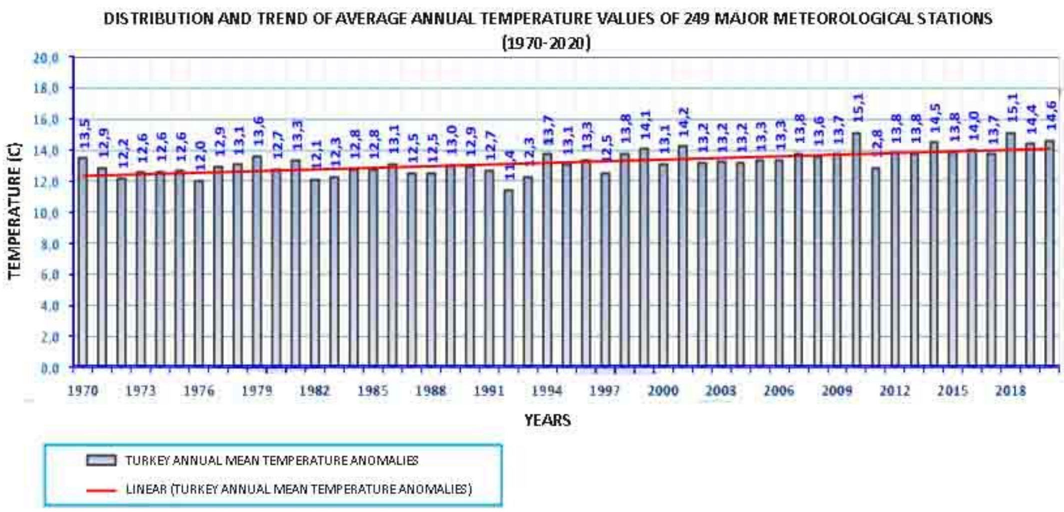


Figure 1.3. Turkey annual mean temperature anomalies between 1970 - 2020 (General Directorate of Meteorology,2021)

Indeed, annual temperatures in Turkey are increasing. Turkey is also feeling the effects of climate change as timing of seasons (phenology) start to shift, and exacerbated drought occurs in areas where precipitation is delayed. The highest increase in annual temperature was realized at 0.7 degrees from 1991 to 2010. Annual average temperatures are predicted to rise between 1.5 to 2.5 degrees according to the RCP4.5 scenario and 2.5 to 3.6 degrees according to the RCP8.5 scenarios for the next 100 years' timeframe in forecasts by the General Directorate of Meteorology (GDM).

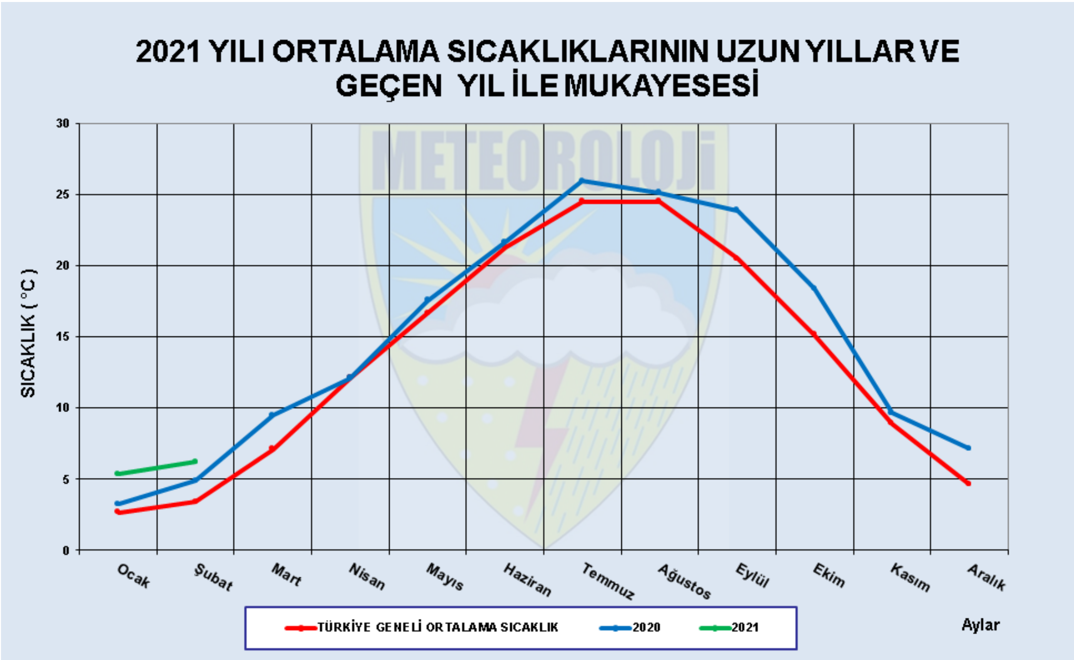


Figure 1.4. 2021 and past years average monthly temperature anomalies (General Directorate of Meteorology,2021)

Also when we look at the seasonal average anomalies, an increasing temperature trend is seen. Turkey's 1981-2010 winter average temperature was 3.6° C. In contrast, the average temperature of the 2020-2021 winter season was 6.2° C, 2.6° C above seasonal norms. Similarly, the average summer temperature between 1981-

2010 was 23.4 ° C while the average temperature of the 2020 summer was 24.3° C, 1.1° C above seasonal norms (General Directorate of Meteorology, 2021).

According to long-term observation results of the General Directorate of Meteorology, Turkey received an average of 500.1 mm of precipitation in 2020. There was a decrease in precipitation compared to normal and last year's precipitation. The annual precipitation across the country decreased by 12.9% compared to normal and 14.5% compared to last year's precipitation.

Table 1.1 Change in precipitation level according to historical precipitation average and precipitation level in 2019 (General Directorate of Meteorology,2020)

TURKEY PRECIPITATION ANOMALIES					
	2020 Precipitation (mm)	1981-2010 Normal Average Precipitation (mm)	2019 Precipitation (mm)	Change (%) According 1981-2010	Change (%) According 2019
TURKEY	500.1	574.0	585.2	%12.9 Decrease	%14.5 Decrease

For Turkey, this rise in unpredictable weather events, the decrease in rainfall, frequent heatwaves, etc will lead to reductions in tourist sales, losses in crops requiring daily irrigation, degradation of many habitats, increases in forest fires, reductions in wetlands, and losses in the storing of water.

1.1.2 Climate Change Effect on Protected Areas

Climate change is the biggest irrevocable problem associated with increasing human pressure on nature. Many species and their habitats have been facing with extinction risk due to habitat loss, so they need conservation. Protected areas are an important tool for conserving nature and preventing habitat loss. An effective protected area system is seen as the best hope for conserving species and biodiversity, and would help to significantly reduce the rate of biodiversity loss due to climate change and other human impacts. Even though protected areas are the main approach to conserve wildlife and ecosystems, they are vulnerable to climate change. Present coverage of protected areas is inadequate to cover the existing variety of species, resulting in significant conservation deficits because of rapid changes in climatic conditions (Üstüner, 2019).

Even though protected areas are vulnerable to climate change effects, they are still the main solution to these challenges. As the first national park in Turkey was declared in 1958, protecting nature increasingly became a major issue. Countries started to pay attention to reduce and prevent excessive and incorrect use of natural resources and to preserve biodiversity. Then with the Stockholm Conference, 1972, and the Rio Declaration and Earth Summit in 1992, conservation of biodiversity picked up speed. Currently UNEP (United Nations Environment Program), WCMC (World Conservation Monitoring Center), IUCN (International Union for Conservation of Nature) are the main organizations that work for ecosystem, biodiversity, and nature conservation. However, even though the awareness of and implementations for biodiversity protection increase and the number of protected areas increase year by year, the dramatical rise of species extinctions and natural area degradation necessitate an assessment of efficiency of protected areas.

1.1.2.1 Protected Areas in Turkey

The geographical location of Turkey, which covers three biogeographical regions, is an important factor that leads to significantly high levels of biodiversity compared to other temperate countries. Turkey's diverse habitats support a varied range of endemic plants, endangered birds, and other wildlife. Therefore, declaration of new protected areas is becoming increasingly important for biodiversity conservation.

Protected areas play a crucial role in Turkey for conservation of biodiversity and, biodiversity is protected by a variety of legislation and protected area designations. Most protected area designations are based on national law, although some (such as Ramsar sites) are based on international agreements. Currently Turkey has 45

National Parks, 84 Wildlife Reserves, and 31 Strict Nature Reserves as of 2020. According to the data of the General Directorate of National Parks, the number of protected areas in Turkey is increasing from year to year, but it can be argued that the effectiveness of protected areas is more important than the increase in the number of protected areas due to the risk of decreasing biological diversity due to climate change.

Climate predictions based on the effects of climate change for Turkey show that Mediterranean and Aegean habitat which is richest areas in terms of protected areas tend to lose and climatic conditions on most of Turkey transform to arid habitats. Climatic conditions are expected to migrate to the different parts in time and also depending on this migrate species habitat will be expected to change. So even if number of protected areas are increased, they may become quite inefficient in terms of conservation. If protected area's resilience capacity to these effects is high then the maintenance of biodiversity conservation can be provided. In this study; the resilience capacity of Turkey’s protected areas to climate change will be discussed.

CHAPTER 2

LITERATURE REVIEW

In this part, theoretical framework of the study will be explained.

2.1 Climate Models, Scenarios and Projections for Turkey

Climate is changing and will continue to change in the foreseeable future. To develop strategies to adapt to this change, climate projections have been made to predict possible changes and their consequences. Climate projections are usually made with a variety of possible pathways, using different scenarios of emissions, concentrations, and temperature change due to human interactions. Projections show predictions about how climatic conditions (mainly temperature and precipitation) will change in the future, based on presumed 'scenarios' for the amounts of greenhouse gases, aerosols, and other atmospheric components relevant to the radiative equilibrium of the earth. Within the scope of the IPCC 5th Assessment Report; annual average temperature increases are foreseen throughout Turkey, in all Global Climate Models (GCMs) projection scenarios, and for all periods. According to annual total precipitation projections, especially in the last period of the century, a decrease in precipitation is predicted. Due to the low resolution of global climate projections, detailed analysis and forecasts at the local scale can be inaccurate. That is why more detailed projections are obtained to increase accuracy by using Regional Climate Models (RCM) concerning GCMs.

The General Directorate of Meteorology has developed climate projections with 3 different regional models for the 2016-2099 period to reveal how climate change will affect our country in the future. The regional climate projections produced by the downscaling method for Turkey are based on the global models within the scope of CMIP5 project and RCP 4.5 and 8.5 scenarios created by IPCC. 3 global model data sets HadGEM2-ES, GFDL-ESM2M, MPI-ESM-MR has been used in projections with 1971-2000 reference period.

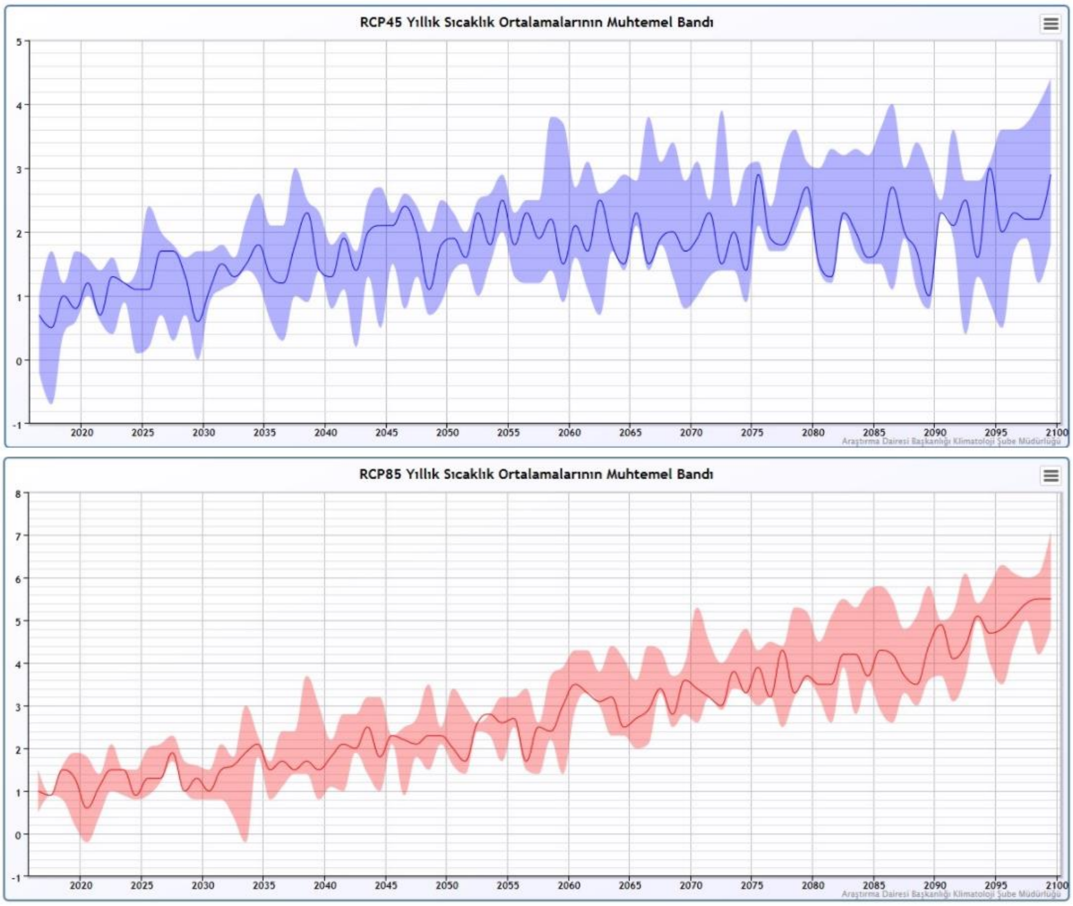
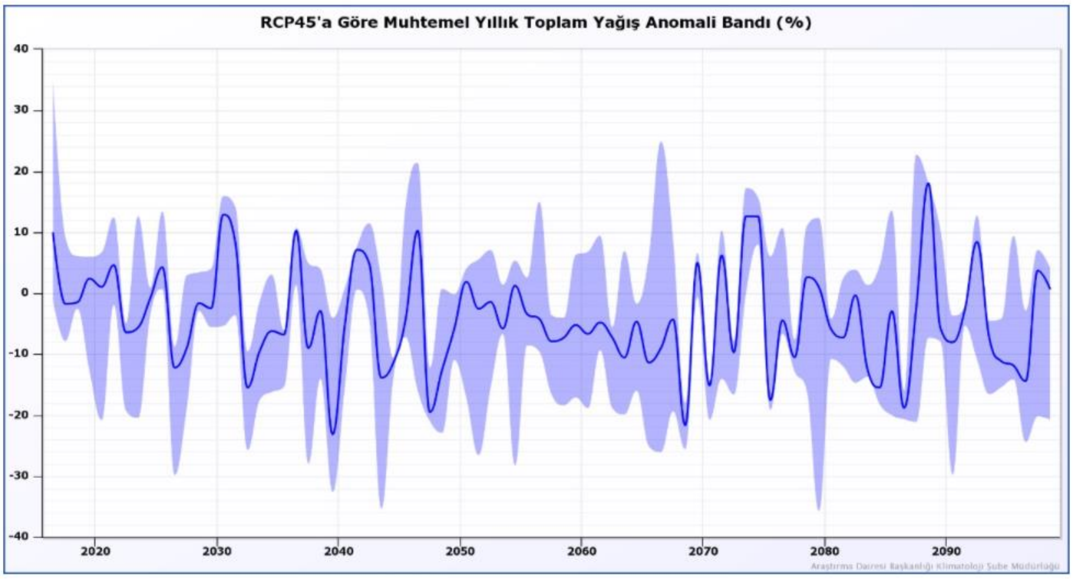


Figure 2.1. Average Temperature Change Projections Between the Period of 2016-2100 for Turkey according to RCP4.5 and RCP8.5 emission scenarios (General Directorate of Meteorology, 2020)

The figure shows that the annual average temperature anomalies of HadDEM2-ES, MPI-ESM-MR, and GFDL-ESM2M models for Turkey in general (GDM). According to the RCP4.5 scenarios, average temperatures in Turkey will increase between 1.5 ° C - 2.6 ° C in the period 2016-2100. Especially in the second period of the century temperature will rise 2.2 ° C. On the other hand, it is expected that the average annual temperature will increase between 2.5 ° C – 3.7 ° C for the RCP8.5 scenario. In the second period of a century, a rise of around 3.8 ° C is foreseen.



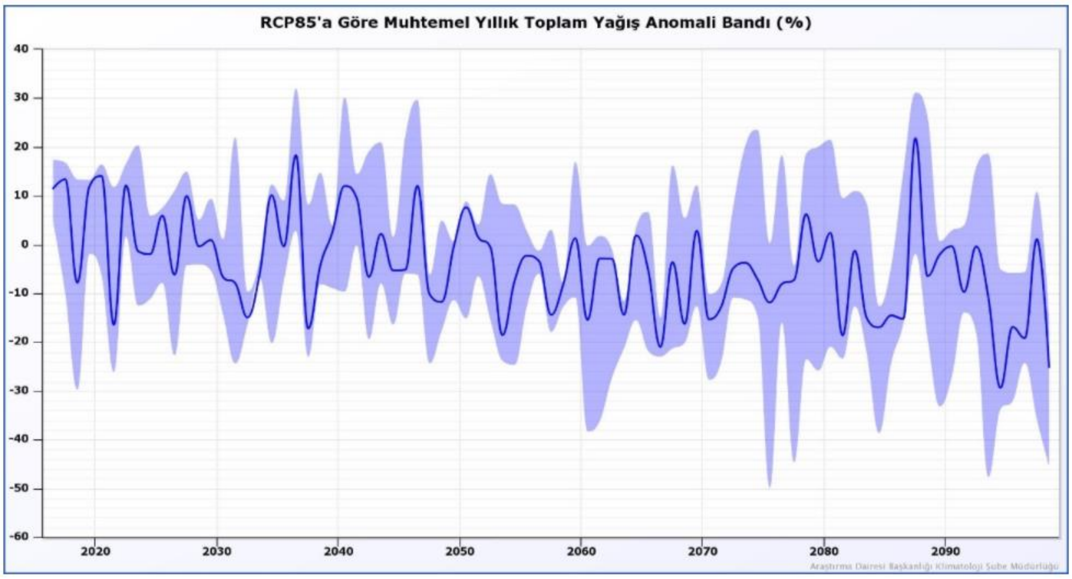


Figure 2.2. Turkey RCP4.5 and RCP8.5 Average Precipitation Change Projections Between the Period of 2016-2100 (General Directorate of Meteorology, 2020)

When we look at the precipitation projections, even though a decrease in precipitation is generally expected, forecasts show that there is no trend of continuous decline in precipitation for Turkey. It is predicted that rainfall irregularities will tend to increase.

Table 2.1 Turkey seasonal temperature projections for 3 RCM model and 3 period in reference to RCP 4.5 and RCP8.5 emission scenarios, (Demircan et al., 2017)

Summarise table of temperature projections (Temperature anomaly (°C) ranges)

Models	Periods	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
		Winter		Spring		Summer		Autumn	
HadGEM2-ES	2016-2040	1,5 - 2	0 - 1	2 - 3	1 - 2	2 - 3	1,5 - 2	2 - 3	1 - 2
	2041-2070	1,5 - 2	1,5 - 2	2 - 3	2 - 3	2 - 3	3 - 4	2 - 3	2 - 3
	2071-2099	2 - 3	2 - 3	2 - 3	3 - 5	3 - 4	5 - 7	3 - 4	4 - 6
MPI-ESM-MR	2016-2040	0 - 1	0 - 1	0 - 1,5	1 - 1,5	1 - 2	1,5 - 2	0 - 1,5	1 - 1,5
	2041-2070	1,5 - 2	1 - 2	1 - 2	2 - 3	1 - 2	2 - 4	1 - 2	1,5 - 2
	2071-2099	1 - 1,5	2 - 3	1,5 - 2	3 - 5	1,5 - 3	4 - 6	1 - 2	3 - 5
GFDL-ESM2M	2016-2040	0,5 - 1	0,5 - 1	0,5 - 1	0,5 - 1	0,5 - 1,5	1 - 2	0,5 - 1	1 - 1,5
	2041-2070	1 - 1,5	1,5 - 2	1 - 1,5	1,5 - 2	1,5 - 2	2 - 3	1 - 2	2 - 3
	2071-2099	0,5 - 1	1,5 - 2	1 - 1,5	2 - 4	1,5 - 3	3 - 5	1 - 2	3 - 4

Table 2.2 Turkey seasonal precipitation projections for 3 RCM model and 3 period in reference to RCP 4.5 and RCP8.5 emission scenarios, (Demircan et al., 2017)

Summarise table of precipitation projections (Rainfall change (%) ranges)

Models	Periods	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
		Winter		Spring		Summer		Autumn	
HadGEM2-ES	2016-2040	-30, +40	-20, +30	-20, +40	-30, +30	-40, +40	-40, +50	-30, +30	-40, +40
	2041-2070	-20, +30	-30, +30	-30, +30	-40, +40	-60,+60	-60, +60	-40, +40	-40,+40
	2071-2099	-40, +40	-30, +40	-40, +40	-40, +40	-50, +50	-60, +60	-50, +40	-50, +40
MPI-ESM-MR	2016-2040	-30, +30	-30, +30	-40, +30	-40, +40	-50, +50	-60, +50	-40, +30	-40, +40
	2041-2070	-30, +30	-30, +30	-40, +40	-40, +30	-50, +50	-60, +50	-40, +30	-40, +40
	2071-2099	-30, +30	-40, +50	-40, +50	-50, +30	-70, +40	-60, +30	-40, +40	-40, +40
GFDL-ESM2M	2016-2040	-30, +20	-40, +40	-30, +30	-30, +20	-40, +30	-30, +40	-40, +20	-40, +30
	2041-2070	-40, +30	-40, +30	-40, +30	-30, +40	-40, +50	-40, +30	-40, +20	-40, +20
	2071-2099	-30, +30	-40, +40	-30, +30	-40, +40	-40, +40	-50, +30	-40, +30	-40, +40

According to the General Directorate of Meteorology forecasts, in the RCP4.5 scenario, it is expected that the total annual precipitation anomaly in Turkey will decrease 3-6 % on average. In RCP8.5 the annual total precipitation anomaly changes in Turkey in the period of 2016-2099 is expected to be in the range of + 3% to -12% on average. Dramatically lower precipitation is foreseen in the second half of the century.

As a result of projections, a 2-4 ° C rise in summer temperatures is predicted for the whole of Turkey except the eastern Black Sea Region. Southeast Anatolia Region and coastal part of Aegean Region will be exposed to most rise in temperatures. Also in winter and spring, 2-3 °C increases are expected (Demircan et al., 2017). For precipitation projections, the general trend is declines in precipitation, especially in spring and summer, with more frequent extreme precipitation events in summer and up to 50% decline in autumn (Demircan et al., 2017). Even though higher temperatures and lower precipitation is predicted, extreme weather climatic conditions such as sudden high rainfall which will lead to floods or sudden temperature increases will also be foreseen. All these predictions are supported by climatic observations in past decade.

According to another study, future climatic scenarios for Turkey predict a fall in frequency of rainy days and rain intensity year by year with large decreases during the autumn and spring seasons. As a result, a decline in total precipitation is mostly due to a reduction in rainy days (Kıtoh, 2007).

Taking into account all of these changes in temperature and precipitation, changing climatic conditions are foreseen for every part of Turkey. Some parts of the country will be exposed to these changes more rapidly than other parts. This brings us to the concept of climate velocity, which measures how fast the projected climatic conditions will change.

2.2 Velocity of Climate Change (VoCC)

Climate change is also a significant threat to biodiversity. Changing climatic conditions affect ecological system at all levels. Ecological responses to climate change are excessive, changes in the distributions of species and ecosystems is the most fundamental effect of climate change on the biota. Shifts in temperature and precipitation as a result of climate change will lead to redistribution of current climatic patterns on the globe. While some climatic patterns may vanish completely, some new ones will emerge. With changing structure in climate in spatial terms, biodiversity distribution will also change due to species movement with climate to find suitable environments to survive. A new measure, called the Velocity of Climate Change, for these changes in climatic pattern and responses of species to climate change was put forward by Loarie and others in 2009. It is a measure for assessing exposure to climate change and gives information about rate and directions that species must move to maintain in a changing climate (Dobrowski & Parks, 2016).

Velocity of climate is a calculation of horizontal velocity of temperature change resulting from the ratio of spatial and temporal gradients of annual mean surface temperature to indicate the rate of speed of climate change ($° C\ yr^{-1} / ° C\ km^{-1} = kmyr^{-1}$) (Loarie et all, 2009). After its formal definition by Loarie et al. (2009), the term climate velocity was started to evolve and be used in new studies for calculation of climatic exposure. Velocity of Climate Change (VoCC) is still a new term and does not have too many studies. Burrows and others (2014) define climate velocity as an approach that considers direction of climate shift (trajectory of changing) and local speed of climate change and prediction of how species' distribution will change their position of thermal niches.

VoCC is an analytical term that can be used to assess species' vulnerability to climate change. Brito-Morales et all (2018) defined Climate Velocity as a straightforward metric that expresses the direction and speed of climatic movement at any given location. It provides conservation-relevant knowledge about the effects of climate change such as the study of protected areas, changes or shifts in climate patterns, and endemism rates. In 2014, Hamann and others introduced improved climate velocity metrics with a new concept for natural resource management and conservation planning. Originally, climate velocity has been used with a single variable. Where multi climatic variables are considered, such as temperature and precipitation both are viewed as distinct factors for shifts in climate patterns. Besides new multivariate approach is developed by Hamann et al. that is based on a principal component analysis of various parameters like maximum, minimum, or mean of temperature or rainfall. This method has the advantage of taking into account the multivariate nature of climate pattern change.

Two main metrics of climate velocity were developed: gradient based and distance based. These metrics are used to describe species extinction risk, change in regional pattern in endemic species, response of marine taxa to climate change, quaternary biota range changes, climate change refugia distribution, and climate change exposure under current and anticipated future conditions (Dobrowski & Parks, 2016).

In the light of original studies for the velocity of climate change (VoCC), there are two main perspectives: theoretical and ecological. From a theoretical perspective, climate velocity is a basic metric representing the speed and direction of climatic movement at a spatial location in space. On the other hand, from an ecological perspective, VoCC is the path and pace of a species which shift its habitat to sustain survival in suitable climatic conditions under the stress of climate change.

Climate velocity have been widely used in conservation planning for biodiversity and protected areas. This measure can be enhanced by determining effectiveness level of protected areas at ecologically relevant scales. Assessing climate change magnitude and spatial variety in a protected area network provides useful input for conservation planning, allowing management to be focused on the PAs that are most vulnerable to climate change (Heikkinen et al. 2020).

2.2.1 Calculation of Velocity of Climate Change

There are two main methods for measuring Climate velocity: local climate velocity which is the original calculation metric proposed by Loarie et all (2009) and climate-analog velocity which is an improvement by Hamann et all (2014).

Local climate velocity; has usually been used for exploring potential responses of biota to single variables (usually temperature but sometimes precipitation). It is the rate of change of a variable (temperature or precipitation) over time and the associated spatial gradient of variable which are required to determine which direction and how far the isogram of climatic variable will travel (Brito-Morales et all, 2018). Climate analog velocity is a metric that takes into account the interval between future climatic analog and points in time, separated by the time differential (Hamann et all, 2014).

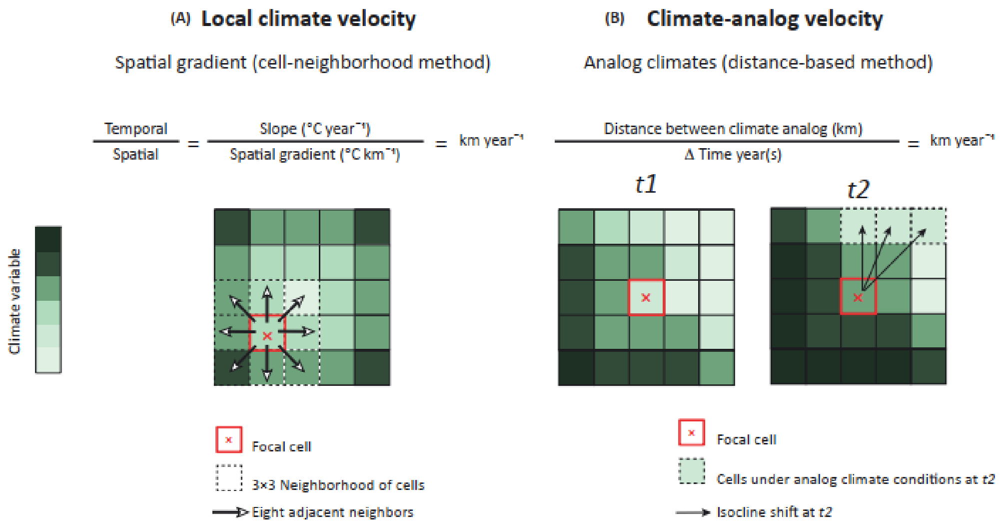


Figure 2.3. Calculation of (A) Local Climate / Gradient based and (B) Climate-Analog Velocities / Distance based (Brito-Morales et all, 2018).

Although both methods are built on the same basis, local climate velocity generally has been used to investigate possible biota reactions to a single variable, most often temperature but also precipitation. This metric is chosen by ecologists when there is only one key variable such as temperature and with the existence of smooth gradients. Climate analog velocity, on the other hand, has typically been used for multiple variables. It is used for working with multiple need species due to it is great ecological sensitivity in diverse ecosystems with varying climatic gradients. Temperature and precipitation are multivariate measures used in climate analog velocity.

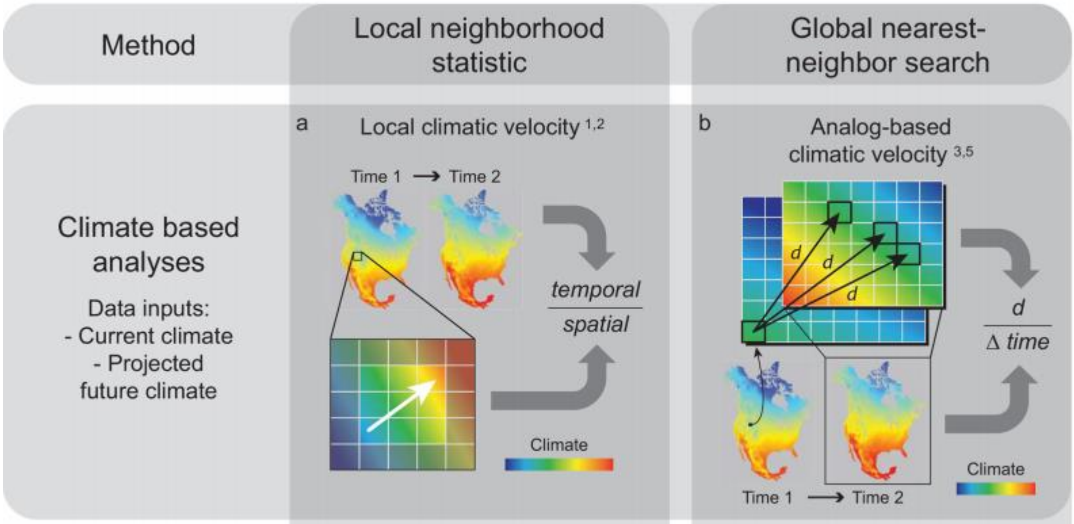


Figure 2.4. Main differences between two VoCC method calculation. Gradient based (left side) use local neighborhood statistic calculation while Distance based used nearest neighbor (left side) calculation (Carroll et all, 2015)

As shown in figure 2.4, local climate velocity is calculated by dividing temporal rate of expected climate change projections by the current gradient over a spatial or geographic neighborhood. This approach only addresses spatial variations within a locations' immediate vicinity. However, the analog-based calculation uses the distance between current climate locations and the closest site with an equivalent potential climate by using search for nearest neighbor. It also calculates the distance between predicted future climate cells and current climate cells.

2.2.1.1 VoCC Trajectories and Residence Time

Climate velocity is a key indicator when predicting the effect of climatic change on species and their biota and deciding on specific conservation actions. When a new climate pattern is formed at a place, species either adapt to this new structure or move to areas where they can survive. In protected areas, where habitats are less fragmented, keeping pace against climate change is more probable, since large, intact habitats act as buffers to climate change effects. To find out the relation between the size of protected area and velocity needed to keep pace, the term residence time is defined by Loarie et all (2009). Residence time is simply the diameter of protected area divided by local climate velocity. Larger protected areas have higher residence times than smaller ones to allow climatic adaptation for the species inside. Similarly protected areas in mountainous regions are more resilient to those in flat plains because temperature shift occurs more slowly in such areas. However, in small and flat protected areas, these climatic shifts occur faster. With the prediction of these shifts, species movement also can be foreseen for the future and taken into consideration in conservation policies. Loarie et al (2009) generated trajectories for climate velocity using moving climate tracers dependent on local climate velocity between neighboring grid cells. A source pixel (start) with a specific temperature under present conditions and a destination pixel (end) with a comparable temperature under future conditions constitute climate trajectories. (Dobrowski & Parks, 2016). Trajectory length is related to exposure is implicit in the usage of velocity; longer trajectory imply higher exposure. Climate trajectories show travel directions in a specific period along an isotherm. Global regions sensitive to impact of spatial limits on climate-driven shifts are identified by using velocity trajectories.

CHAPTER 3

DATA AND METHODS

In this chapter, data and methods used in the study are explained.

3.1 Aim of The Study

Climate velocity is a key indicator for conservation. Especially for protected area studies, it gives information about a change in climatic conditions, range of shift, and movement of climates. This study aims to investigate and analyze the climate velocity surface for Turkey and estimate the effectiveness of protected areas in the new climate space. Also, it aims to assess whether protected areas will be able to maintain their functions under the condition of changing climate and their resilience status to climate change.

Under the scope of the study, the main research questions are as followed:

- What is the Climate Velocity surface of Turkey?
- Will our protected area network continue to be sufficient in the future due to expected climate change?

In line with the purpose of the study, three main parts were used while answering these research questions. The first part is preparing and analyzing CORDEX climatic data projections which will form the base of part two. The second part is a calculation of climate velocity of Turkey using the outputs of the first part. In the last part effectiveness and vulnerability of protected areas are examined on the basis of velocity of climate change in Turkey.

Detailed methodology and data used are specified on the figure3.1.

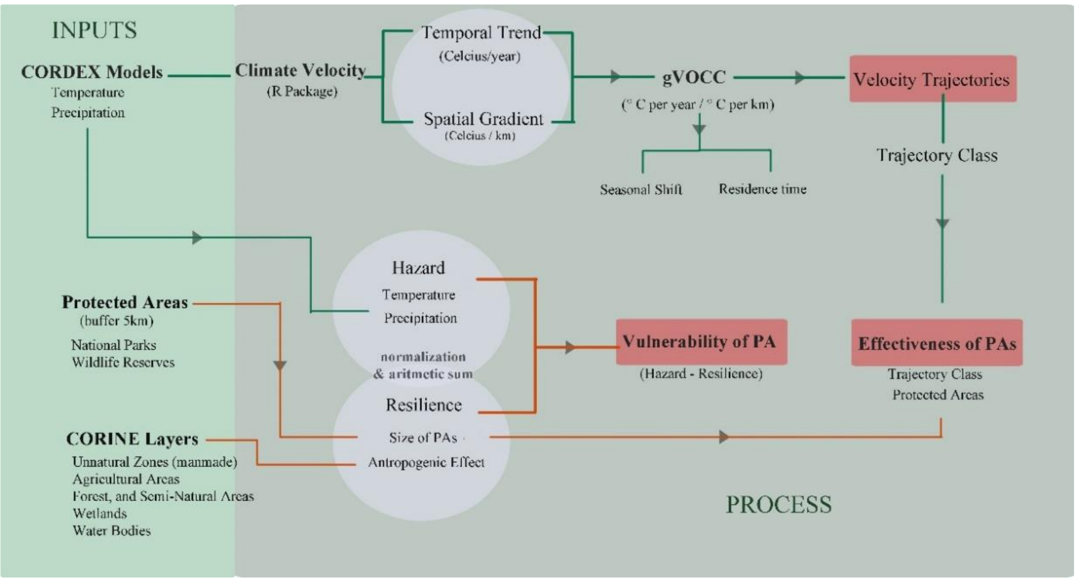


Figure 3.1. Data and Methodology flowchart that used in study

Cordex Models temperature data is used as an input for velocity calculation. Protected Areas (National Parks and Wildlife Reserves) and Corine layers (Unnatural / Manmade zones, Agricultural areas, Forest and Semi-Natural Areas, Wetlands and Water bodies) and as well as precipitation and temperature data also take into consideration for vulnerability calculation.

3.2 Climate Projections Data and Methodology

Climate projections are usually calculated with a variety of possible mechanisms, outcomes that capture the interactions between human decisions, air pollution, emission concentrations, and shift in temperature. They are computer models of the future climate of Earth until 2100 based on assumptions about greenhouse gas, and atmospheric reactions. Projections are acquired from numerical models that can span specified geographic areas. The evolution and implementation of climate models at the spatial and temporal scales have been predicted by globally analyze in historical, current, and future climate change and variability. Projections provide climate data about the response of biota and biodiversity to climate change. To endorse studies on the historical record, a wealth of observational data is available. For example, geological archives offer indirect evidence for past temperature changes. Future climate forecasts include surface climate variables like emission levels. Global climate simulations are carried out with general circulation models that are designed to align the resolution of the model and physics with computational specifications and constraints.

Global Climate Models (GCMs) – also known as General Circulation Models – and Regional Climate Models (RCMs) are the two types of models. Regional climate modeling is output from GCM simulations by using downscaled methodology because of taking accuracy in more precise grid level. Output from GCM simulations is a 3-dimensional model domain that is chosen to capture the significant synoptic and mesoscale atmospheric circulation characteristics that define the climatology of an area of interest, surface boundary conditions are determined. Different research centers provide data for projection and simulation of future climates like WorldClim and CORDEX. For this analysis, CORDEX-based predictions of regional climate scenarios were used.

3.2.1 Climatic Models and Variables Used

This research is aimed to observe the possible changes of future climatic conditions under the effect of climate change for Turkey and its Protected Areas. CORDEX (Coordinated Regional Climate Downscaling Experiment), Regional climate projections are chosen to understand variability and changes of regional/local climate. It is provided by the World Climate Research Program (WCRP) and aims to develop a unified method for improving and analyzing techniques of regional climate downscaling. CORDEX also offers high-resolution downscaled climate forecasts for various domains around the globe.

CORDEX has 13 main domains in which the regional downscaling is taking place. Turkey is completely or partially included in 5 of those domains. The most popular domain for CORDEX is Europe that also covers most of Turkey. Study area of this thesis covers all regions of Turkey, but an extended area is chosen to avoid the errors that may occur on the borders and to take into consideration of climatic shift in a wider perspective. That is why Middle East North Africa (MENA) domain was chosen. This domain is only domain that involves the study area entirely. MENA domain provides two different gridded resolution data MENA22 and MENA44. MENA 44 is decided in terms of preference rate and included data set.

Three Global Circulation Models as CNRM-CERFACS-CNRM-CM5, ICHEC-EC-EARTH, and NOAA-GFDL-GFDL-ESM2M are selected. RCA4 as a Regional Climate Model was determined with GCM model combinations. Models were chosen concerning RCP4.5 and RCP8.5. RCPs (Representative Concentration Pathway) refers to a section of the concentration pathway that runs up to year 2100. RCPs derived from Integrated Assessment Models were used as the basis for climate forecasts and projections in the Fifth IPCC Assessment.

Based on the GCM and RCM data, with 44km gridded resolution, temperature and precipitation projections covering the date between 1951-2005 and the period 2006-2100 for RCP4.5 and RCP8.5 were used as a climatic variable in the study.

3.2.1.1 Climatic Variables Analysis

Monthly surface temperature data and precipitation data were downloaded from the CORDEX website (https://cordex.org/). Monthly means were calculated for each variable then transformed from monthly to the annual average value for each grid. Explained processes were applied to all models. Then RMSE (Root Mean Square Error) bias analysis was calculated for the historical era (1961-2005) for each model by using real station temperature data and ERA5 reanalyzed data.

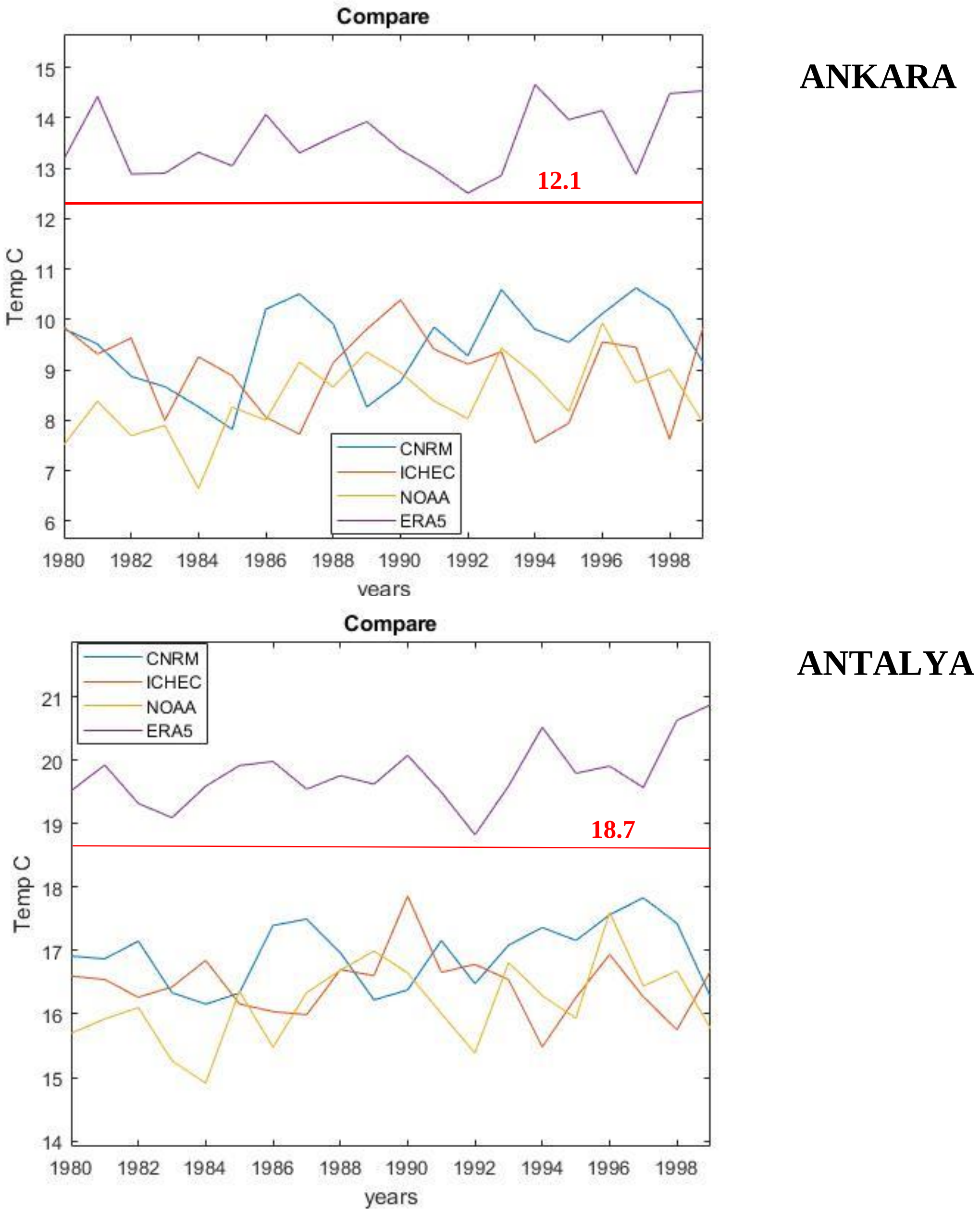


Figure 3.2. Comparison of the annual temperatures from ERA5, CORDEX models, and Meteorological Station in a historical period between 1980-2000

The figure 3.2 shows the temperature trends of the 3 CORDEX model and ERA5 model differences for Ankara and Antalya based on General Directorate of Meteorology measuring (Shown with the red straight line). As it can be seen in the figure, CORDEX models are close to each other and give a lower trend than the normal anomalies and ERA5follows a higher trend than normal. The difference between these models is due to the difference in grid resolutions at which the models are run. Even if there is a difference between long-term temperature trends of the models, the climate velocity calculations are close to each other.

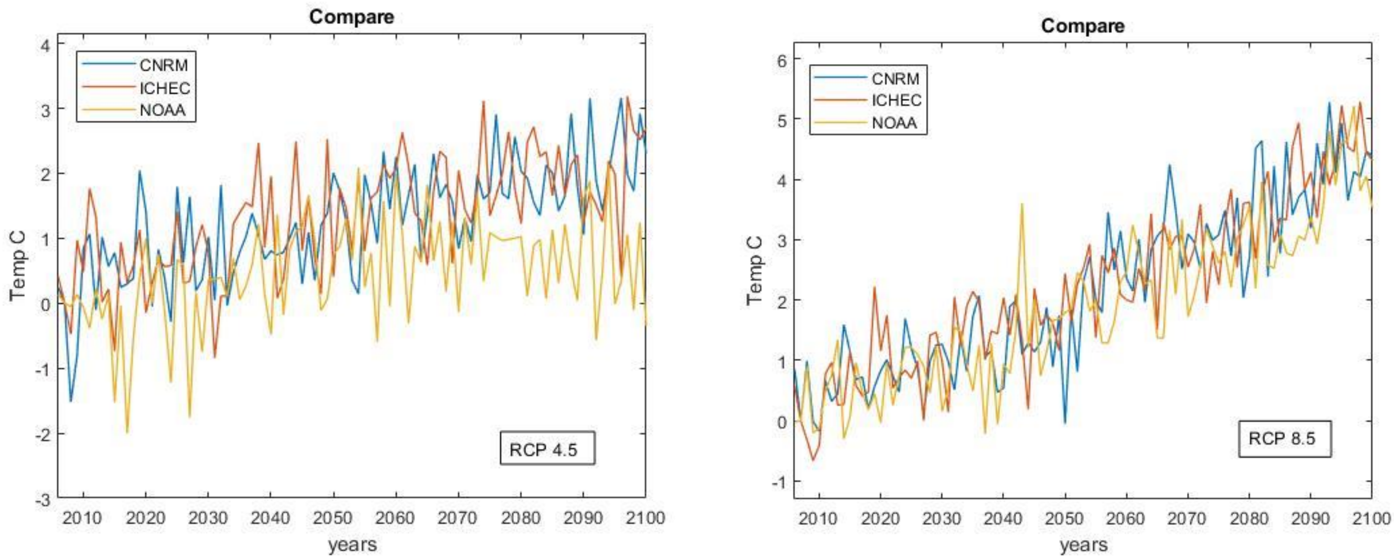


Figure 3.3. Comparison of 3 CORDEX models future scenarios regarding RCP4.5 and RCP8.5

After the bias analysis and correction needs are checked, three CORDEX models' future scenarios were compared regarding RCP 4.5 and RCP 8.5. In compliance with RCP 4.5 scenarios, both models are follows the same increasing trend in average temperature. CNRM-CERFACS-CNRM-CM5 model has foreseen a 2.6 ° C – 3.0 ° C increase in temperature for Turkey until 2100. ICHEC-EC-EARTH model shows the 2.7 ° C - 3.0 ° C increase at the end of century and these two models show remarkably close degrees of change up to 2100 on average annual temperature. On the other hand, NOAA-GFDL-GFDL-ESM2M model prediction follows a lower trend compared to others and after 2070 it shows a decreasing trend in temperature. This model forecasts a temperature increase about 1.7° C – 2.0° C until 2100.

When RCP 8.5 scenarios are evaluated; models generally showing a 5° C increase in temperature by the end of the century. All three models are foreseeing the same trend and show a 4-5° C increase in annual average temperature. Although NOAA-GFDL-GFDL-ESM2M follows comparably low anomalies in the last quarter of the century, it shows a rapid increase between 2090 and 2100, as well.

Based on these results, Turkey appears to be one of the countries which will face dramatic temperature increases, as well as drought. When we look at the maps of these upcoming changes, it is clear that Aegean and Mediterranean coastal areas will face against rising temperatures the most. Central Anatolia regions come next in line of the regions that are under the stress for a drought. East part of Anatolia and Middle Black Sea region will expect to be less effected by temperature changes than the other parts of Turkey.

3.2.2 Output Results of Stage 1

The resulting maps of the first step are given in the following figures with regards to CORDEX models and RCP scenarios. Temperature map of Turkey is given for three reference period as 2006 – 2050 – 2100 for each models.

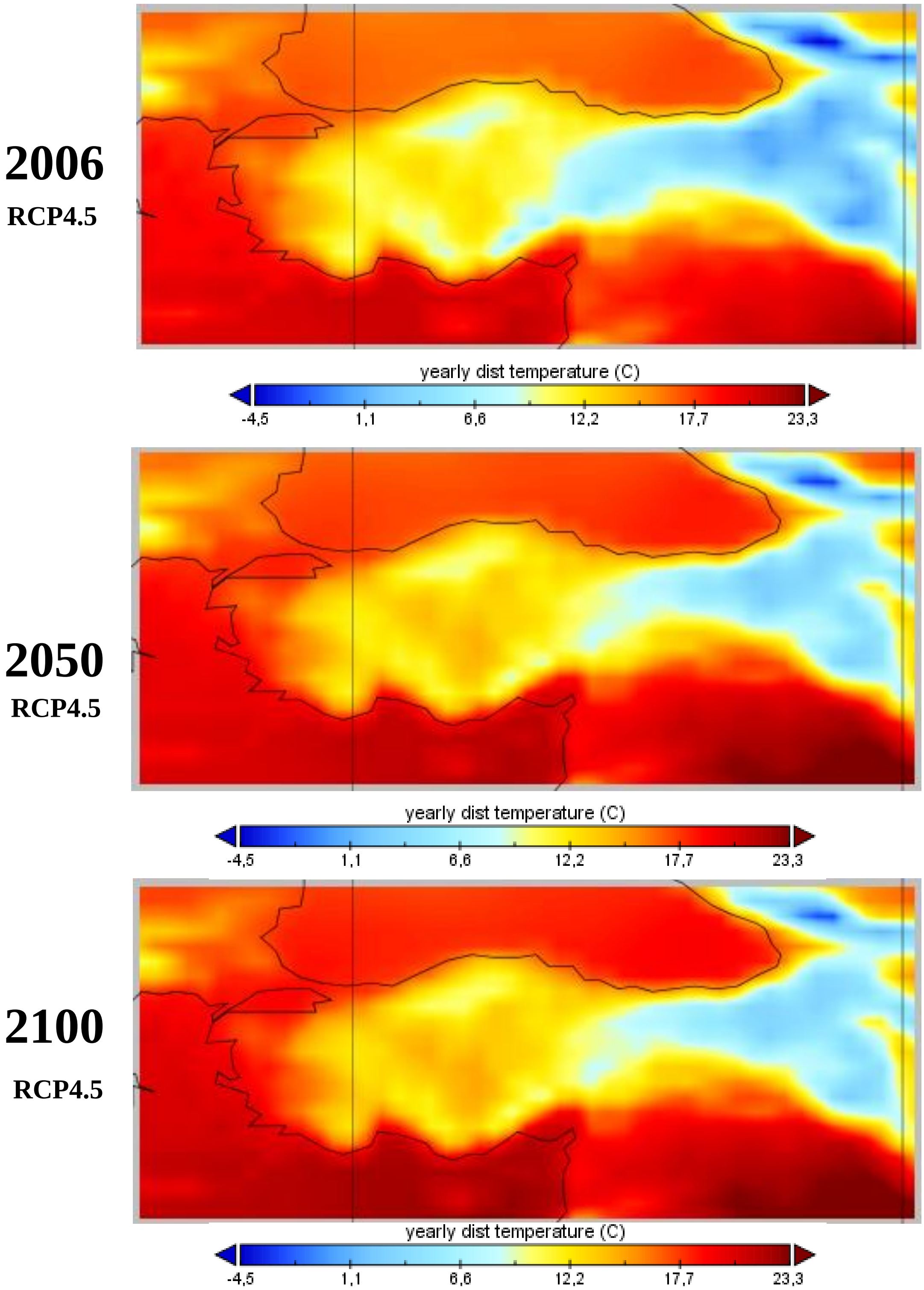


Figure 3.4. CNRM-CERFACS-CNRM-CM5 Annual Average Temperature

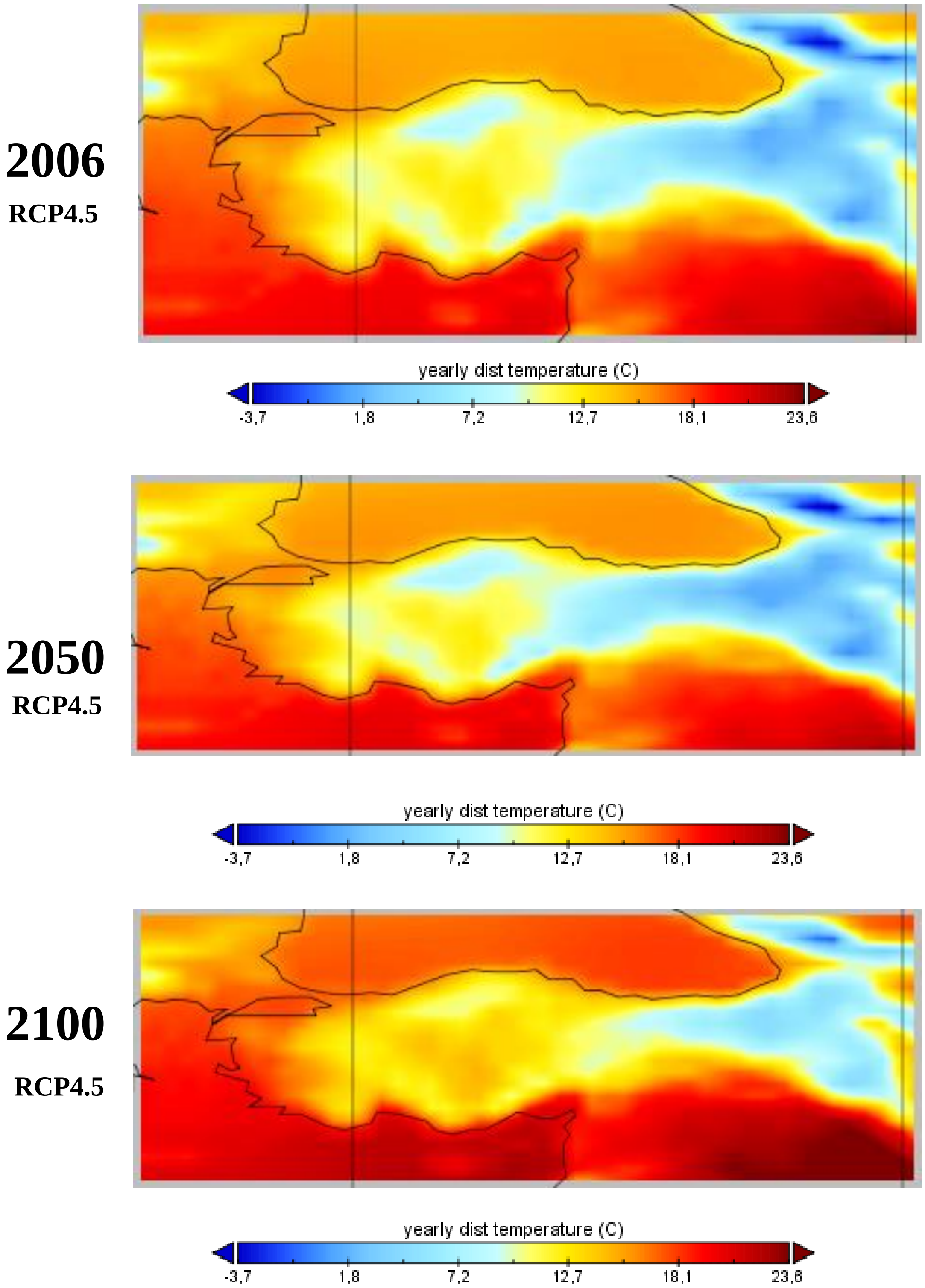
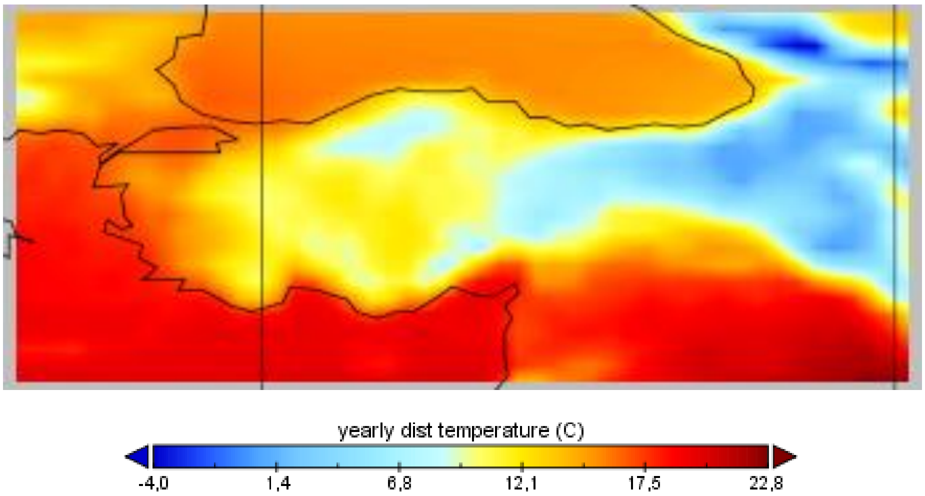


Figure 3.5. ICHEC-EC-EARTH Annual Average Temperature

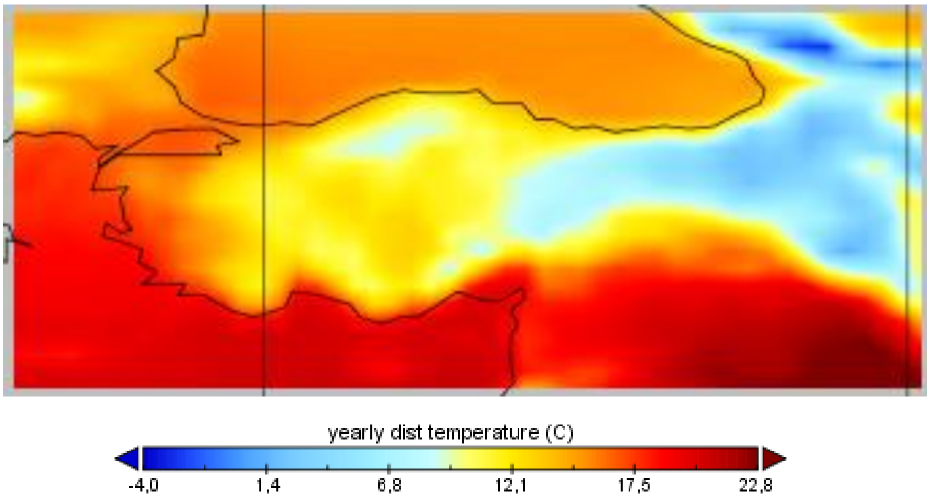
2006

RCP4.5



2050

RCP4.5



2100

RCP4.5

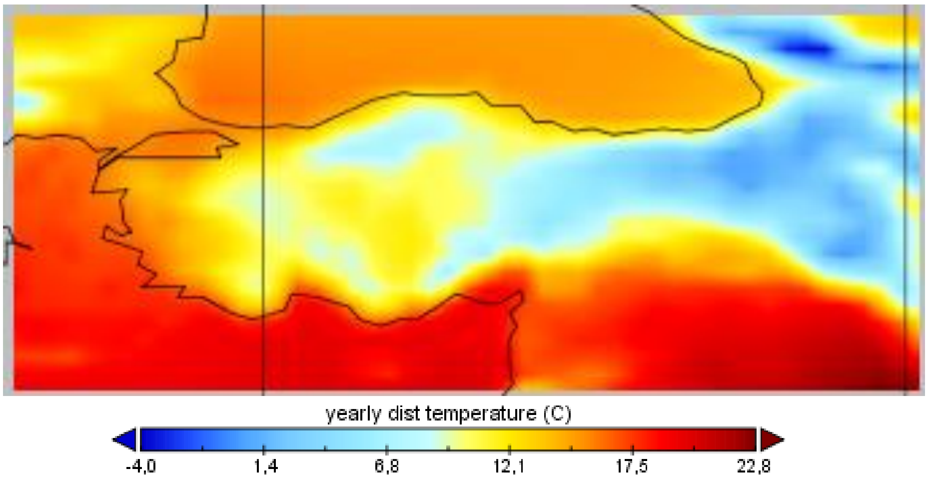


Figure 3.6. NOAA-GFDL-GFDL-ESM2M Annual Average Temperature

2006

RCP8.5

2050

RCP8.5

2100

RCP8.5

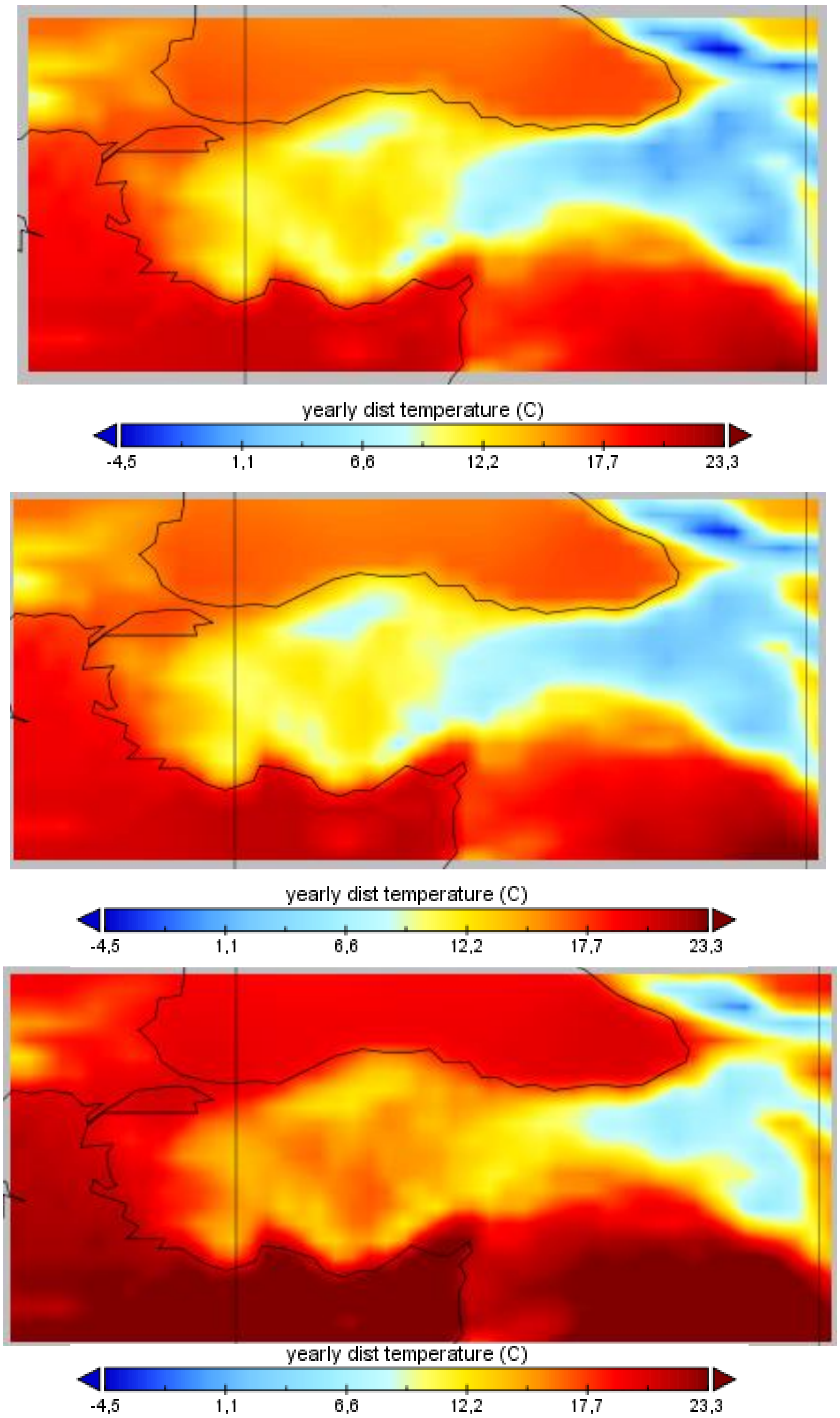


Figure 3.7. CNRM-CERFACS-CNRM-CM5 Annual Average Temperature

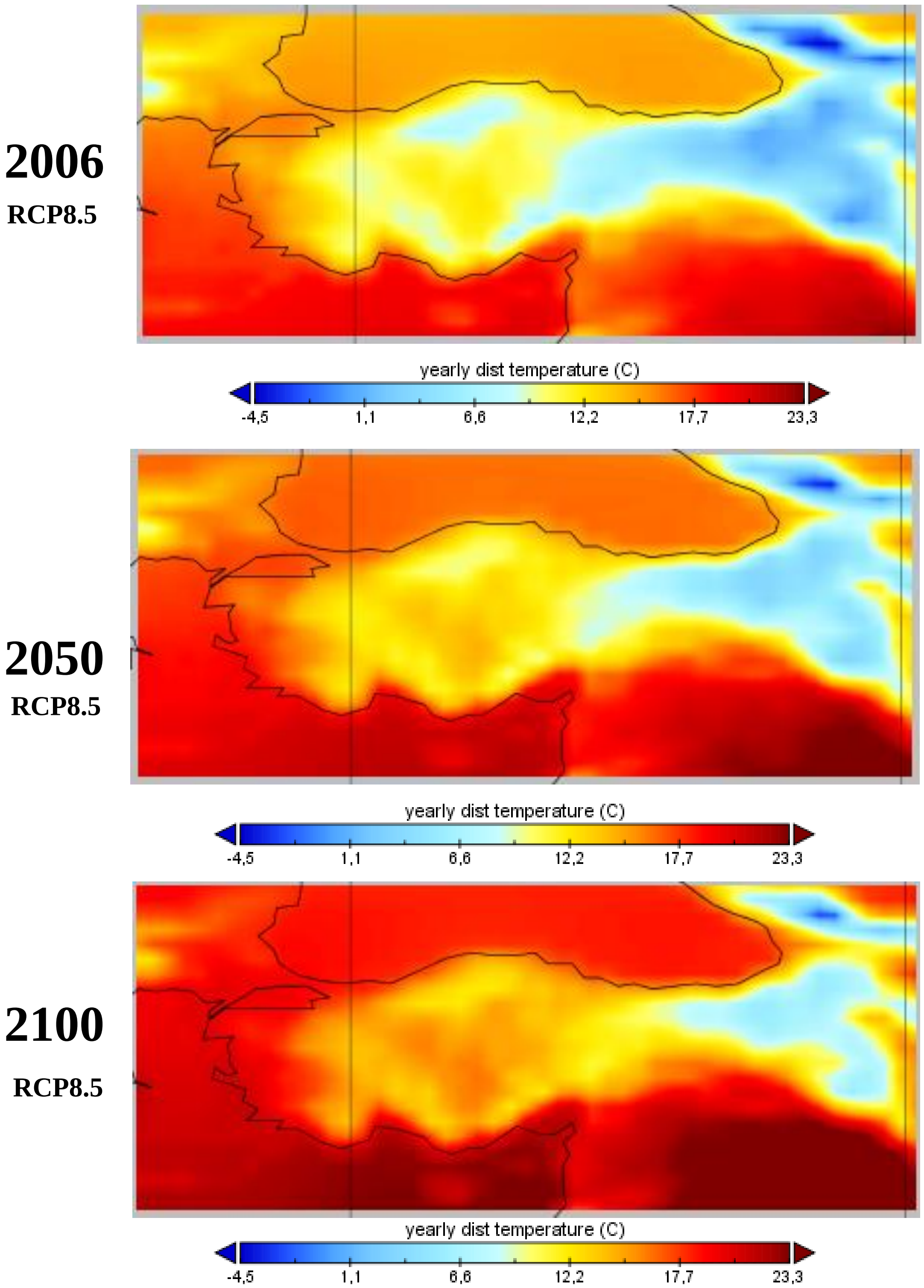


Figure 3.8. ICHEC-EC-EARTH Annual Average Temperature

2006
RCP8.5

2050
RCP8.5

2100
RCP8.5

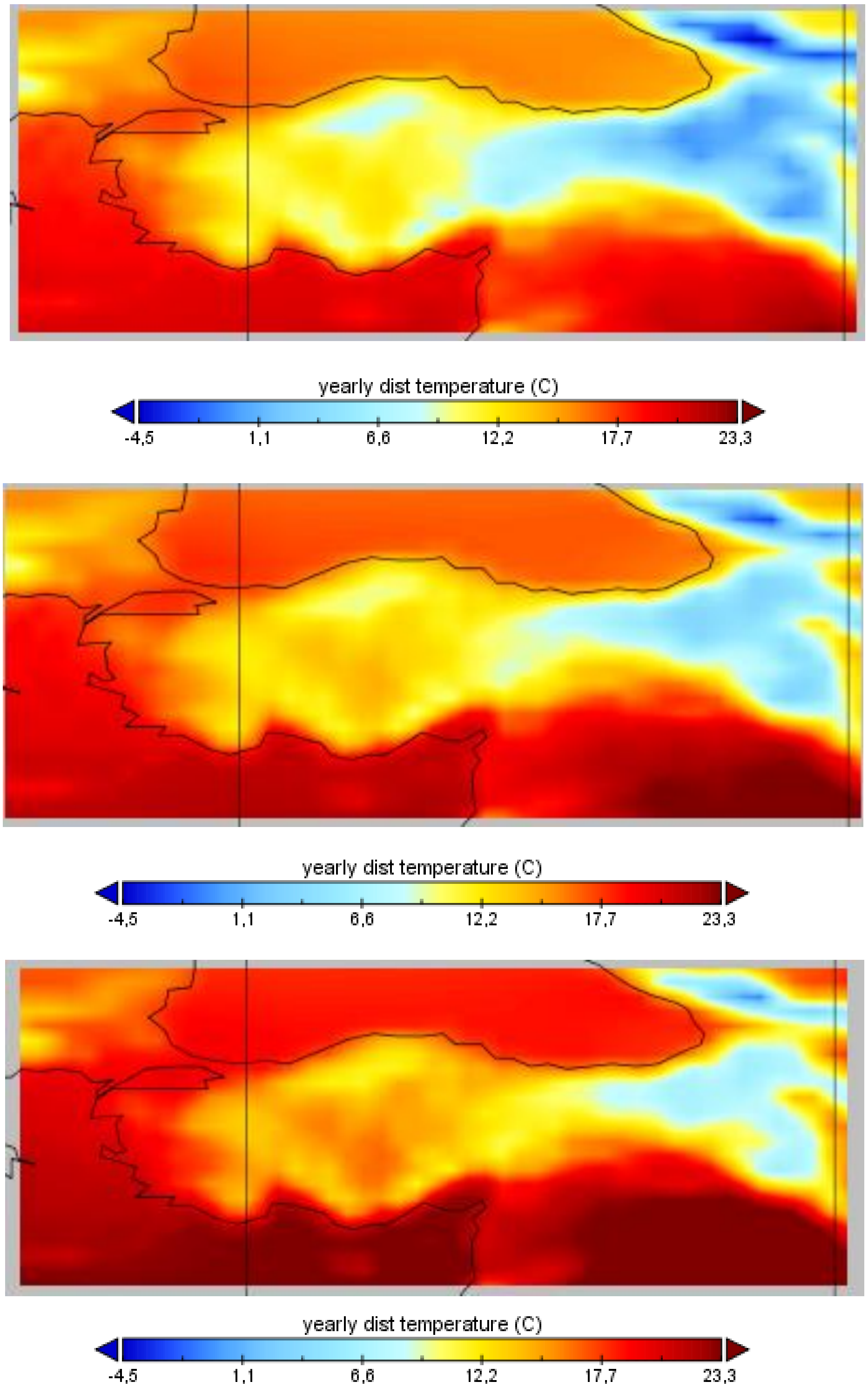


Figure 3.9. NOAA-GFDL-GFDL-ESM2M Annual Average Temperature

3.3 Velocity of Climate Change (VoCC) Calculations

VoCC is defined as the spatial and temporal change in climate variables in the long run and represents the pace of migration of climatic isopleths through a landscape. It provides a survey of climate change vulnerability, allowing for a greater understanding of the possible shift in climate and response of species with range shift. Climate velocity has developed into two major forms (distance-based and gradient-based) since its systematic description nearly a decade ago as an indicator of climatic exposure (Loarie et al., 2009). After widely used of climate velocity in climate change-related ecological researches; García Molinos and others, (2019) provide a R package. R package brings all methods together from original formulation by Loarie and others (2009) and the most recent improvements by Hammann and others (2015). VoCC Package provides a detailed set of functions that measure climate velocity and its related metrics.

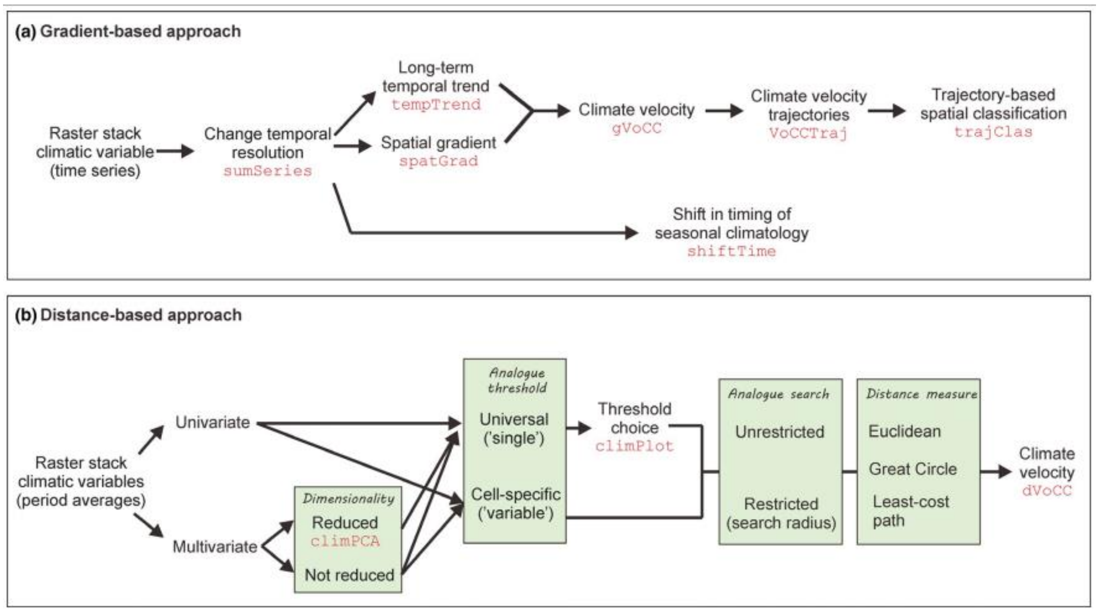


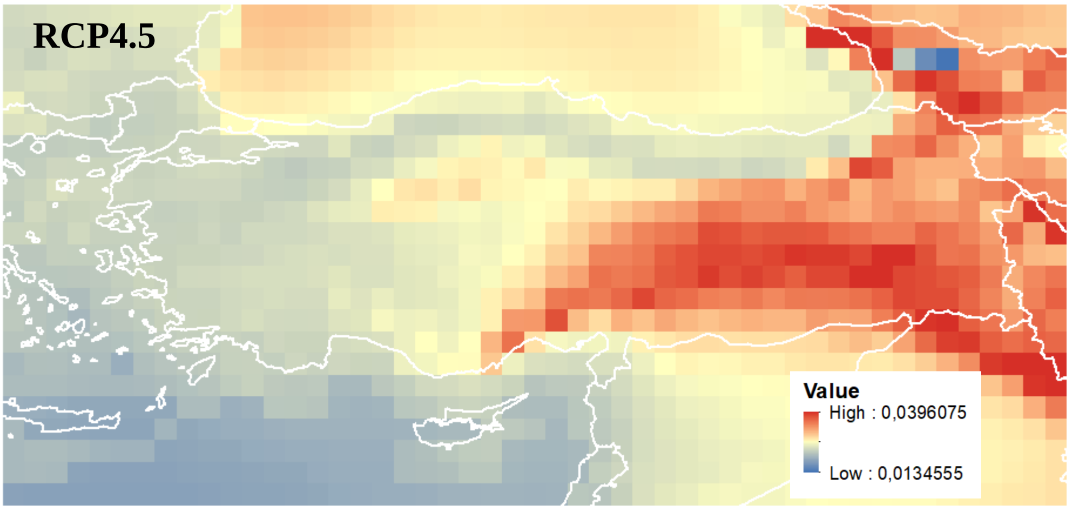
Figure 3.10. Flow chart of (a) gradient-based and (b) distance-based approaches (García Molinos et al., 2019)

Figure 3.10 shows the functions in the R package for calculation of VoCC based on two main methods of climate velocity. As explained in section 2.2.1, these two models differ depending on the intended use case.

Velocity of Climate Change is calculated for using the VoCC R Package supplied freely on GitHub by García Molinos and others, (2019). Gradient-based approach is chosen for this study due to the ease of calculation of exposure and potential responses of biota for one climatic variable. The package also provides information about climatic connectivity by constructing climate velocity trajectories. In this study, Turkey's velocity of climate change was calculated from 2000 through 2100 with annual mean surface temperature data with a 44km grid cell resolution by using the beforementioned R package. Each step is repeated for all CORDEX Models and both of the RCP scenarios.

On the gradient-based velocity (gVoCC) process, steps from figure 3.10 (a) are followed. Firstly, annual mean temperature data from the years 1951 to 2100 is transformed from NetCDF format, that was prepared in step one, into raster stack. A raster stack is a group of raster layers that all have the same spatial scale and resolution. Raster stacks are usually used for multidimensional data. Then "sumSeries" function is used to convert the data into a higher temporal resolution. This function has some parameters to identify the period of reference timeframe which is chosen as 2000-2100. Afterwards, long-term temporal trend and spatial gradient that forms the basis of gVoCC were calculated.

Temporal Trend (temptrend): A 100-year linear trend in temperature is calculated by using "temptrend" function with 20 years which is the smallest number of observations used to quantify the pattern at each cell in the sequence. As an output of this function; cell-specific temporal trends derived from simple linear regressions of temperature versus time ("slpTrends" in degrees Celsius per year) is given in the figure below:



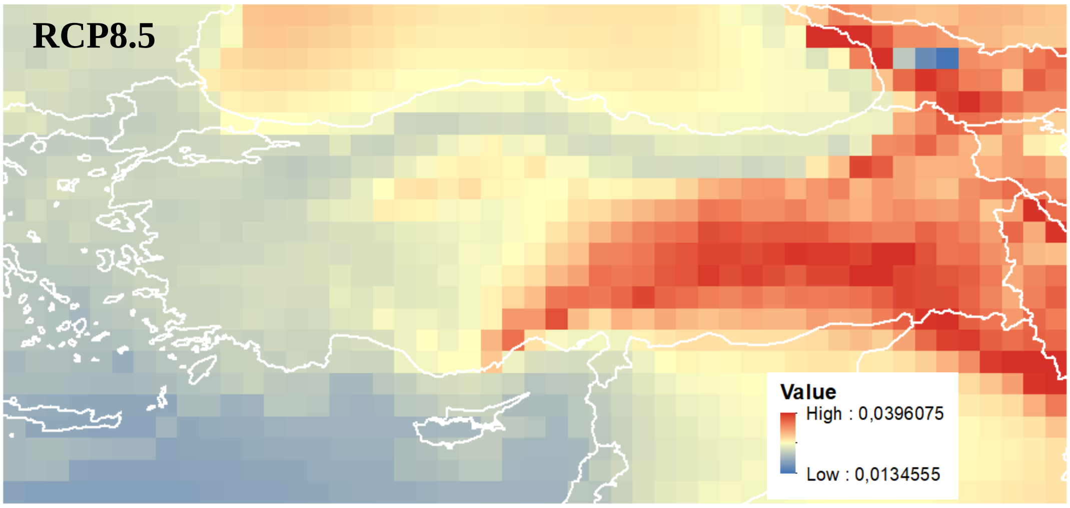


Figure 3.11. According to CNRM-CERFACS-CNRM-CM5-Cordex Model; Cell-specific temporal trends in - degree Celsius / year- (slpTrends) with respect to emission scenarios RCP4.5 and RCP8.5. Colors (blue: lower, red: higher) show range of temporal trend in 100 years.

Spatial Gradient (SpatGrad): The spatial gradient (size and angle) was calculated for the average annual temperature. "SpatGrad"-function that calculates the magnitude and direction of the spatial slope associated with the temperature used. The result of this function is the magnitude and angle of the spatial gradient computed for each grid cell. Maps are given below:

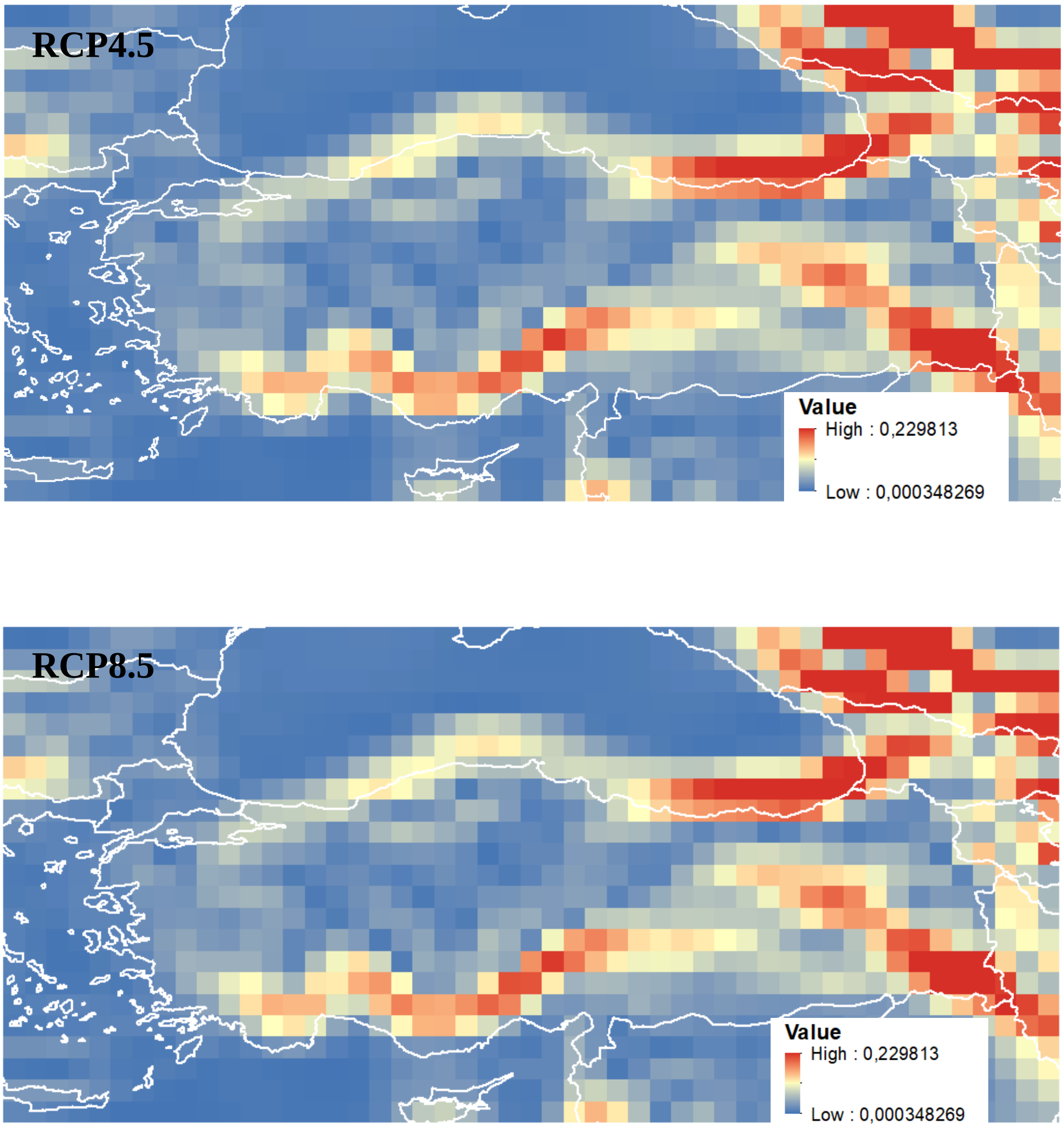


Figure 3.12. According to CNRM-CERFACS-CNRM-CM5-Cordex Model, The magnitude of spatial gradient (Celsius/km) for RCP 4.5 and RCP8.5 emission scenarios. Colors (blue: lower, red: higher) show level of magnitude for each grid for 100 years.

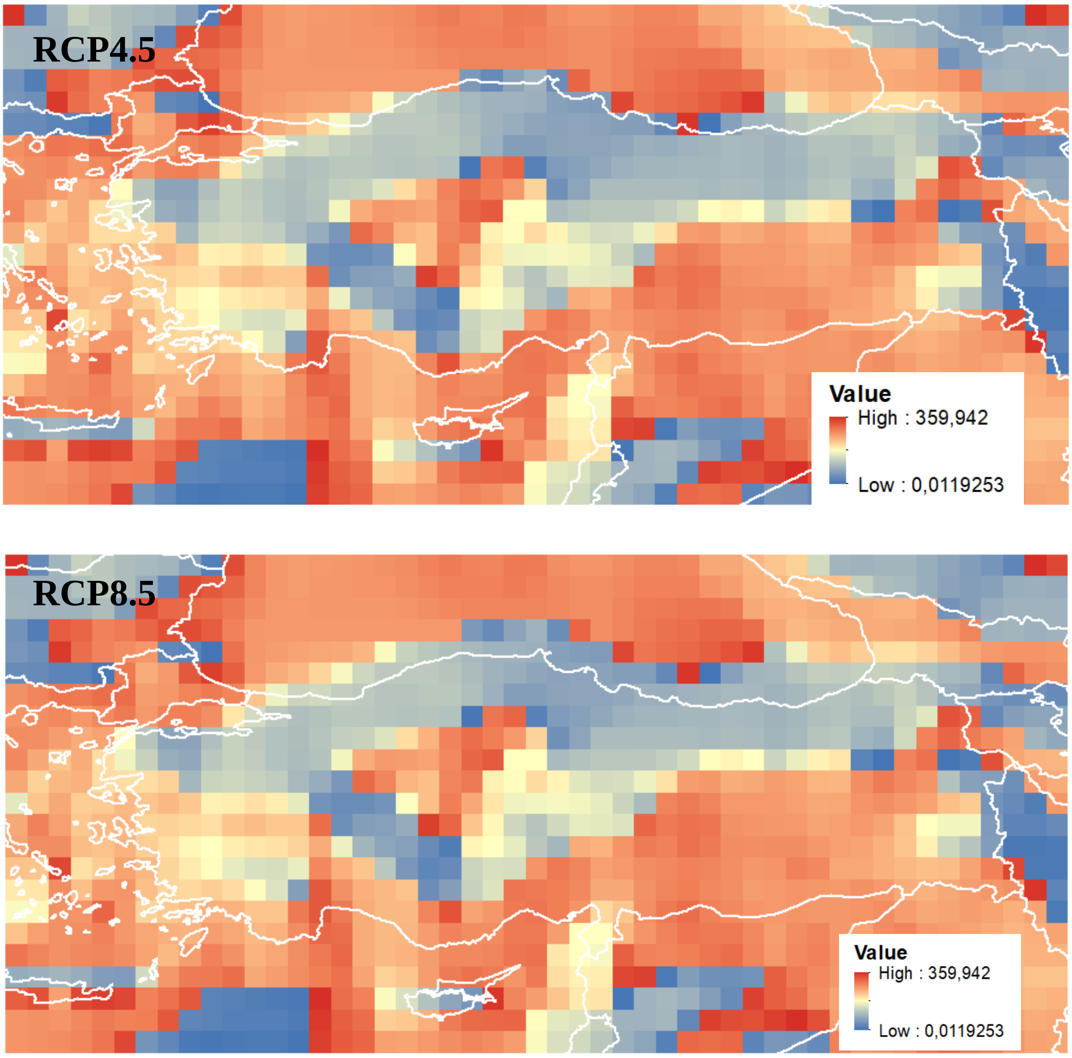


Figure 3.13. According to CNRM-CERFACS-CNRM-CM5-Cordex Model, Spatial gradient Angle in degrees for RCP 4.5 and RCP8.5 emission scenarios. Colors (blue: lower, red: higher) show degree level which form base angle for velocity trajectories.

Climate Velocity: The velocity of climate change for Turkey is calculated from the direction of the spatial gradient by dividing the local 100-year temp trend (° C per year / ° C per km) for 44 km resolution grid cell by using the “gVocc” function. As an output of the function, velocity magnitude (km/year) and angle in degrees maps are obtained. These maps are shown in the following maps. If it is warming, velocity angles will be in the opposite direction of the spatial climatic gradient; if it is cooling, velocity angles will be in the same direction (cold to warm).

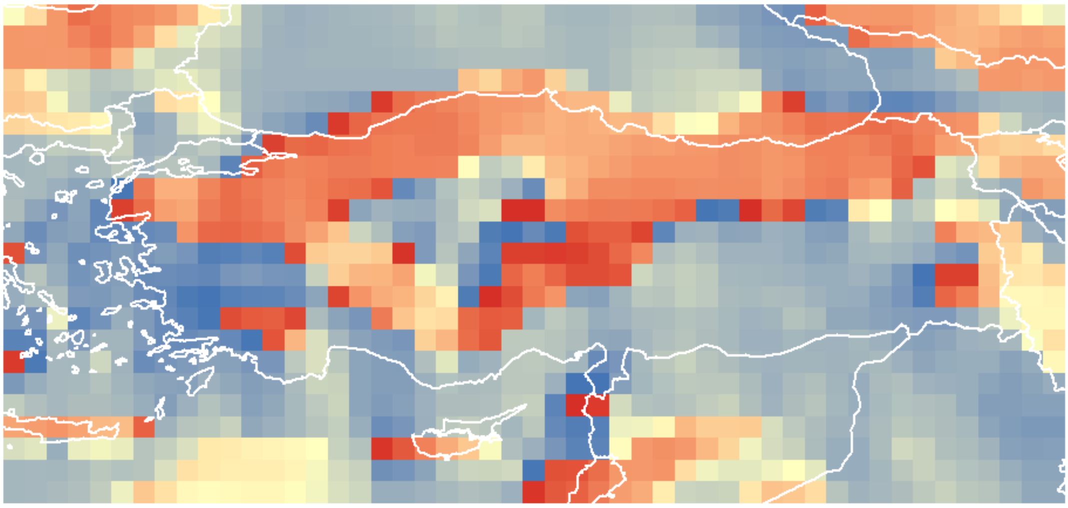
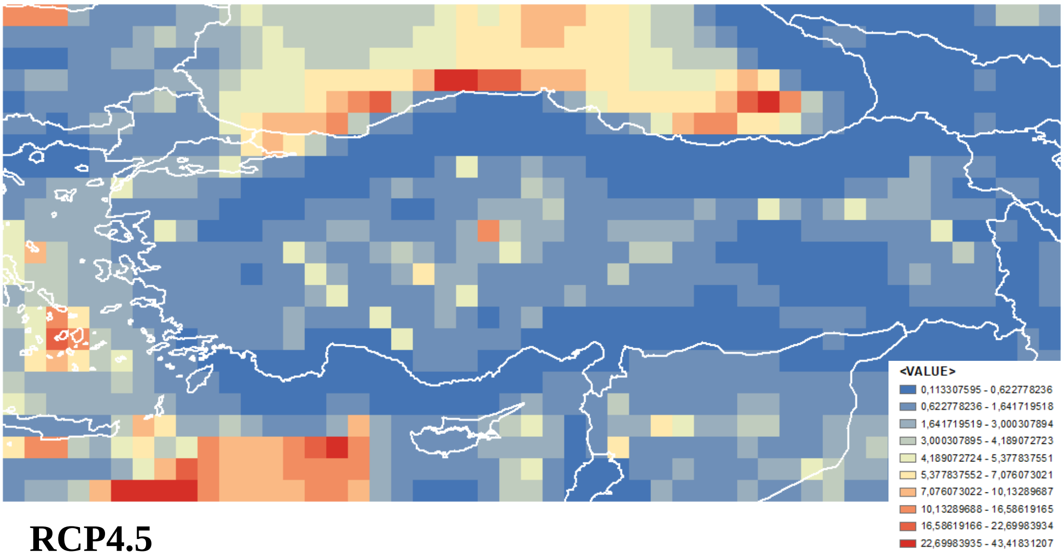
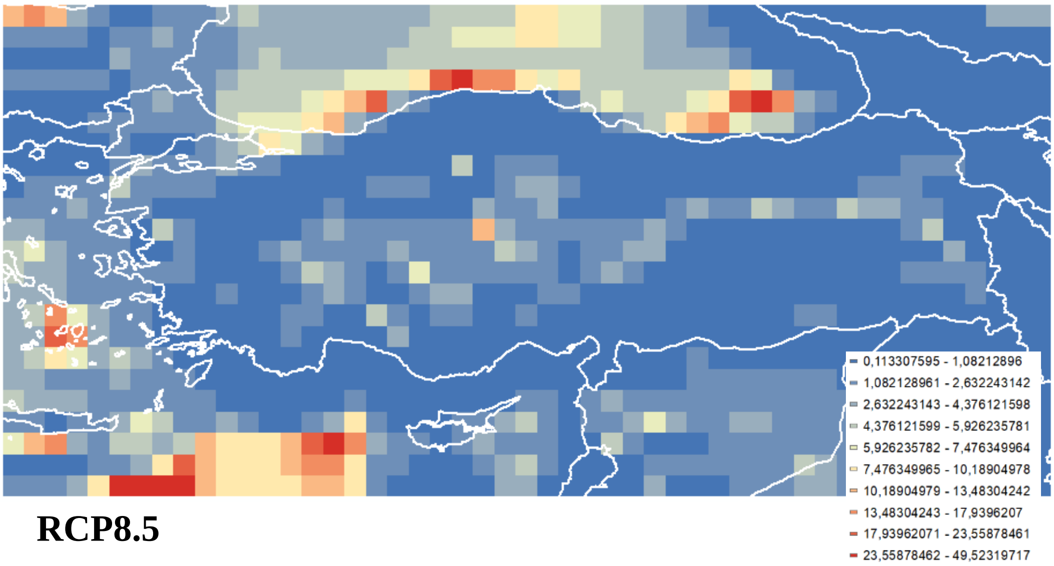


Figure 3.14. The angle of velocity of climate change for the 2000-2100 period.



RCP4.5



RCP8.5

Figure 3.15. According to CNRM-CERFACS-CNRM-CM5-Cordex Model, Magnitude velocity of climate change for 2000-2100 period (km/yr) for RCP 4.5 and RCP8.5 emission scenarios. Colors (blue: lower, red: higher) show degree level which form base angle for velocity trajectories.

These steps are carried out for all three CORDEX layers regarding RCP4.5 and RCP8.5 emission scenarios. After VoCC calculation is completed, trajectories that give information about climatic range shift and also possible climate-driven movement of species were computed. The magnitude and position of local (cell) velocities between the year 2000 and 2100 were used to measure trajectories. Trajectories represent the velocity speeds and directions over a specific period of time. While calculating the trajectories, “voccTraj” function (García Molinos et al., 2019) is used. The function is using longitude and latitude data for trajectories' start points and endpoints, magnitude and angle of velocity, and overall mean of temperature within the reference period. As function outputs, trajectories were obtained as lines of different angles and lengths. These differences and characters of trajectories are classified to take wider predictions and inferences about the niches and biodiversity pattern for the future by - Loarie and others (2009).

In this study, the trajectory classifications defined by Burrows and others were used as a reference to see biological important refuge and corridor. By using “trajClass” function from the VoCC R package (García Molinos et al., 2019) -nine classes is specified for Turkey’s velocity of climate change. Classes are based on the length and the relative abundance of trajectories starting from each cell and ending with each cell. “Trajclasses” Turkey have is defined below: (Loarie et al., 2009)

-Class 1: non-moving: shows the cells that have non-moving short trajectories.

-Class 2: slow-moving: shows the cells that have slow-moving short trajectories.

-Class 3: internal sinks: shows the cells that large percentage trajectories terminated

-Class 5: sources: shows the cells that have no trajectory ended

-Class 6: relative sinks: shows the cells that trajectories converged in neighboring cells

-Class 7: corridors: shows the cells that large percentage trajectories passing through

-Class 8: divergence: shows the cells that fewer trajectories finished than began.

-Class 9: convergence: is vice versa of divergence

3.3.1 Seasonal Shift Time Calculation by using VoCC Package

The change of seasonal climatic conditions over time is estimated by using the calculated climate velocity (Burrows et all, 2014). Even if some areas have a small velocity of change, temporal climatic environment fluctuations can affect some species and biodiversity in terms of their vital activities that occur at specific times of the year. To facilitate the calculation, the VoCC R package was used to observe the change in seasonal climatic conditions over time. The function “shiftTime” is carried out for years between 2010 and 2100, for the month of April which was chosen as a specific month since its importance to most species. Long-term temperature trends monthly (° C per year) were divided by the seasonal rate of temperature change based on each month to quantify seasonal temperature shift (Burrows et all, 2014). Half of the difference in temperature between the previous and subsequent months (°C/month) is used to calculate the seasonal rate of change. By multiplying it by 10 years, 365.25 days a year, and dividing by 12 months, the results for the seasonal changes (month/year) is translated to days per decade (Burrows et all, 2014).

3.3.2 Residence Time for Turkey's Protected Areas Calculation by using VoCC Package

Protected areas are key habitats to cope with the effects of climate change. Residence time can be defined as the resistance/duration of stay of an area or species to climate change effects. Residence times compared with climate velocity is calculated for National Parks ("Milli Park") and Wildlife Reserves ("Yaban Hayatı Geliştirme Sahası") using the "Restime" function in VoCC package (García Molinos et al., 2019) is used. National Parks and Wildlife Reserves are prepared as a shapefile as an input to the function and climate velocity calculation were used as a second input. This function calculates the area of polygons in km^2 and divides into each polygon's diameter of the equivalent circle then uses formulation given as: $2\times\sqrt{(\text{Area polygon})/\pi}$). Afterwards, the result is divided into climate velocity (km/year) for the reference term between 2000 to 2100.

3.4 Calculation of Vulnerability for Protected Areas in Turkey

The last part our method is to analyze the vulnerability of National Parks and Wildlife Reserves. To investigate vulnerability, two main calculations, hazard and resilience were carried out.

3.4.1 Resilience of PAs

Two variables are used to calculate resilience; size of protected areas and the ratio of anthropogenic areas.

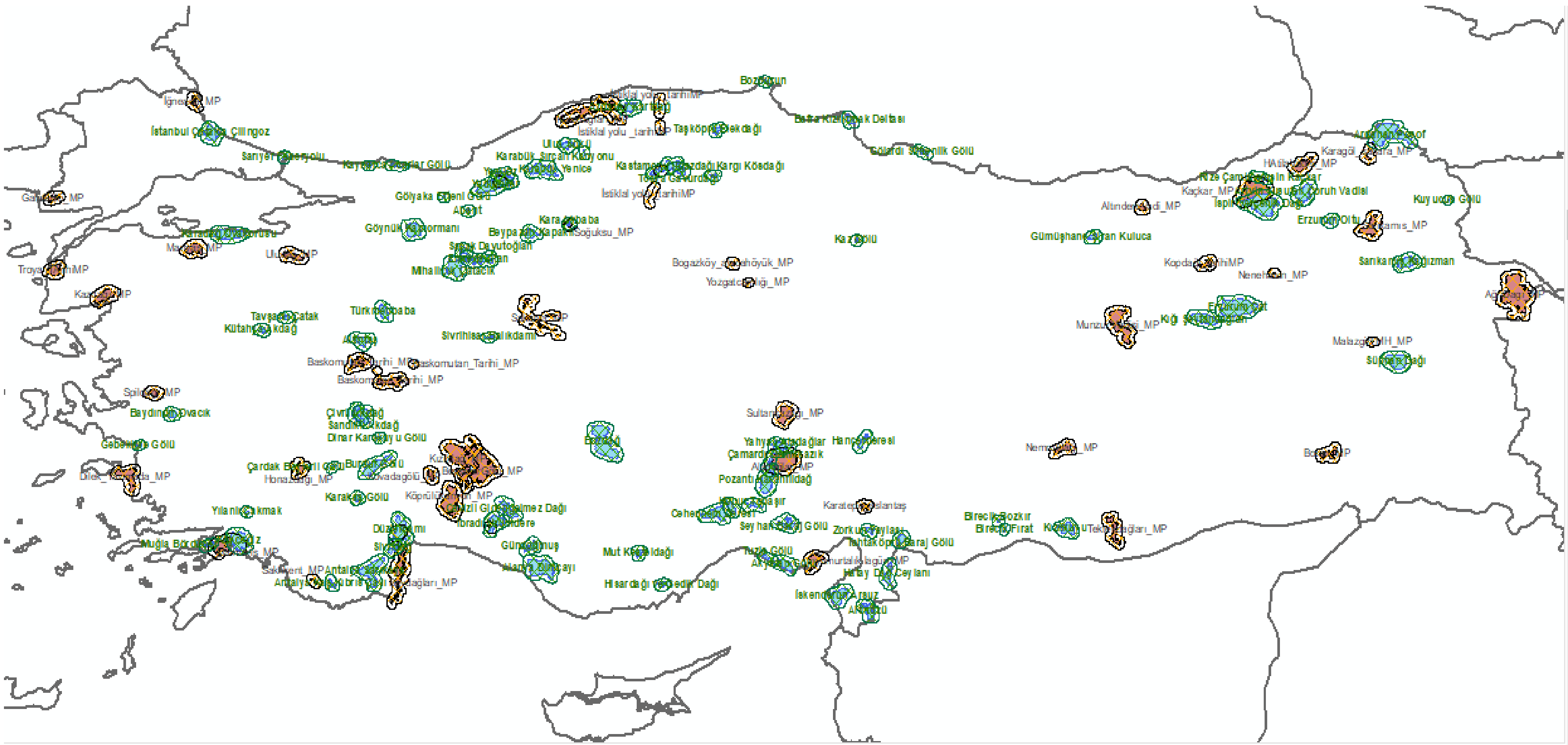
The size of a protected area (PA) is chosen as one of the variables. Size variation of PAs has different ecological consequences for conservation biology. Larger areas are better especially for species which need larger ranges. Also larger protected areas have less edge effects and provide more interior habitat (Laurance et al., 2007). Small PAs are more vulnerable to edge effects and this cause higher risk for species number and increase rates of extinction. Large PAs are better for long-term species survival and provide more diverse habitat which has higher resistance level to changing environment for species. The size of a PA also effects the level of exposure to anthropogenic disturbances.

Another variable used is proportion of anthropogenic areas. Unnatural land-use outside or inside protected areas are likely to have a detrimental impact on species diversity (Carroll et al., 2003). Anthropogenic areas negatively impact biodiversity and their habitats in protected areas. As a result, these two variables are specified for resilience calculation for protected areas. Calculation steps are given below.

A buffer area of 5 km is set around each protected area and the total area of buffer zone for each PA is calculated in terms of km2. Then, anthropogenic level within the buffered PA zone is found. To check the anthropogenic areas, CORINE (Coordination of Information on the Environment) layers were obtained from the ministry of agriculture and forestry as a shape file. CORINE is database that shows the land cover-use produced according to the Land Cover - Use Classification determined by the European Environment Agency. CORINE data provides area usage information of the 5 classes defined in certain years from 1990 to 2018. The 5 Corine classes are defined as follows: Unnatural Zones (manmade), Agricultural Areas, Forest, and Semi-Natural Areas, Wetlands, and Water Bodies. For this study, 2018 data is taken into consideration. On the next step, percentages are calculated by taking the area of the 5 classes falling into the polygon of buffered Protected Areas. Then the definition of anthropogenic effect rate is defined. The anthropogenic effect is calculated by taking the sum of Unnatural Zones (manmade) and Agricultural Areas in terms of km2 and by taking the percentage of these 2 classes in the sum of 5 classes. After preparing variables, resilience was computed by normalizing area of Buffered Protected Areas and anthropogenic results. After normalization arithmetic sum of 2 variables was taken. One important point, before taking normalization of anthropogenic area, the inverse of values is taken since those two values are inversely related, i.e. the size of a protected area is positively correlated to its resilience while its anthropogenic value is negatively correlated.

3.4.2 Hazard for PAs

The second step of computing the vulnerability of protected areas is to calculate the Hazard. Hazard is defined here as the level of exposure to the climate change effect. Two variables are used in this step: temperature, and precipitation. Even small change in these climatic variables have a significant effect on species distribution and ecosystem. Change in climatic environment can lead to change in species phenology, range shifts and their morphology. That's why precipitation and temperature are take into consideration while computing climate change hazard level. According to CORDEX CNRM 4.5 data, 100-year temperature and precipitation variation rates per protected area grid is calculated. There is a general increase in temperature and all values are positive, but there are regions with both an increase and a decrease in precipitation. Since, the precipitation value is indirectly proportionate to hazard, the inverse of precipitation values is taken. After these steps, both high precipitation and temperature values represent the high hazard level. While calculating the hazard, variables are normalized and an arithmetic sum of two normalized variables is computed. Later, these two results (hazard and resilience) are divided into quarters and they are grouped into low and high values.



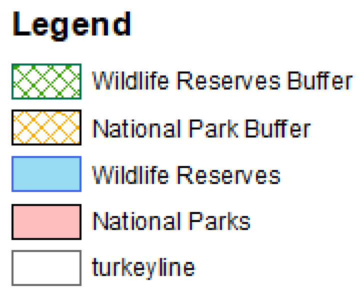


Figure 3.16. Turkey’s Protected Areas with 5km Buffer. Colors represents area of National Parks and Wildlife reserves while shaded polygons show buffered areas of PAs.

CHAPTER 4

RESULTS and DISCUSSION

This section includes the results of the study and the discussion part.

4.1 Comparison of CORDEX MODELS

3 GCM models were chosen as mentioned in the methodology part. These GCM models were analyzed (see part 3.2.1.1) to see their accuracy by using ERA5 and real station data. Then these models were examined to find out the best suitable model to use velocity for Turkey and other analyses.

Table 4.1 CORDEX Models comparison about minimum, maximum and mean temperature value in 4 referenced year according to RCP 4.5 emission scenario

Model		2000	2021	2050	2100
CNRM-CERFACS-CNRM-CM5 **RCP4.5**	**Min**	-3.11	-3.65	-3.16	-2.69
	Max	22.73	23.53	25.19	25.31
	Mean	13.98	14.13	15.74	16.19
ICHEC-EC-EARTH **RCP4.5**	**Min**	-4.06	-4.83	-4.29	-1.12
	Max	23.21	22.66	22.80	26.25
	Mean	13.66	13.29	13.66	16.10
NOAA-GFDL-GFDL-ESM2M **RCP4.5**	**Min**	-3.21	-3.16	-2.65	-3.56
	Max	23.18	23.62	24.50	23.23
	Mean	13.79	13.79	14.43	15.68

The table shows minimum, maximum, and means temperature of reference year in terms of ° C . As seen on the table, three models have very close results and increasing trends between years. CNRM-CERFACS-CNRM-CM5 mean temperature has sharp increase with 2.5 ° C until 2050, between 2050 – 2100 the increase is less than before with almost 1 °C. ICHEC-EC-EARTH mean temperature values shows a small increase till the middle of the century but after 2050 dramatically increase. At the end of the century it reaches the same mean temperature as CNRM-CERFACS-CNRM-CM5. The mean temperature value of NOAA-GFDL-GFDL-ESM2M shows a lesser but similar trend with CNRM-CERFACS-CNRM-CM5. This model also has a sharp increase after mid-century as ICHEC-EC-EARTH. Even though in 2100 all three models have very close values on mean temperature, in intermediate periods they have slightly different increase trends.

Table 4.2 CORDEX Models comparison about minimum, maximum and mean temperature value in 4 referenced year according to RCP 8.5 emission scenario

Model		2000	2021	2050	2100
CNRM-CERFACS-CNRM-CM5 **RCP8.5**	**Min**	-3.11	-3.44	-3.57	-1.02
	Max	22.73	23.83	24.02	27.28
	Mean	13.98	14.31	14.41	17.96
ICHEC-EC-EARTH **RCP8.5**	**Min**	-4.06	-3.16	-2.97	-1.85
	Max	23.21	24.53	25.47	28.17
	Mean	13.66	14.82	15.66	17.78
NOAA-GFDL-GFDL-ESM2M **RCP8.5**	**Min**	-3.21	-3.49	-3.22	-1.1
	Max	23.18	23.55	24.34	27.08
	Mean	13.79	13.85	14.69	16.61

The table shows minimum, maximum, and mean temperature of reference year in terms of ° C. Corresponding with RCP 8.5, the mean temperature rising trend is higher than for RCP 4.5. All models have nearly 4 °C increase at the end of the century. All models follow a significant increase after 2050 in both mean and maximum temperatures. CNRM-CERFACS-CNRM-CM5 and ICHEC-EC-EARTH have more rise in mean temperature. Same as for RCP4.5, NOAA-GFDL-GFDL-ESM2M follows others in lower trend. A 1 ° C to 2 ° C variation is seen between those two emission scenarios.

4.2 Velocity of climate change in Turkey

The velocity of climatic change is calculated for each model separately to see how the difference in mean temperature will reflect on the velocity maps. Even if there are some gaps between the models depending on the prevailing emissions scenario, trajectories have very close pattern.

Figures 4.1 and 4.2 show the velocity map of Turkey for various emission scenarios and CORDEX models. The three models have few differences which is seen only on the sea in terms of trajectory patterns of velocity. The fact that there is no difference in the models indicates the strength of the analysis by showing their consistency. Because of such consistency, we used only one of these models in further analysis using velocity as input. The CNRM-CERFACS-CNRM-CM5 CORDEX model based on the RCP4.5 emission scenario was used as a reference model in all velocity maps and analyzes.

The colored map at Figures 4.1 and 4.2 indicates the overall mean temperature value over the period of interest during the years between 2000-2100. Red shades represent higher and blue lower values. Climate trajectories are the directions along which points on an isotherm can pass over time. They give information about climatic range shift and also possible species climate-driven movement.

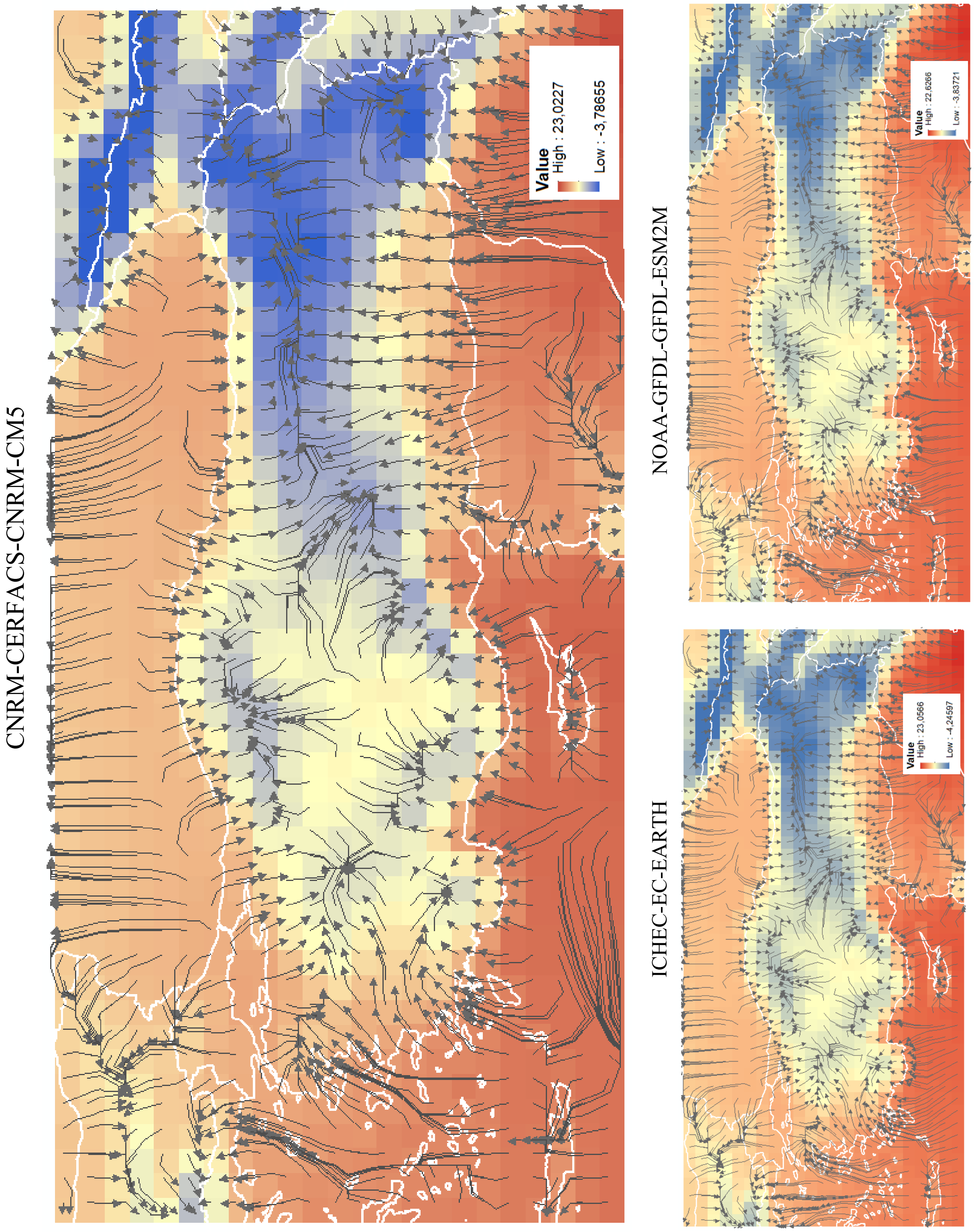


Figure 4.1. Velocity map of 3 CORDEX models in RCP 4.5 emission scenario. Arrows represent velocity trajectories and color range shows mean temperature.

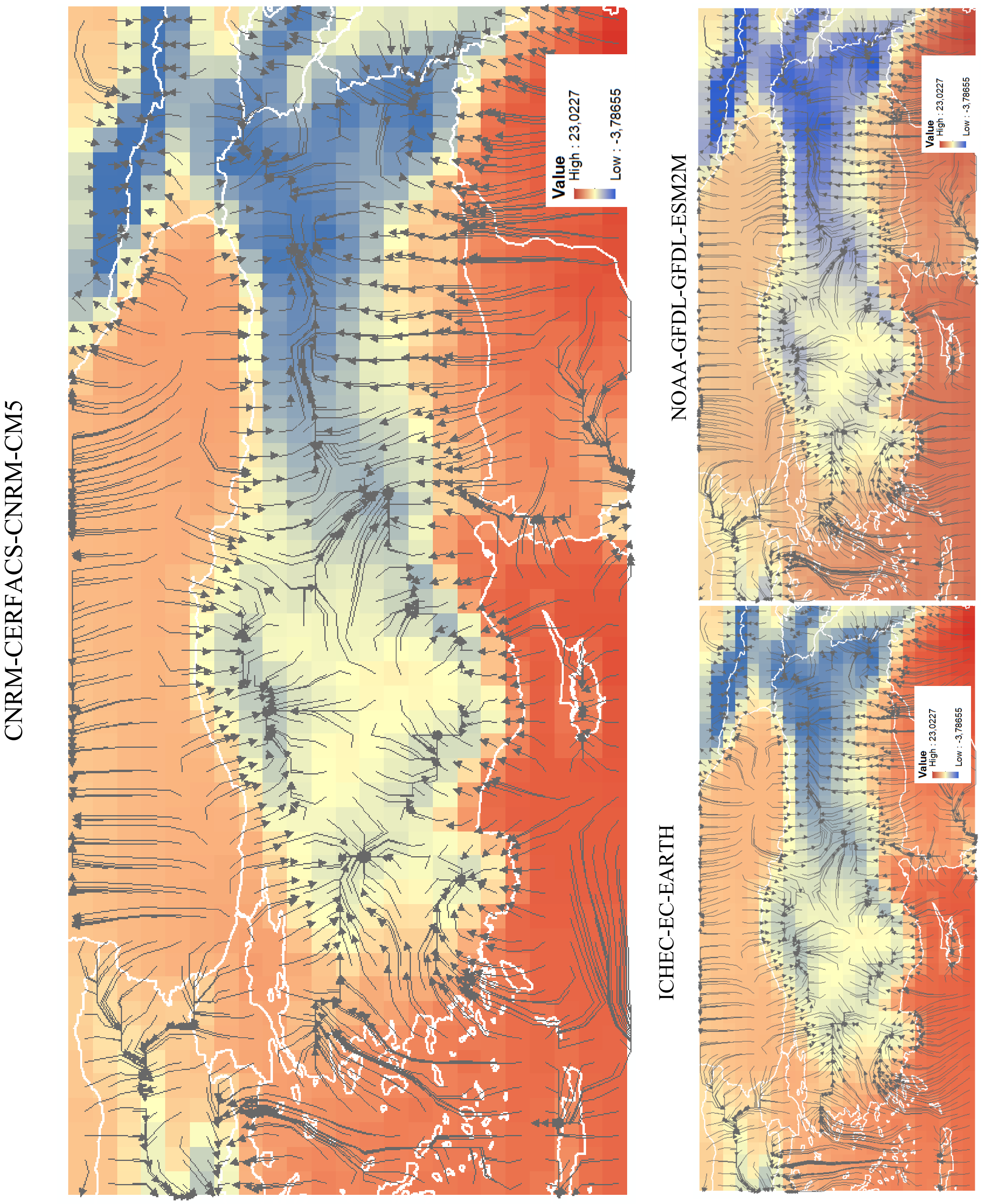


Figure 4.2. Velocity map of 3 CORDEX models in RCP 8.5 emission scenario. Arrows represent velocity trajectories and color range shows mean temperature.

According to the 100-year velocity map, velocity is higher in the sea areas than the terrestrial. More rapid warming occurs in especially the Mediterranean Sea than the others. In terrestrial areas, it is seen that the coastal part of Turkey especially the Aegan coasts will experience higher velocities. The longest trajectories represent the most shift and shortest ones represent less movement. Central Anatolia is the most vulnerable to rapid thermal shifts and climatic migration that might also lead to species movements. According to projections, this area will face drought and water stress in the future. Western Turkey has more clustering patterns in trajectories while eastern Turkey has more linear features. On the west part, trajectories cluster on mountains. It is clearly seen that mountains act as refuge areas, most of the trajectories ended in mountains.

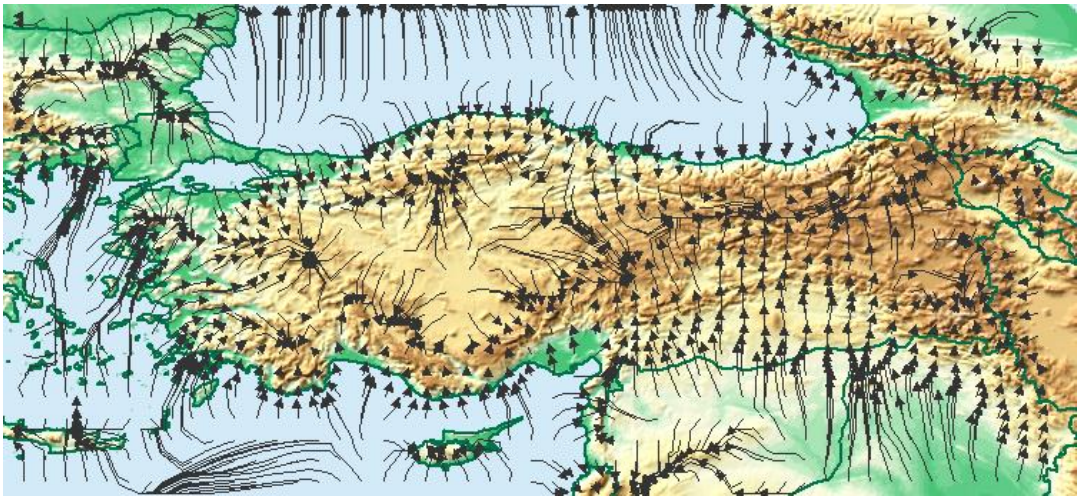


Figure 4.3. The elevation map of Turkey with velocity trajectories. Arrows represent trajectories that computed as regards velocity level.

The figure shows that the North, West, and Northeast parts of Turkey have high mountains which act as a key area for trajectories that indicate thermal shifts. It can be inferred that mountains will have a change in niche due to having higher changes in climatic patterns. Mountains can be seen as home to the diverse ecosystem but these areas are the most vulnerable areas to climatic change. On the western part, Kaz Mountains, Bey Mountains, Sultan Mountains, Simav Mountain; on the middle Blacksea region, Köroğlu Mountains; on the East Blacksea Part, Mercan, Palandöken, Karsu Mountains are important areas that will be exposed to change in biodiversity and new climatic conditions and species. As clearly seen, mountains are also key hot points for climatic range shift and species migration. So mountains act like refuges for species, their velocity of climate change smaller than the flat terrains.

4.2.1 Classification of Climate Velocity Trajectories

Cell classes were generated according to pattern and length of trajectories by reference to Burrows et al (2014). Turkey has eight different trajectory classes which are shown in figure 4.4, each class provide important predictions and inferences for future biodiversity conservation-related decisions.

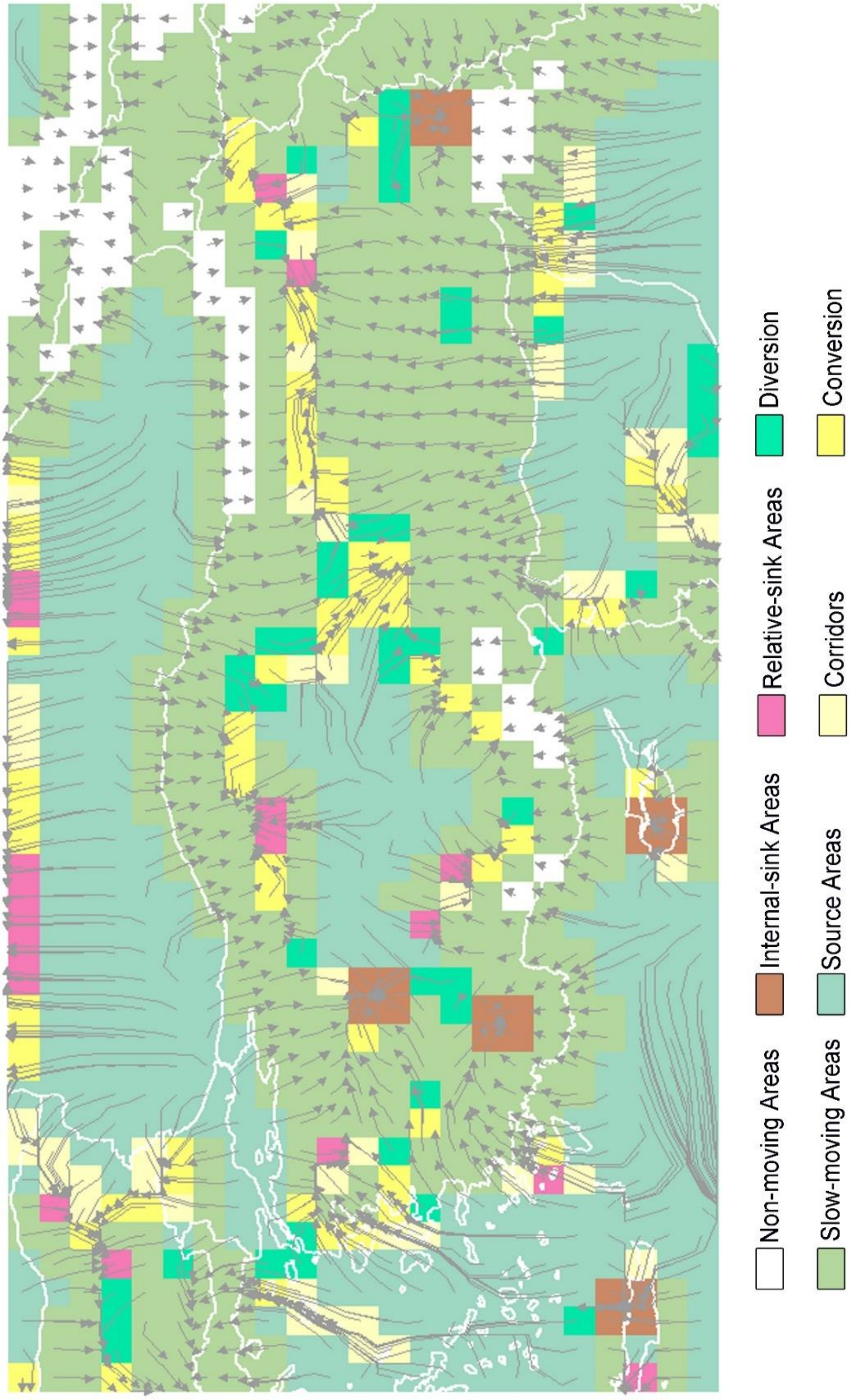


Figure 4.4. According to CNRM-CERFACS-CNRM-CM5-Cordex Model, Classification of Trajectories, Colored map represent trajectory based classes. Arrows shows trajectories.

In non-moving and slow-moving areas, little or non-temperature change will be expected. Due to non-change in climatic patterns, range shift or migration also not foreseen and in these areas, there will be no change in existing biodiversity and habitat conditions. The sink areas are the areas where the most change and impact will be seen and the temperatures will shift significantly. It is expected in these areas, the existing thermal environment will be lost and high biodiversity loss and high range shift and migration will be observed. On the other hand; in source areas of Central Anatolia, new climatic migration will not be expected but a new climatic pattern will have emerged for this area. Drought is projected for these areas according to the General Directorate of Meteorology. These areas also face with loss of current biodiversity and niches. As regards trajectory classification, cells with a high proportion of trajectories passing through were classed as corridors. Corridor cells give information about the paths of climatic migrants. On these cells, different and numerous climate migrants, as well as new interactions, will be inevitable due to new thermal niches. These areas also can be seen as key areas for biodiversity diversity and possible species migration paths. Diversion and conversions are another class for Turkey; they have high velocity and a rapidly changing thermal environment. Mountainous areas seem to have these classes mostly because of fast thermal shift in mountains. It can be said that these cells will take noteworthy migration of species and climate concerning high levels of warming up. As a result, sink areas, corridors and conversion areas will be faced with diversity loss. It can be said that these 3 classes will be very prominent in parts of Turkey, especially in mountainous areas with high altitudes. It must be taken into consideration for future conservation plans. Figure 4.4 provides key information based on future scenarios for Turkey's possible biodiversity pattern change. Finally, protected areas were inserted into these maps to make inferences for probable biodiversity loss or change in them.

4.3 Vulnerability of Protected Areas in Turkey

Turkey has significant biodiversity due to its geographical position and occurrence of widely varied climatic conditions. Protected Areas are seen as a key conservation element for protecting biodiversity and natural resources. Like anywhere else in the world, they play a crucial role in Turkey for conservation of biodiversity. However, an increase in anthropogenic pressure and a fast-changing climate may lead to a reduction in the effectiveness of protected areas. That is why this study has aimed to estimate the positions of protected areas in the future climate space, and then assess whether they will be able to maintain their functions under the stress of climate change.

As mentioned in 3.4, the vulnerability of Wildlife Reserves and National Parks in Turkey was calculated by using two parameters, resilience and hazard. Resilience reflects the size of the protected area and the level of anthropogenic pressure. Hazard involves the change in temperature and precipitation within the next 100 years. A vulnerability graph is created for Turkey PAs following Lapola et al. (2019). Figure 4.5 shows resilience capacity and hazard level for Protected Areas against the climate change effects. Dots represent National Parks (green) and Wildlife Reserves (blue) while red dashed lines show the quartiles of resilience and hazard based on median values. Hazard and resilience values were divided into 3 levels as low, moderate and high. Based on these distinctions, vulnerability was divided into 5 classes. From blue to red the fragility of protected areas is gradually increasing.

According to the vulnerability graph, it is understood that most of the protected areas in Turkey have low to medium resilience, and medium to high hazard in the face of future climate change.

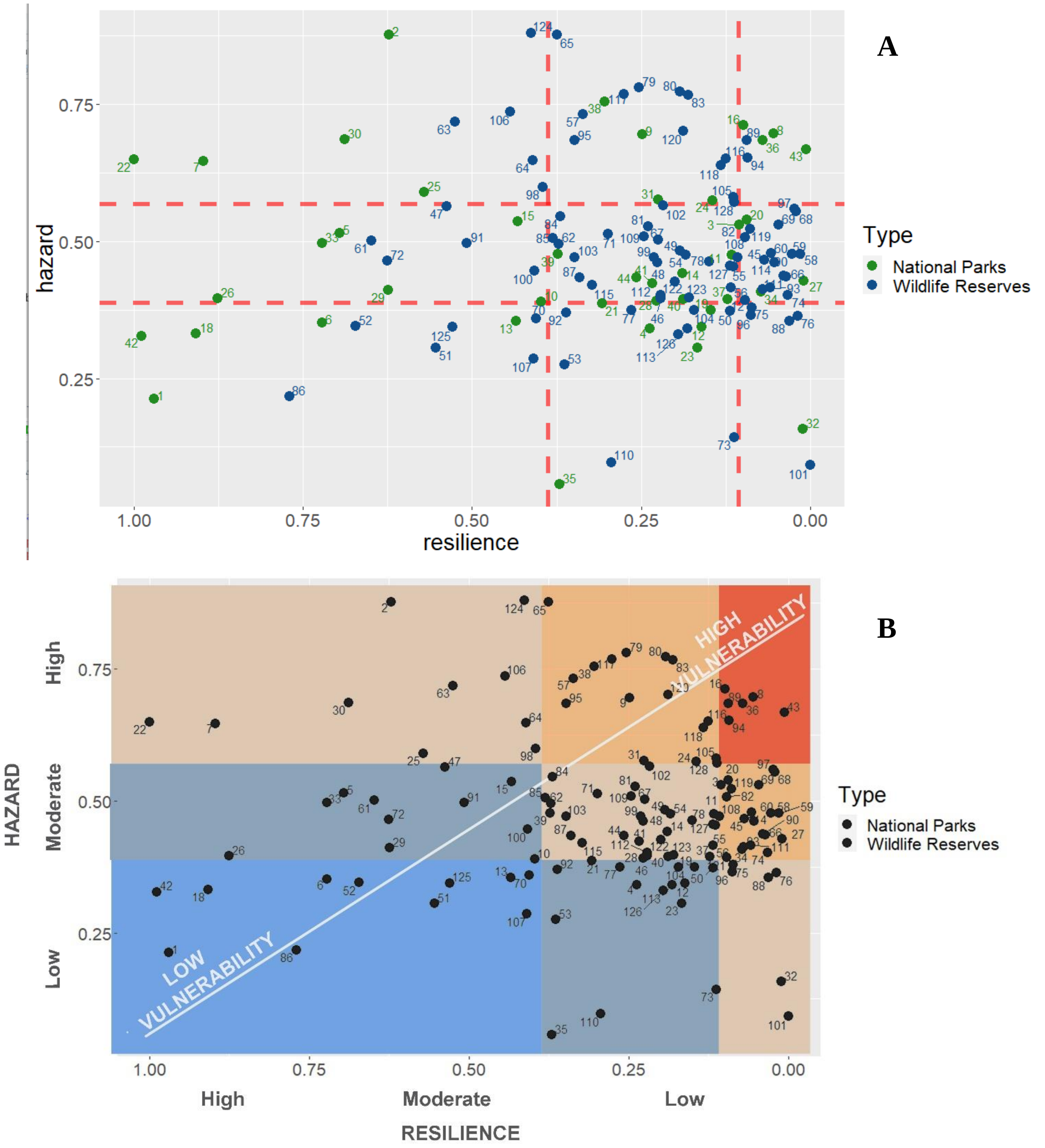


Figure 4.5. Vulnerability of Protected Areas in Turkey. Graph A shows National Parks (green) and Wildlife Reserves (blue) vulnerability level. Graph B shows the vulnerability classes that divided into five according to quartiles

Figure 4.5 displays that three National Parks (Boğazköy Alacahöyük, Yozgat Çamlığı, Ilgaz Mountain) and two Wildlife Reserves (Kargı Kösdağı, Kara Akbaba) have very high vulnerability. These are small protected areas with considerable human presence inside or adjacent to them. On the other hand, Ağrı Mountain, Yedigöller, Kaçkar, Beydağları National Parks and İspir Vercenik Mountain and Ardahan Wildlife Reserve areas have both high resilience and low hazard values, hence show the lowest vulnerability. These PAs are large in size and away from human settlements or farmland, possibly acting as key areas as refugia for species. Most high vulnerability sites face significant anthropogenic pressure besides the climate change effects. The anthropogenic effect has an adverse impact on the resistance of the protected areas to outside influences.

Interestingly, some PAs have high resilience but face high hazard. Kızıldağ, Beyşehir Gölü, Aladağlar, Munzur Vadisi National Parks are vulnerable to high hazard levels due to increasing temperatures and declining precipitation within the next 100 years. However, those sites have low anthropogenic pressures and are of a bigger size than the others. That's why their resilience level also is higher (blue areas in the second graph). These PAs might allow natural adaptation to the predicted changes within their boundaries.

There are also some PAs that show both low resilience and low hazard. Kuyucuk Lake, Erzurum Oltu, Sarıkamış Kağızman Wildlife Reservea and Nenehatun, Sarıkamış National Parks can possibly maintain their ecosystem integrity for a while but not until the end of the century.

As a result; even if natural adaptative and refugia PAs have existed, a very dense part of PAs belongs in the high level vulnerability. Their situation in future probably will not be sufficient for maintain their conservation situations.

4.3.1 PAs and their Velocity Trajectory Classes

Trajectory classes based on the velocity with 2000-2100 referenced term were defined above. Non-moving and slow-moving cells (white and green) will have no or very little change in climatic patterns. Biodiversity in those areas can be maintained effectively. In figure 4.6 it is clearly seen that less vulnerable PAs (based on figure 4.5) fall within non- or slow-moving areas like Ağrı Mountain, Yedigöller, Kackar, Beydağları National Parks, Ardahan Posof, İspir Vernecik Wildlife Reserves. Even those with a high hazard level, such as Aladaglar, Kızıldag, and Munzur Valley NPs occur in non- or slow-moving cells. The most important features of those protected areas are that (1) they are far from anthropogenic effects and (2) they have a size of 900 km^2 or above. These sites also can function as a refugia with high natural adaptation capacity. Biodiversity conservation strategies will be more effective for these areas because range shifts or migration are expected to be rare, and current biodiversity elements will probably continue to exist into the future.

Figure 4.6 also highlights conversion and sink areas as important hotpoints that might lose their biodiversity. Soguksu, Ilgazdagı, Sultansazlıgı National Parks and Kara akbaba, Kargı Kosdag Wildlife Reserves will be exposed to high migration rates and loss of their thermal environment due to rapid thermal shift. These PAs also have high vulnerability due to high anthropogenic effect (based on figure 4.5). Such sink and conversion areas are most problematic, and PAs that fall within these areas may not be able to maintain their conservation functions. Burdur Lake, Dinar Karakayasu Lake Wildlife Reserves display a high velocity and are located in areas that might experience habitat loss. Sarıkamış and Nenehatun National Parks fall within the relative-sink and conversion area. These NPs have also less resilience, so dramatic biodiversity loss and thermal shift or loss are expected.

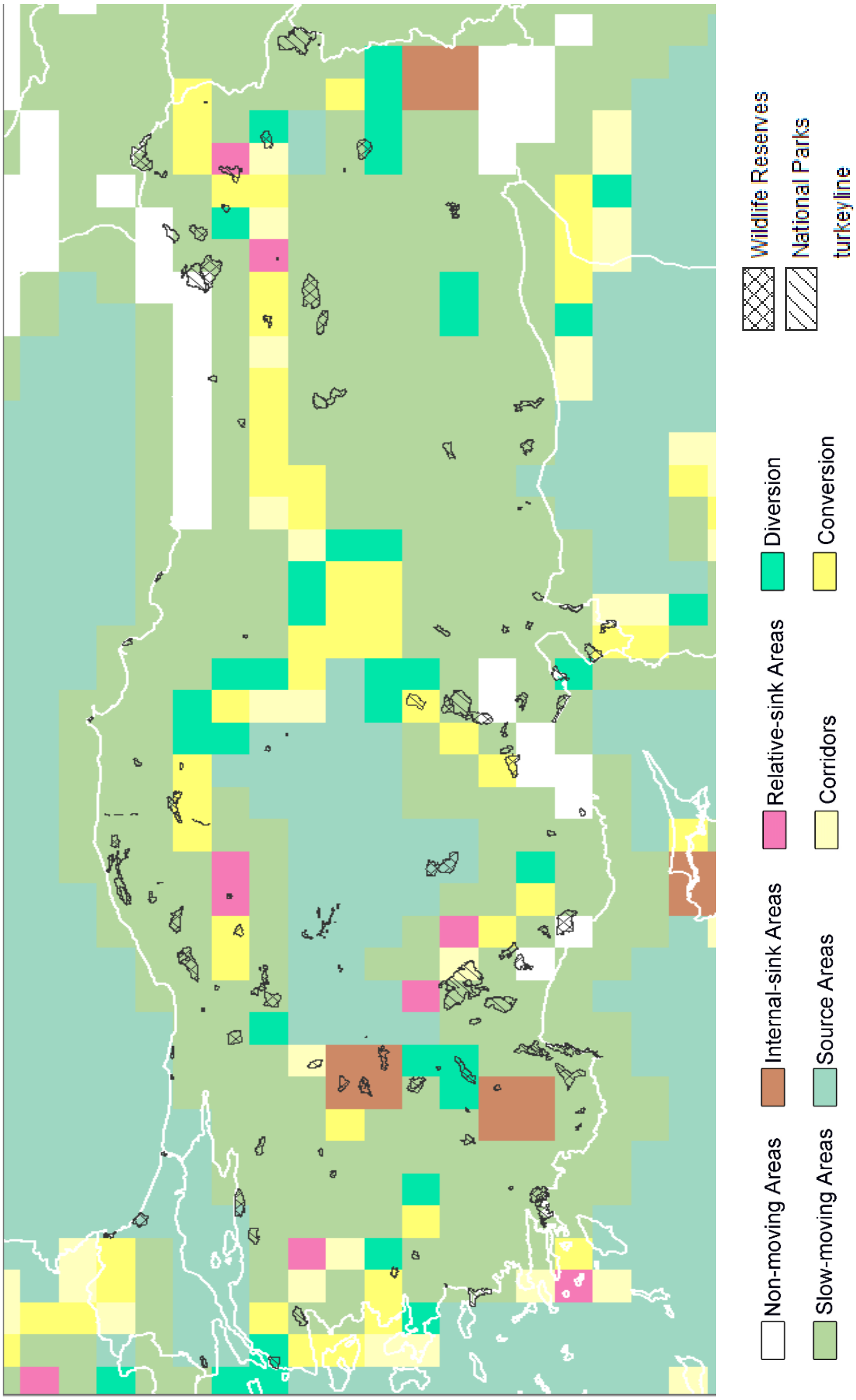


Figure 4.6. Protected Areas with trajectory classes

Blue cells represent the source areas with disappearing existing climatic patterns and forming new thermal environments. Sakarya, Bogazkoy-Alacahoyuk, Yozgat Camlıgı National Parks, and Bozdag Wildlife Reserve will not maintain their function and have biodiversity loss, although new arrivals are likely.

Having said that, even though velocity of climate change is high, the large size and undisturbed nature of PAs are important for their maintenance. Although mountains are more exposed to climatic changes, if they are far from human influence, their natural adaptation capacity is also often high. For Turkey, mountainous areas of Northeastern and Northern Anatolia will experience most changes both in biodiversity and thermal pattern. Species can migrate to these areas from elsewhere, and while losing some species and biota, new ones can emerge.

4.3.2 The residence time of PAs based on Velocity

The size of PAs is important for vulnerability and adaptation of PAs to climatic changes. While calculating vulnerability, temperature and precipitation data were used as a hazard, and the size of PAs was taken into consideration as a positive resilience feature. Climatic velocity is used for residence time calculation to see how velocity and PAs size are in relation. Residence time offers opportunities to infer consequences for biodiversity survival (species continuity) and conservation goals. Residence times were also measured to investigate the relationship between protected area sizes and the velocities needed to keep up with climate change. The size of PAs is important but obviously climate velocity also highly influence residence times. Kackar, Kuredağları, Hatilavadisi, Saklıkent, Botan NPs have highest residence time. Even if Saklıkent and Botan NPs are smaller than others, all these NPs are in slow-moving cells which shows low velocity. Alanya Dimcayı, Artvinyusufeli, İbradi Üzümdere, İspir Vercenik Wildlife reserve areas have the highest residence time due to both bigger size and occurrence in non-moving cells.

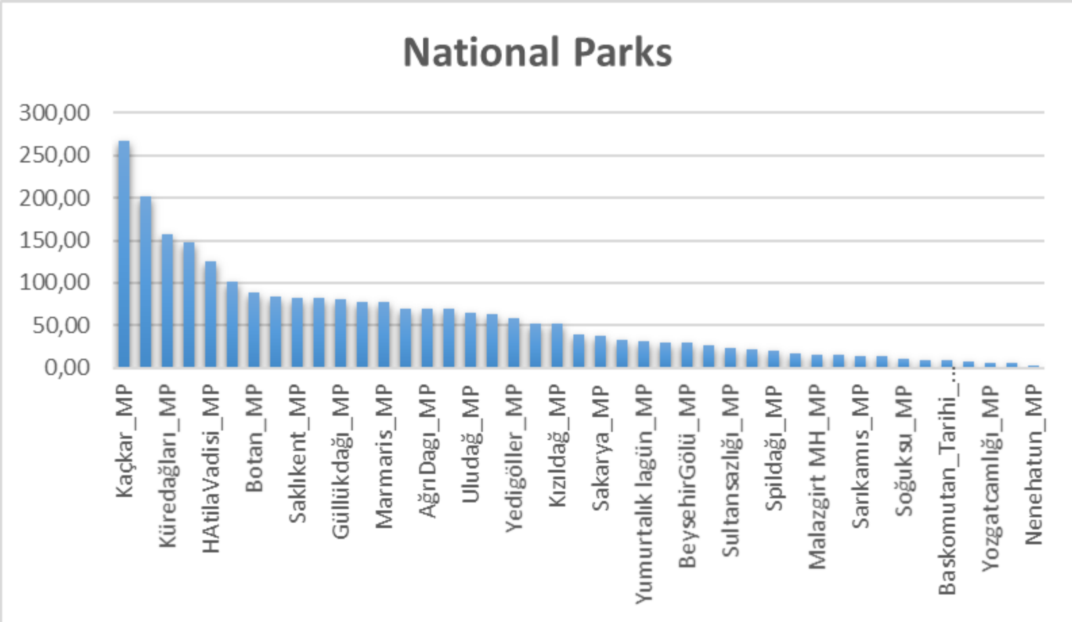


Figure 4.7. Residence Time of National Parks from higher to lower (diameter of the equivalent circle (km), and residence time (years) as the ratio D/vel)

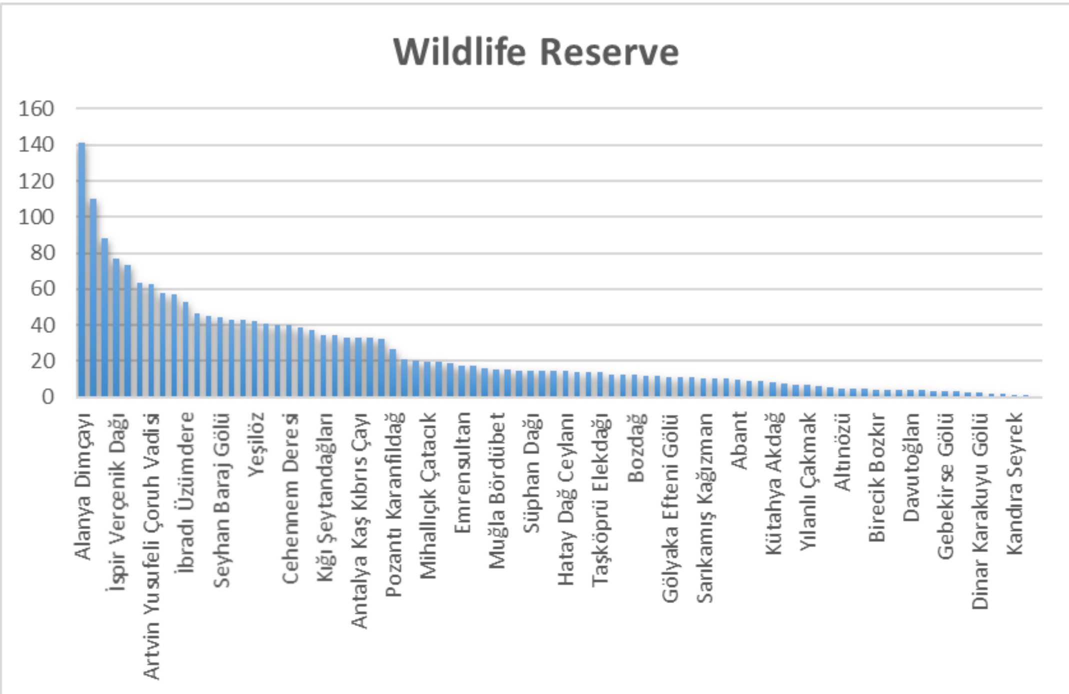


Figure 4.8. Residence Time of Wildlife Reserves from higher to lower (diameter of the equivalent circle (km), and residence time (years) as the ratio D/vel)

Residence time which takes only into consideration the size of PAs and velocity were compared with resilience to see the accuracy and the reliability of calculations. As expected there is a correlation and direct proportion between them. It can be confirmed that the size of a PA is important to improve effectiveness and maintenance in the long term.

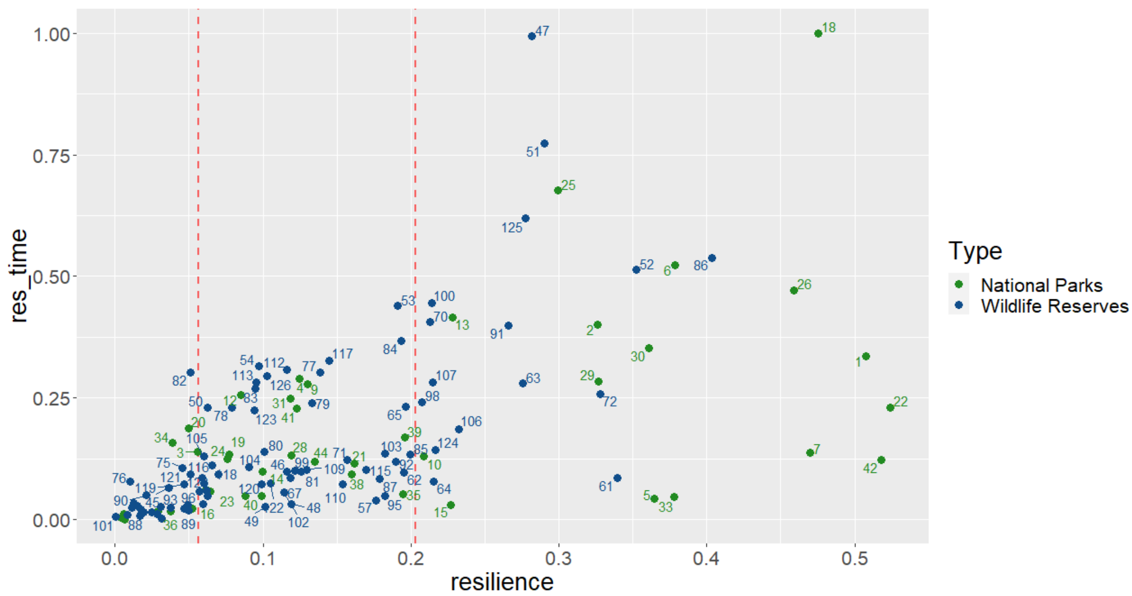


Figure 4.9. Comparison of Residence time versus Resilience for National parks (green) and Wildlife Reserves (blue)

4.3.3 Seasonal Shift based on Velocity

PAs can adapt to change in climatic conditions and maintain their conservation functions depending on their hazard and resilience levels. Although mainly it provides natural adaptation to changes, some species probably will have trouble with even small changes in their thermal environments. The seasonal shift shows earlier timing of events which matters for species that closely track thermal conditions or those that depend on accurate seasonal timing of reproduction or migration. Not being able to keep up with advancing seasons may lead to uncoupling of natural resource peaks and important stages in the life cycle of many species (such as breeding). Also shift in seasonal temperature may cause change in timing seasonal events of species and misleading their phonological events. Earlier spring may bring problems in species life cycle and can cause decrease in their populations. Even if Protected Areas adapt change in climate change or have resilience, some species can effect very little temperature changes.

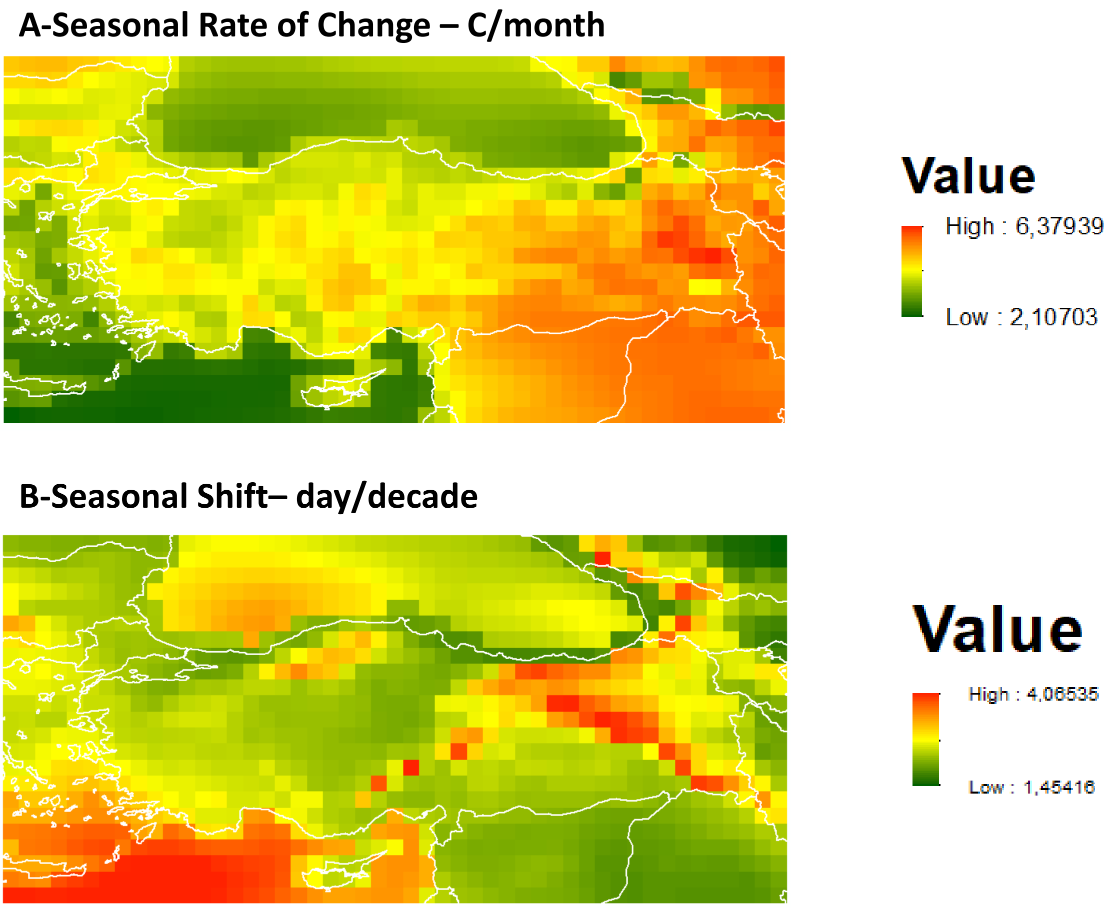


Figure 4.10. Spring seasonal shift is shown for April. A shows spring seasonal rate of temperature change (C/ month). B shows seasonal shift for April (day/decade)

According to figure 4.10: on A; seasonal rate of change was given by half the difference in temperature between preceding and following months (°C/month) will follow the range between 2.10 - 6.37 °C/month. on B; for Turkey 2 to 4 days' seasonal shift in April is expected within 10 yearly periods.

CHAPTER 5

CONCLUSION & DISCUSSION

Protected Areas are cornerstones of biodiversity conservation. They preserve natural ecosystems by acting as refuges for species and provide maintenance of ecological processes. According to IUCN definition (2008) a protected area is: "A clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values". The primary goal of a National Park is to protect natural biodiversity, its underlying biological structure, and the supporting environmental processes, while enabling recreation for people. Protected areas are often chosen because they are biologically rich, have diverse or unique ecosystems, and provide key natural areas for many species. Moreover, presence of endangered, threatened or endemic species or ecosystems is another criteria for site selection. However, such sites need to be of a large enough size to sustain ecosystem functions, and to enable populations of focal species survive.

Since protected areas are designed to protect the natural habitats of the species against sudden changes, they can be considered a very effective protection method in the short term. However, they may be insufficient to deliver long-term protection against climate change, which has already effected biodiversity in the last 50 years. While protected areas provide resilience against climate change, they also experience increasing pressures against its impacts. Differences in seasonal distribution and yearly precipitation, as well as mean monthly temperature patterns and fluctuation, may have an influence on the local-regional ecosystem, as well as on the welfare of people and the biodiversity within it. These changes may bring out a new ecosystem and most importantly induce geographic range shift in species. Change in ecosystem structure and function may lead to introduction of new species and shape species interactions in terms of predator – prey and plant – herbivore relations. Movements of species into novel environments, or their loss from previously occupied regions, or changes in the quantity and distribution of individuals within a species' range are main outcomes for protected areas due to ongoing climate change. The level of shift depends on the velocity of change of climatic conditions. So, it is important that vulnerability of PAs to climate change need to be evaluated and solutions be developed to effectively safeguard biodiversity into the future.

In this study, the predicted climate change dimensions in Turkey by using climate velocity and the effectiveness of protected areas were evaluated. According to the findings on study, average velocity of climate change in Turkey is found to be 2.4 km/20-year in terrestrial area. Geographical features have a significant role in variability velocity of climate. Center Anatolia has high velocity, with all trajectories departing from this part towards the encircling mountain areas. Eastern Anatolia and Northern Blacksea regions have low velocity due to high topographic relief. Our findings show that elevation highly effect climate velocity in Turkey. Elevated lands are more likely to slow velocity. Velocity trajectories gives information about the migration patterns of climate-sensitive species. Our analyses show that species richness in central Anatolia will probably decline (or at least change significantly) in the future and National parks such as Yozgat Camlıgı NP or Sakarya NP will not maintain their ecological functions. Mountainous areas will likely have new species arriving but also will experience changes in their current biodiversity patterns.

According to trajectory patterns and classes of Turkey which formed from gradient based velocity calculation, species in some protected areas, especially those in coastal and central Anatolia will lose their habitats inside Protected Areas. On the other hand, protected areas in mountains around Central Anatolia will have new migrants, and probably their environments and biological patterns will change. That’s why these PAs need new conservation regulations. All these thermal range shifts and species migration are ongoing and will occur in a different time interval. These time interval depends on the residence time of Protected Areas and as well as their geographic elevation or locations whether is in mountain or not. It can be claimed for Protected Areas in Turkey that new advanced conservation strategies are needed. Dynamic protected areas need to created by improving linkages between PAs via biological corridors in sink and conversion classes. PAs located in slow moving areas and sink areas can be refugia and their size and capacity can be increased to compensate for arrival of more species which might need different habitat conditions. Corridor classes gives information about the species migration paths, these areas can be evaluated as a biological corridors or connective lands between protected areas. Northeastern Turkey can be thought as a biological migration path.

This study assumes that species will shift ranges following the predicted velocity trajectories. Inferences are made assuming that species track velocity trajectories in response to climate change. However, only the temperature variable is considered for calculating these trajectories. Occurrence of habitats of the species or movements of species can be affected by a range of variables (water resources, biotic interactions, dispersal capacity, human-induced effects, geographical obstacles, etc.) other than the climate. It cannot be said for certain that all species will fully behave according to these trajectories.

It is possible to compare the calculated climate velocity in Turkey (2.40 km/100-year) with some historical migration rates. Species must adapt, migrate, or perish against climate change. Although some species are already migrating, it is uncertain whether they will be able to keep up with the rapid changes predicted in the future (Corlett & Westcott, 2013). As Although many species faced climate change during the glacial and interglacial periods and could maintain their survival, but with additional anthropogenic climate effects, change is faster in now. Some paleoecological records show that species survived before and was capable to adapt velocity of climate change, but especially some plant species could not move fast enough due to higher velocity (Corlett & Westcott, 2013). Feurdean et al., 2013 shows in their research that migration speed of species are also dependent on dispersal level and their movement level is changing with respect to early or late succession time.

In conclusion, in order for the functions of protected areas to continue more effectively against climate change, some improvement and management decisions should be developed. While these decisions are being developed, the residence time and trajectory classes give us ideas about which protected areas need to be expanded, and which corridors need to be created. PAs with high resilience and low hazards can be key biodiversity habitats for the future and any anthropogenic effects must be minimized on these sites.

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APPENDICES

A. Residence Time of Protected Areas – National Parks

TYPE	PA_Name	ResidenceTime (velocity/areaofPA)
National Park	Kaçkar_MP	266.76
National Park	Beydağları_MP	202.26
National Park	Küredağları_MP	157.38
National Park	Köprülükanyon_MP	148.42
National Park	HAtilaVadisi_MP	124.98
National Park	AltındereVadi_MP	101.32
National Park	Botan_MP	88.32
National Park	Munzur Vadisi_MP	83.23
National Park	Saklıkent_MP	83.03
National Park	Aladağlar_MP	82.10
National Park	Güllükdağı_MP	80.47
National Park	Altınbesik Magara_MP	78.12
National Park	Marmaris_MP	78.07
National Park	Karatepe_aslantaş	70.38
National Park	AğrıDagı_MP	70.15
National Park	Nemrutdağı_MP	69.64
National Park	Uludağ_MP	65.31
National Park	Karagöl_sahara_MP	63.05
National Park	Yedigöller_MP	58.68
National Park	Tektekdağları_MP	52.52
National Park	Kızıldağ_MP	51.60
National Park	Kovadagölü_MP	39.74
National Park	Sakarya_MP	37.57
National Park	Honazdağı_MP	33.05
National Park	Yumurtalık lagün_MP	32.24
National Park	Kazdağı_MP	29.18
National Park	BeysehirGölü_MP	29.16
National Park	Dilek_Yarımada_MP	27.47
National Park	Sultansazlığı_MP	22.87
National Park	Manyas_MP	22.60
National Park	Spildağı_MP	20.19
National Park	Kopdağı_tarihiMP	17.80
National Park	Malazgirt MH_MP	15.92
National Park	İğneada_MP	15.15
National Park	Sarıkamıs_MP	14.29
National Park	Troya_TArihiMP	13.44
National Park	Soğuksu_MP	10.21
National Park	GalaGölü_MP	9.85
National Park	Baskomutan_Tarihi_MP	8.76
National Park	Bogazköy_alacahöyük_MP	7.93
National Park	Yozgatcamlığı_MP	6.08
National Park	Ilgazdağı_MP	5.21
National Park	Nenehatun_MP	2.67

B. Residence Time of Protected Areas – Wildlife Reserves

TYPE	PA_Name	ResidenceTime (velocity/areaofPA)
Wildlife Reserve	Alanya Dimçayı	141.285
Wildlife Reserve	Antalya Sarıkaya	109.987
Wildlife Reserve	Yedigöller	88.287
Wildlife Reserve	İspir Verçenik Dağı	76.828
Wildlife Reserve	Ardahan Posof	73.221
Wildlife Reserve	Köyceğiz	63.502
Wildlife Reserve	Artvin Yusufeli Çoruh Vadisi	62.655
Wildlife Reserve	Düzlerçamı	58.034
Wildlife Reserve	Karabük Yenice	56.892
Wildlife Reserve	İbradı Üzümdere	52.526
Wildlife Reserve	Tarsus Kadıncık Vadisi	46.618
Wildlife Reserve	Azdavay Kartdağ	45.280
Wildlife Reserve	Seyhan Baraj Gölü	44.237
Wildlife Reserve	Göynük Kapıormanı	43.292
Wildlife Reserve	Hisardağı ve Gedik Dağı	43.267
Wildlife Reserve	Yeşilöz	42.217
Wildlife Reserve	Sivridağ	40.503
Wildlife Reserve	Rize Çamlıhemşin Kaçkar	40.423
Wildlife Reserve	Cehennem Deresi	40.117
Wildlife Reserve	Hopur Topaşır	38.578
Wildlife Reserve	Erzurum Çat	37.041
Wildlife Reserve	Kığı Şeytandağları	34.738
Wildlife Reserve	Gündoğmuş	34.259
Wildlife Reserve	Çamardı Demirkazık	33.320
Wildlife Reserve	Antalya Kaş Kıbrıs Çayı	33.175
Wildlife Reserve	Gümüşhane Şiran Kuluca	33.006
Wildlife Reserve	Ulus Sökü	32.181
Wildlife Reserve	Pozantı Karanfildağ	26.829
Wildlife Reserve	Yahyalı Aladağlar	20.829
Wildlife Reserve	Hançerderesi	20.153
Wildlife Reserve	Mihallıçık Çatacık	19.608
Wildlife Reserve	İskenderun Arsuz	19.314
Wildlife Reserve	Mut Kesteldağı	18.786
Wildlife Reserve	Emrensultan	17.851
Wildlife Reserve	Karadağ Ovakorusu	17.269
Wildlife Reserve	Tahtaköprü Baraj Gölü	16.197
Wildlife Reserve	Muğla Bördübet	15.729
Wildlife Reserve	Gölardı Simenlik Gölü	15.529
Wildlife Reserve	Sandıklı Akdağ	15.034
Wildlife Reserve	Süphan Dağı	14.903
Wildlife Reserve	Kızılkuyu	14.728
Wildlife Reserve	Akyatan Gölü	14.449
Wildlife Reserve	Hatay Dağ Ceylanı	14.380

Wildlife Reserve	Hatay Dağ Ceylanı	14.380
Wildlife Reserve	Burdur Gölü	14.203
Wildlife Reserve	Tuzla Gölü	13.730
Wildlife Reserve	Taşköprü Elekdağı	13.646
Wildlife Reserve	Çivril Akdağ	12.695
Wildlife Reserve	Zorkun Yaylası	12.649
Wildlife Reserve	Bozdağ	12.441
Wildlife Reserve	İstanbul Çatalca Çilingoz	12.206
Wildlife Reserve	Cevizli Gidengelmez Dağı	11.592
Wildlife Reserve	Gölyaka Efteni Gölü	11.431
Wildlife Reserve	Türkmenbaba	10.972
Wildlife Reserve	Bafra Kızılırmak Deltası	10.944
Wildlife Reserve	Sarıkamış Kağızman	10.796
Wildlife Reserve	Tavşanlı Çatak	10.631
Wildlife Reserve	Tosya Gavurdağı	10.618
Wildlife Reserve	Abant	9.601
Wildlife Reserve	Baydındır Ovacık	8.929
Wildlife Reserve	Saçak	8.724
Wildlife Reserve	Kütahya Akdağ	8.295
Wildlife Reserve	Karabük Sırçalı Kanyonu	7.518
Wildlife Reserve	Kastamonu Ilgazdağı	7.260
Wildlife Reserve	Yılanlı Çakmak	7.242
Wildlife Reserve	Beypazarı Kapaklı	6.074
Wildlife Reserve	Kaz Gölü	5.218
Wildlife Reserve	Altınözü	4.950
Wildlife Reserve	Erzurum Oltu	4.858
Wildlife Reserve	Kargı Kösdağı	4.681
Wildlife Reserve	Birecik Bozkır	4.306
Wildlife Reserve	Bozburun	4.215
Wildlife Reserve	Altıntaş	4.115
Wildlife Reserve	Davutoğlan	4.014
Wildlife Reserve	Karakaş Gölü	3.777
Wildlife Reserve	Kaynarca Acarlar Gölü	3.552
Wildlife Reserve	Gebekirse Gölü	3.326
Wildlife Reserve	Kara Akbaba	3.108
Wildlife Reserve	Çardak Beylerli Gölü	2.637
Wildlife Reserve	Dinar Karakuyu Gölü	2.579
Wildlife Reserve	Sivrihisar Balıkdamı	2.038
Wildlife Reserve	Birecik Fırat	1.794
Wildlife Reserve	Kandıra Seyrek	1.465
Wildlife Reserve	Kuyucuk Gölü	1.141
Wildlife Reserve	Sarıyer Feneryolu	0.787

C. Vulnerability Table of Protected Areas in Turkey – National Parks

Name of PAs	Velocity of PAs (km/year)	Residence Time of PAs	Resilience Level of PAs	Hazard Level of PAs	Resilience Class	Hazard Class
AğrıDagı	0.673775	47.961581	0.969495	0.212066	high	low
Aladağlar	0.470912	57.144418	0.622269	0.876227	high	high
Altınbesik Magara	0.195251	20.205543	0.105774	0.530458	low	moderate
AltındereVadi	0.182694	41.592170	0.237176	0.341574	moderate	low
Baskomutan Tarihi Milli Parkı	3.339481	6.632157	0.695892	0.515181	high	moderate
Beydağları	0.276197	74.630872	0.721881	0.351445	high	low
BeysehirGölü	1.693091	19.822615	0.896498	0.645881	high	high
Bogazköy Alacahöyük	2.091334	2.850967	0.054509	0.696046	low	high
Botan	0.291799	39.996387	0.248162	0.695768	moderate	high
Dilek Yarımadası	1.051655	18.877716	0.397382	0.390004	high	moderate
GalaGölü	1.044175	9.040194	0.116431	0.474587	moderate	moderate
Güllükdağı	0.260401	36.807346	0.161260	0.343966	moderate	low
HAtilaVadisi	0.246220	59.406464	0.434778	0.355108	high	low
Honazdağı	0.800214	14.363785	0.189444	0.441377	moderate	moderate
İğneada	1.473459	4.678092	0.433095	0.536330	high	moderate
Ilgazdağı	1.072227	3.693335	0.099179	0.711648	low	high
Kaçkar	0.182282	142.256728	0.907502	0.331869	high	low
Karagöl Sahara	0.327782	19.440437	0.146758	0.374683	moderate	low
Karatepe Aslantaş	0.269591	27.112057	0.093791	0.538717	low	moderate
Kazdağı	1.051696	16.695182	0.307810	0.386933	moderate	low
Kızıldağ	1.001155	33.187723	1.000000	0.648901	high	high
Kopdağı Tarihi Milli Parkı	1.238992	7.226576	0.167214	0.306005	moderate	low
Kovadagölü	0.528340	17.980747	0.144485	0.574372	moderate	high
Köprülükanyon	0.265552	96.355462	0.571121	0.589753	high	high
Küredağları	0.345405	67.302010	0.875794	0.395811	high	moderate
Malazgirt	0.867689	1.957560	0.010178	0.427953	low	moderate
Manyas	0.821792	19.263274	0.227193	0.391104	moderate	moderate
Marmaris	0.505637	40.818823	0.623618	0.411626	high	moderate
Munzur Vadisi	0.463011	50.341135	0.688658	0.685889	high	high
Nemrutdağı	0.371049	35.589457	0.225334	0.576725	moderate	high
Nenehatun	4.698497	0.467848	0.011261	0.158348	low	low
Sakarya	2.003851	6.932471	0.721694	0.497030	high	moderate
Saklıkent	0.208193	22.837577	0.072960	0.407730	low	moderate
Sarıkamıs	2.131327	7.820476	0.370815	0.057015	moderate	low
Soğuksu	1.463536	2.792611	0.070839	0.684986	low	high
Spildağı	1.136274	8.717203	0.122516	0.395001	moderate	moderate
Sultansazlığı	1.310814	13.700362	0.304271	0.755406	moderate	high
Tektekdağları	0.636706	24.272803	0.372933	0.477144	moderate	moderate
Troya Tarihi Milli Parkı	1.946054	7.283687	0.188245	0.394959	moderate	moderate
Uludağ	0.418443	32.840253	0.233232	0.424081	moderate	moderate
Yedigöller	0.271540	17.750010	0.988465	0.327744	high	low
Yozgatcamlığı	1.977816	0.963146	0.006642	0.668083	low	high
Yumurtalık lagün	0.850415	17.398669	0.257467	0.433699	moderate	moderate

D. Vulnerability Table of Protected Areas in Turkey – Wildlife Reserves

Name of PAs	Velocity of PAs	Residence Time of PAs	Resilience Level of PAs	Hazard Level of PAs	Resilience Class	Hazard Class
Abant	0.547320	9.600886	0.068359	0.466152	low	moderate
Akyatan Gölü	0.973815	14.449382	0.221499	0.396014	moderate	moderate
Alanya Dimçayı	0.179812	141.285305	0.537858	0.563980	high	moderate
Altınözü	2.650843	4.949914	0.226722	0.461415	moderate	moderate
Altıntaş	3.383742	4.115170	0.193007	0.482191	moderate	moderate
Antalya Kaş Kıbrıs Çayı	0.210505	33.175105	0.118323	0.372509	moderate	low
Antalya Sarıkaya	0.213699	109.986720	0.553499	0.305531	high	low
Ardahan Posof	0.369744	73.221225	0.672386	0.344817	high	low
Artvin Yusufeli Çoruh Vadisi	0.272623	62.655213	0.363651	0.275428	moderate	low
Azdavay Kartdağ	0.279180	45.279753	0.184574	0.475384	moderate	moderate
Bafra Kızılırmak Deltası	0.770436	10.944423	0.113812	0.453543	moderate	moderate
Baydındır Ovacık	1.020697	8.928995	0.117659	0.416453	moderate	moderate
Beypazarı Kapaklı	1.904907	6.073670	0.336228	0.732460	moderate	high
Birecik Bozkır	0.838891	4.306314	0.027850	0.476771	low	moderate
Birecik Fırat	0.838891	1.793534	0.014969	0.476385	low	moderate
Bozburun	0.912029	4.214923	0.057937	0.478328	low	moderate
Bozdağ	2.278020	12.440619	0.648237	0.500582	high	moderate
Burdur Gölü	1.343582	14.203083	0.371929	0.494831	moderate	moderate
Cehennem Deresi	0.473682	40.117189	0.525537	0.717694	high	high
Cevizli Gidengelmez Dağı	1.276851	11.592015	0.410584	0.647739	high	high
Çamardı Demirkazık	0.470912	33.320461	0.374836	0.876150	moderate	high
Çardak Beylerli Gölü	1.357778	2.636699	0.036385	0.435509	low	moderate
Çivril Akdağ	0.960747	12.694977	0.225165	0.502661	moderate	moderate
Davutoğlan	0.629745	4.014406	0.021409	0.555277	low	moderate
Dinar Karakuyu Gölü	1.697093	2.578530	0.046881	0.530453	low	moderate
Düzlerçamı	0.343446	58.033508	0.405804	0.359899	high	low
Emrensultan	0.810781	17.850758	0.298995	0.513936	moderate	moderate
Erzurum Çat	0.754648	37.040769	0.625281	0.464703	high	moderate
Erzurum Oltu	1.620167	4.857996	0.112385	0.142839	moderate	low
Gebekirse Gölü	0.840462	3.326396	0.033003	0.402519	low	moderate
Gölardı Simenlik Gölü	0.433388	15.528576	0.086358	0.379803	low	low
Gölyaka Efteni Gölü	0.289869	11.430939	0.018629	0.363130	low	low
Göynük Kapıormanı	0.409423	43.292285	0.263966	0.375307	moderate	low
Gümüşhane Şiran Kuluca	0.249550	33.006177	0.149975	0.462872	moderate	moderate
Gündoğmuş	0.310530	34.258613	0.253581	0.780010	moderate	high
Hançerderesi	0.503132	20.152964	0.192439	0.773013	moderate	high
Hatay Dağ Ceylanı	0.904230	14.379911	0.239671	0.527936	moderate	moderate
Hisardağı ve Gedik Dağı	0.171579	43.266508	0.097022	0.507846	low	moderate
Hopur Topaşır	0.229745	38.577701	0.180472	0.766860	moderate	high
İbradı Üzümdere	0.301395	52.526025	0.369019	0.545011	moderate	moderate
İskenderun Arsuz	0.945071	19.314009	0.380553	0.505144	moderate	moderate
İspir Verçenik Dağı	0.365779	76.827720	0.770106	0.217667	high	low
İstanbul Çatalca Çilingoz	1.374408	12.205536	0.340808	0.434642	moderate	moderate
Kandıra Seyrek	2.630835	1.465225	0.031370	0.354152	low	low

Kara Akbaba	1.463536	3.108124	0.094642	0.684986	low	high
Karabük Sırçalı Kanyonu	0.321501	7.518238	0.039968	0.437435	low	moderate
Karabük Yenice	0.343513	56.891626	0.507254	0.496659	high	moderate
Karadağ Ovakorusu	1.184102	17.269319	0.361463	0.370148	moderate	low
Karakaş Gölü	1.975275	3.777467	0.070523	0.412756	low	moderate
Kargı Kösdağı	1.116081	4.680897	0.092587	0.652397	low	high
Kastamonu Ilgazdağı	2.131465	7.260352	0.348072	0.684039	moderate	high
Kaynarca Acarlar Gölü	1.780499	3.551616	0.088359	0.364892	low	low
Kaz Gölü	0.775164	5.218324	0.023667	0.559580	low	moderate
Kığı Şeytandağları	0.508417	34.738460	0.395072	0.599386	high	high
Kızılkuyu	0.938365	14.727959	0.231182	0.470582	moderate	moderate
Köyceğiz	0.329678	63.501984	0.407826	0.446466	high	moderate
Kuyucuk Gölü	1.501451	1.140685	0.000000	0.091645	low	low
Kütahya Akdağ	0.861482	8.295327	0.216965	0.565048	moderate	moderate
Mihallıçık Çatacık	0.991816	19.607644	0.348325	0.471018	moderate	moderate
Muğla Bördübet	0.440926	15.729193	0.171917	0.374496	moderate	low
Mut Kesteldağı	0.413299	18.786460	0.113476	0.580091	moderate	high
Pozantı Karanfildağ	0.749260	26.828553	0.443056	0.735876	high	high
Rize Çamlıhemşin Kaçkar	0.182282	40.423348	0.408989	0.286020	high	low
Saçak	0.991816	8.724205	0.107652	0.471018	moderate	moderate
Sandıklı Akdağ	0.960747	15.033709	0.246192	0.509245	moderate	moderate
Sarıkamış Kağızman	1.443598	10.796073	0.293593	0.097340	moderate	low
Sarıyer Feneryolu	5.873527	0.787009	0.059299	0.415230	low	moderate
Seyhan Baraj Gölü	0.275851	44.236689	0.221358	0.402602	moderate	moderate
Sivridağ	0.260401	40.503080	0.181474	0.340819	moderate	low
Sivrihisar Balıkdamı	2.146216	2.038114	0.053592	0.461097	low	moderate
Süphan Dağı	1.289485	14.902740	0.322955	0.419986	moderate	moderate
Tahtaköprü Baraj Gölü	0.625304	16.196948	0.124863	0.651423	moderate	high
Tarsus Kadıncık Vadisi	0.229745	46.618238	0.276024	0.768771	moderate	high
Taşköprü Elekdağı	0.564616	13.645945	0.132355	0.637954	moderate	high
Tavşanlı Çatak	0.596788	10.631444	0.088559	0.522378	low	moderate
Tosya Gavurdağı	1.072227	10.618282	0.187989	0.701868	moderate	high
Tuzla Gölü	0.523410	13.730012	0.096802	0.392214	low	moderate
Türkmenbaba	1.184381	10.971973	0.200164	0.426709	moderate	moderate
Ulus Sökü	0.296439	32.181248	0.179094	0.397587	moderate	moderate
Yahyalı Aladağlar	0.470912	20.828882	0.412648	0.880208	high	high
Yedigöller	0.271540	88.286879	0.529402	0.343585	high	low
Yeşilöz	0.271540	42.216542	0.195915	0.330087	moderate	low
Yılanlı Çakmak	0.633953	7.241791	0.118283	0.455524	moderate	moderate
Zorkun Yaylası	0.557020	12.649340	0.112077	0.571151	moderate	high