DEVELOPMENT OF A CLIMATE RISK ASSESSMENT METHOD FOR THE PROVINCES OF TURKIYE

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ABSTRACT

DEVELOPMENT OF A CLIMATE RISK ASSESSMENT METHOD FOR THE PROVINCES OF TURKIYE

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Climate change is disproportionately threatening vulnerable systems and amplifying existing risks. Considering the increasing impacts of climate change, assessing climate-related risks and identifying respective critical vulnerabilities have gained vital importance in addressing climate change. This thesis aims at examining the climate risk and vulnerability levels of provinces by conducting a climate risk and vulnerability assessment at the national scale provincial level to respond to the immediate climate challenges, as well as understanding to what extent mainstream spatial plans address the corresponding risk and vulnerability profiles. This research assesses climate risks and vulnerabilities of 81 provinces, also known as NUTS 3 regions in Turkey, by adopting the current risk-based framework of the Intergovernmental Panel on Climate Change (IPCC) which conceptualizes risk as a function of hazard, exposure, and vulnerability. Secondary data are used in the statistical and spatial analyses via SPSS and ArcGIS software. Composite indexes are developed for heat wave, drought, forest fire, and flood risks and their determinants. According to the findings, although the highest climate risk prevails in Amasya and Tokat in the north, Mersin, Kahramanmaraş, in the south, Kayseri in the inner part, and Muş and Ağrı in the east part of Turkey, the overall climate risk assessment show that 36% of provinces are of high or very high levels of climate risk. Moreover, there is a lack of integration between climate policy-making and spatial planning in terms of addressing climate risks and vulnerabilities which results in mainstream spatial planning system at different scales could not address climate risks and vulnerabilities in Turkey. By determining particularly vulnerable provinces to climate risks, this assessment is considered to be instrumental for establishing the necessary linkages between climate policy-making and spatial planning, identifying the points of intervention and priority activities relevant for spatial planning, and giving input to policy prioritization and resource allocation.

Keywords: Climate Risk Index, Climate Vulnerability, Climate Adaptation, Spatial Planning, GIS

ÖZ

TÜRKİYE İLLERİ İÇİN İKLİM RİSKİ DEĞERLENDİRME YÖNTEMİ GELİŞTİRİLMESİ

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İklim değişikliği, zarar görebilir sistemleri orantısız bir şekilde tehdit etmekte ve mevcut riskleri arttırmaktadır. İklim değişikliğinin artan etkileri göz önüne alındığında, iklimle ilgili risklerin değerlendirilmesi ve zarar görebilirliğin belirlenmesi, iklim değişikliğini ele almak için hayati önem kazanmıştır. Bu tez, acil hale gelen iklim sorunlarına yanıt vermek için ulusal ölçekte il düzeyinde bir iklim riski ve zarar görebilirlik değerlendirmesi yaparak illerin iklim riski ve zarar görebilirlik düzeylerini incelemeyi ve ana akım mekânsal planların ilgili risk ve zarar görebilirlik düzeylerini ne ölçüde ele aldığını anlamayı amaçlamaktadır. Bu araştırma iklim değişikliğine uyum konusunda Hükümetler Arası İklim Değişikliği Paneli'nin (IPCC) riski tehlike, maruziyet ve zarar görebilirliğin bir fonksiyonu olarak kavramsallaştıran mevcut risk temelli çerçevesini benimseyerek Türkiye'de NUTS-3 bölgesi olarak da bilinen 81 ilin iklim risklerini ve zarar görebilirliklerini değerlendirmektedir. İkincil veriler SPSS ve ArcGIS yazılımları aracılığıyla istatistiksel ve mekansal analizlerde kullanılmıştır. Sıcak hava dalgası, kuraklık, orman yangını ve sel riskleri ve belirleyicileri için kompozit endeksler geliştirilmiştir. Bulgulara göre en yüksek iklim riski kuzeyde Amasya ve Tokat'ta, güneyde Mersin ve Kahramanmaraş'ta, iç kesimde Kayseri'de, Türkiye'nin doğusunda ise Muş ve Ağrı'da hakim olmakla birlikte, genel iklim riski değerlendirmesi illerin %36'sının yüksek veya çok yüksek iklim seviyelerinde olduğunu göstermektedir. Ayrıca, iklim politikası üretme süreçleri ve mekânsal planlama arasında bir entegrasyon sorunu bulunmakta ve bu durum Türkiye'deki farklı ölçeklerde geliştirilen ana akım mekânsal planlama sisteminin iklim risklerini ve zarar görebilirliği ele alamamasına neden olmaktadır. İklim risklerine karşı zarar görebilir illeri ortaya koyan bu değerlendirmenin, iklim politikası oluşturma ve mekânsal planlama arasında gerekli bağlantıların kurulması, mekânsal planlama ile ilgili müdahale noktalarının ve öncelikli faaliyetlerin belirlenmesi ve politika önceliklendirmesi ve kaynak tahsisine girdi sağlanması için araçsal olduğu düşünülmektedir.

Anahtar Kelimeler: İklim Risk Endeksi, İklim Değişikliğinden Zarar Görebilirlik, İklim Değişikliğine Uyum, Mekânsal Planlama, CBS

To the planet Earth

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LIST OF ABBREVIATIONS

ABBREVIATIONS

DRR: Disaster Risk Reduction

EEA: European Environment Agency

FA: Factor Analysis

HFA: Hyogo Framework for Action 2005-2015

IPCC: Intergovernmental Panel on Climate Change

MoEU: Turkey's Ministry of Environment and Urbanization

MoEUCC: Turkey's Ministry of Environment, Urbanization and Climate Change

NSSP: National Spatial Strategy Plan of Turkey

OECD: Organization for Economic Cooperation and Development

PCA: Principal Component Analysis

SFDRR: The Sendai Framework for Disaster Risk Reduction 2015–2030

TURKSTAT: Turkish Statistical Institute

UNDESA: United Nations Department of Economic and Social Affairs

UNISDR: United Nations International Strategy for Disaster Reduction Secretariat

UNDRR: United Nations Office for Disaster Risk Reduction

WMO: World Meteorological Organization

CHAPTER 1

INTRODUCTION

Climate change is accepted as the most severe and challenging issue today (IPCC, 2007a; IPCC, 2013; IPCC, 2014b). Although there are efforts to limit global warming at 2 ◦C increase in temperature in the context of the Paris Agreement, models show that climate change will continue to intensify and accelerate in the future because of increase in temperatures at an unprecedented rate (IPCC, 2007; IPCC, 2014; IPCC, 2022). IPCC's Special Report on Managing Risks from Extreme Events and Disasters to Advance Climate Change Adaptation (IPCC, 2012) states that climate extremes have significantly increased in many parts of the world based on the records collected since 1950. Likewise, the 6th Assessment Report of IPCC finds that hot extremes (including heatwaves) and heavy precipitation events have increased in frequency and intensity since the mid-1900s; thus, compound extreme events are more likely to occur when increasing human influence is considered (IPCC, 2022). This includes compound *floods* in certain areas, an increase in the frequency of *heat waves* and *droughts* occurring simultaneously on a global scale, and *fire* weather in some areas of all inhabited continents (IPCC, 2022). Changes in heat waves, drought, forest fire, and flood, as climate-change-induced extreme events, will adversely impact natural and human systems with high confidence.

In this context, increasing attention has been given to climate-related studies considering the substantial increase in the frequency of extreme climate events, including heatwaves, floods, droughts, and forest fires. By its very nature, climate change is a global issue that adversely affects every single part of the world at all geographic scales. In this sense, although cities have been receiving most of the attention in the climate change field since the early 1990s, they are not the only ones suffering from the impacts of climate change. Climate change threatens their rural surroundings, as well.

Cities are facing various climate-related hazards to which vulnerable systems exposed. Urban development and urbanization are directly related to the climate change problem for several reasons. The ratio of the world's urban population is projected to increase from 55% in 2018 to 68% by 2050 and 85% by 2100 (UNDESA, 2018). Rapid urbanization produces critical urban challenges which not only exacerbate but also be exacerbated by climate change. The urbanization process adversely affects the carbon cycle because of land use and land cover changes that damage ecosystems. Cities were historically located close to coastal areas and by the riverside that are especially vulnerable to climate change. However, now their waterside locations put cities at risk by subjecting them to sea level rise, heavy rains and flooding. These hydro-meteorological hazards are coupled with high temperatures, heat waves, and droughts in cities with warmer climatic conditions. Furthermore, cities host a variety of vulnerable groups which are exposed to climate-related hazards. These groups are disproportionately affected by changing climate and its related uncertainties which may worsen their situation and exacerbate already existing inequalities. Due to the reasons mentioned, urban areas are highly vulnerable to climate change, which poses severe threats to entire urban systems. As more people live in urban areas, and more adverse impacts of climate change take place in cities, the vulnerability of cities to climate change is expected to increase. Combating climate change includes the integration of adaptation and mitigation efforts at the local level, which initially requires understanding the risks of climate change and the main dynamics behind urban vulnerability.

Rural areas are also at risk due to being substantially affected by the adverse impacts of climate change as they are highly dependent on natural resources. Rural areas have already been experiencing several economic, demographic, and spatial challenges, including limited economic diversity, high unemployment, population decrease, urban sprawl. These problems are amplified by climate-related risks, including heat waves, drought, flooding, storms, and fires, which place excessive stresses on livelihoods, quality of life, and health of rural communities. However, rural communities have limited financial and institutional capacities to anticipate the adverse effects of climate change.

While mitigation has dominated climate change policy and research, adaptation policies have been overshadowed by mitigation in policymaking at the local level. However, the implementation of mitigation measures solely is not enough to tackle climate change because adapting to future conditions is required in order to alleviate the adverse impacts of climate change on vulnerable entities. Since the negative effects of climate change have become more dramatically observable around the world, adaptation, as one of the two main approaches to combating climate change, has attracted increasing attention among both policymakers and scholars (Schlosberg et al., 2017; Berrang-Ford et al., 2021), especially after Paris Agreement in 2015 (Persson, 2019). Adaptation is recognized as a "global challenge" in Paris Agreement in which "enhancing adaptive capacity, strengthening resilience, and reducing vulnerability to climate change" together were determined as a global goal on adaptation (UNFCCC 2016, Paris Agreement, Art. 7). IPCC defines adaptation as "the process of adjustment to actual or expected climate and its effects to moderate harm or exploit beneficial opportunities" (IPCC, 2014a p.118; IPCC, 2022). Adaptation actions are instrumental in reducing impacts and increasing the resilience of the systems in a continuous and transformative process (Smith et al., 2011).

According to IPCC (2014c, 2022), several ecosystems and many human systems are vulnerable to current climate variability with very high confidence because of the effects of recent climate-related extremes. Moreover, the Sixth Assessment Report of IPCC highlights that the world needs an urgent action since exceeding the 1.5°C threshold brings ecosystems and human society to the limits of adaptation (IPCC, 2022). For the latter, the majority of the consequences of climate change on biodiversity and ecosystem functioning are predicted to be negative and to get worse with further global warming. The majority of terrestrial species' ranges are expected to drastically diminish, in the case of 1.5°C to 2°C warming. The percentage of species at risk of extinction due to climate change is 5% at 2°C warming and increases to 16% at 4.3°C warming (IPBES, 2019).

According to Schlosberg (2017), climate adaptation needs addressing and challenging the sources of risk and vulnerability. In this context, risk and vulnerability assessments are one of the essential tools for a better understanding of key climate risks and vulnerabilities (Klein et al., 2014; Jurgilevich et al., 2017; Connelly et al., 2018); and to produce policies, strategies, and practices to adapt (Sharma et al., 2018). Assessing climate risks and vulnerabilities includes taking scenarios, probabilities, and uncertainties into consideration and is essential for developing demand for and stimulating mitigation and adaptation actions (Sharma et al., 2018).

Risk and vulnerability assessment may be used not only to identify the potential damage stemming from climate change but also to tackle poverty, population, development, and environmental-related problems (Cutter, 1996). Thus, risk and vulnerability assessment is not just an academic exercise but started to be a political necessity because it addresses policy-making by drawing attention to climate change, setting mitigation targets, improving the management of current climate risks, prioritizing the adaptation needs of particularly vulnerable sectors and regions, developing/monitoring adaptation measures, and identifying options that reduce vulnerability (Downing et al., 2005; Füssel and Klein, 2006; Patt et al., 2008; Hinkel, 2011, Klein et al., 2014). Moreover, vulnerability assessments are considered beneficial in fostering sustainable transition by integrating knowledge and action (Patt et al., 2005, p.412).

The recent conceptual understanding of climate vulnerability and risk mostly grounds on the scientific works of the IPCC. IPCC's definition, conceptualization, and operationalization of vulnerability indicate a significant change with the 5th Assessment Report released in 2014 which tends to harmonize climate change adaptation and disaster risk reduction approaches. This framework highlights that risk results from the interaction of vulnerability, exposure and hazard, therefore, climate-related hazards together with vulnerability and exposure of human and natural systems comprise co-factors of risk of climate-related impacts (IPCC, 2014b). Hazard is defined as "the potential occurrence of a natural or human-induced physical event that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources", while exposure refers to "the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected" (IPCC, 2014b). Vulnerability, on the other hand, is defined as "the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts including sensitivity or susceptibility to harm and lack of capacity to cope and adapt" (IPCC, 2014b, p.1048). Therefore, vulnerability is deemed to be characterized by sensitivity and adaptive capacity, which are related to the internal weaknesses and strengths of a system, respectively.

Climate adaptation needs to address and challenge the drivers of risk (Schlosberg, 2017). The local level is given strong emphasis in terms of adaptation in climate change literature. A considerable number of scholars take adaptation as a local level issue, which can be successfully implemented at the local scale (Bosello et al., 2010; Satterthwaite et al., 2011; Duffy, 2011). However, local governments face some challanges to successfully implement adaptation strategies (Nalau et al., 2015). Especially in developing countries, they mostly lack the technical, financial, and governance frameworks as well as the clear guidance of the national government to cope with the impacts of climate change. Although climate change impacts are evident at the local level, and it is essential to comprehend the nature of vulnerability from a sub-national perspective (UNDP, 2010), adaptation to cope with them necessitates the involvement and engagement of different levels of government (Adger, 2005; Leck and Simons, 2012; Baurer and Steurer, 2014; Nalau et al., 2015), and effective policies from multiple scales, levels, and sectors, due to the cross-cutting and pervasive state of climate change adaptation (Kruse et al., 2013; Widmer, 2018). Therefore, rather than being addressed as an issue whose responsibility is left solely to local governments, multi-sector, multi-actor, and multi-level collaboration is needed to implement climate change adaptation effectively.

Although local governments have been essential policy players in responding to climate change since the early 1990s, local actors, especially in developing countries, lack the required information on local climate vulnerabilities and risks even in their jurisdictions. Thus, there is a strong need for risk and vulnerability studies to understand the local climate change risks and the vulnerable systems, which could further be used to design policies to mitigate the negative impacts of climate change at the local level.

Turkey, on which this study focuses, is subject to climate change and its adverse effects as well. There is a substantial increase in the frequency and severity of hydro-meteorological hazards, such as floods, storms, hails, and droughts. Turkey is geographically located in the Mediterranean Basin, which is one of the most vulnerable areas to climate change because of the decrease in precipitation levels and desertification (IPCC, 2007, p. 256). Having been in a warming trend, especially after the 1990s, Turkey is expected to experience temperature increases ranging between 2.5 °C and 4 °C by 2100 (Gosling et al., 2011). In addition, decrease in precipitation, sea-level rise, water stress, and droughts are among the observed and projected effects of climate change in Turkey (Gosling, 2011; Şen, 2013; Yeldan et al., 2015). Although Turkey is at risk of being substantially affected by the adverse impacts of climate change, as mentioned above, scientific contributions regarding climate change vulnerability and risk are quite limited.

Assessing climate vulnerability is important for identifying climate risks and vulnerable systems and linking them with spatial development policies. Because vulnerability is a dynamic concept (Schneiderbauer et al., 2017), it is vital to better understand these risks and how they vary in time and space, and how they can affect vulnerable systems. Such knowledge is essential for decision-makers and spatial planners to compare the relative climate risk and vulnerability at different spatial levels, to prioritize the areas of concern, and to direct spatial development policies accordingly. Vulnerability and risk reduction, in this vein, are directly related to spatial development policies as those policies may exacerbate vulnerability thereby risk, in return to which vulnerability and risk may weaken or negate the planning decisions to be actualized. Therefore, operationalization of vulnerability and risk and integrating them into spatial planning discipline is a major challenge.

This research, in that sense, differs from the studies in the related literature for several reasons:

- By adopting the current risk and vulnerability framework of IPCC, this thesis is the first study that assesses climate risk and vulnerability at the national level, including 81 provinces in Turkey. Since the impacts of climate change are observed in various urban areas and their rural surroundings, it is considered appropriate to handle the subject at the provincial level as the geographically largest administrative entity.
- The index-based assessment of risk and vulnerability grounds on comprehensive data of 92 indicators in total -21 for heat wave, 22 for drought, 21 for forest fire, and 28 for flood risk-.
- The design of the assessment method is built flexible and adaptable so that changes in the indicators can be easily implemented without disrupting the research structure. When considering the comprehensiveness of data used, this flexibility makes the research operational when indicator data is limited or a new indicator is added.
- This research also contributes to the field by linking climate risk and vulnerability conditions to spatial planning and giving insights into how spatial planning can be instrumental in adapting to climate change and reducing climate-related risks and vulnerabilities.

1.1. The Aims and the Research Questions of the Study

Considering the increasing impacts of climate change, assessing climate-related risks and respective key vulnerabilities has gained vital importance in addressing climate change. Reducing current vulnerabilities is critical for preparing for the future. In this vein, analyzing climate risks and vulnerabilities and developing planning strategies accordingly are necessary at different spatial planning processes from national to local levels. Risk types elaborated in this study are determined as heat wave, drought, forest fire, and flood risk for several reasons:

- *Heat waves* have increased since the mid-20th century and the duration, frequency, and intensity of heat wave events will very likely increase by 2100 (IPCC, 2012; IPCC, 2022).
- *Drought* risks are predicted to increase in many regions with very high confidence (IPCC, 2022).
- *Fire* risks have increased due to heat and drought conditions in many parts of the world and are projected to further increase as heat and drought conditions worsen (medium confidence) (IPCC, 2022).
- *Floods* are increasing in many regions with more frequent heavy rainfall events (IPCC, 2012; IPCC, 2022). Their intensification is also projected to increase with high confidence, which results in an increase in local flooding with medium confidence (IPCC, 2022). With medium confidence, it is predicted that flood risks will rise as global warming continues (IPCC, 2022).

IPCC points out that ecosystems and human systems are likely to be adversely influenced by changes in those climate extremes mentioned above (IPCC, 2022). When the severity of the findings is considered, there are two main aims of the study.

The first aim of the research is to assess the climate change risk and vulnerability at the national scale and provincial level in order to respond more effectively to urgent climatic concerns, which can pave a way to more detailed assessments and adaptation strategies to be developed. This includes applying a comprehensive climate change risk and vulnerability assessment framework, which consists of aggregate indicators regarding different sets of indicators that reflect both the biophysical and socio-economic circumstances and comparing the 81 provinces in Turkey based on the aggregate indicator of vulnerability to climate change.

Therefore, one of the aims of the thesis is to examine the risk and vulnerability to climate change by mapping a nationwide, province-level risk and vulnerability profile of provinces in Turkey. In this respect, province-level vulnerability profiles give a comparable insight on how to develop adaptation strategies that would decrease climate risk and vulnerability through spatial planning.

In this vein, the second aim is to evaluate risks and vulnerabilities in terms of spatial planning and to designate the level of interaction between climate adaptation policy and actions and spatial planning. This includes investigation of adaptation action plans and mainstream spatial plans in order to understand to what extent they are interconnected, considering that reducing risk and vulnerability and adapting to climate change, beyond any doubt, necessitate spatial planning system to consider these issues.

By determining particularly vulnerable provinces to climate risks, this assessment is considered to be instrumental in establishing the necessary linkages between climate policy-making and spatial planning, identifying the points of intervention and priority activities relevant for spatial planning and giving an input to policy prioritization and resource allocation.

Based on the aim of the research explained above, two main questions of the thesis are provided below as:

- what are the climate risks and vulnerabilities that provinces in Turkey face?
- do climate risk and vulnerability profiles of provinces in Turkey conform with the spatial development policies at the national level?

1.2. Method of the Research

This section outlines the method.in general terms. More detailed information on the method is presented in Chapter 4. As it is previously mentioned, one of the aims of the thesis is to conduct a comprehensive current climate risk and vulnerability assessment for 81 provinces of Turkey. To do this aim, this thesis develops a static assessment of current risks and vulnerabilities based on current and historical data by adopting the IPCC's 2014 framework of risk. This framework necessitates specifying hazards, the presence of various systems that could be adversely affected, and vulnerability that contribute to risk. In this sense, heat wave risk, flood risk, drought risk, and forest fire risk are calculated based on the interaction of three factors including hazard, exposure, and vulnerability (vulnerability as a function of sensitivity and adaptive capacity) components.

The top-down, data-driven, and indicator-based approach is adopted for this assessment. The assessment framework is provided in Table 1 below.

Table 1: Climate Change Risk and Vulnerability Assessment Framework (Prepared by the author)

Purpose of the assessment	To identify the points of intervention and priority activities To give input to policy prioritization and resource allocation To give input to spatial plans to direct spatial development policies
System of interest	Urban and rural population, infrastructure, agricultural livelihood, biodiversity, water resources, forest areas and forest-based livelihoods
Unit of analysis	Provinces
Unit of observation	Provinces
Spatial Scale	National
Level of measurement	Both interval and ratio
Assessment type	Current risk and vulnerability assessment
Assessment approach	Top-down, indicator-based

Scientific literature on climate risks is reviewed, and theories, methodological approaches, empirical findings, and discussions are followed to better understand climate risks. This study uses indicators that reflect both the biophysical and socio-economic circumstances to construct the climate risk and vulnerability index for the provinces in Turkey. The indicator approach is widely adopted for quantifying the risk and developing a better understanding of the factors contributing to vulnerabilities. Indicators are identified as a result of scientific literature review in which scientific articles, institutional reports, and case studies are reviewed. The indicators then are identified, shortlisted, and revised based on the relevance, analytical soundness, timeliness, and availability of data in the Turkish context. The data for indicators are retrieved from secondary sources, including the relevant institutions and organizations, through official correspondences or in person.

In order to reveal the risk and vulnerability levels of the provinces in Turkey through a composite index, the quantification of the indicators is needed. Several techniques are used when quantifying indicators. Climate-related indicators (e.g., increase in hot days/year, increase in the number of tropical nights, increase in annual mean temperature, decrease in annual total precipitation, increase in days/year with heavy precipitation, increase in annual maximum temperature) are quantified and analyzed using Mann-Kendall Test and Sen's Slope Estimator to find out the overall trend of temperature and precipitation for all 81 provinces for the time period, 1971 to 2018 using MAKASENS 1.0 software. The rest of the indicators are quantified through simple mathematical operations (e.g., share of children and elderly population or agricultural GDP per agricultural worker) or through spatial analysis (e.g., population settled in flood-prone area or road-networks in flood-prone area) which are conducted in ArcGis 10.7 software. After indicators are quantified, there is a need to convert all the values into dimensionless units in order to aggregate them. In this vein, z-score transformation is conducted in SPSS as a standardization method to make the variable scale-free.

In order to systematically aggregate the indicators for designating the risk and vulnerability levels of provinces in Turkey, dimension reduction and weighing the selected variables of hazard, exposure, sensitivity, and adaptive capacity separately, which signal the contribution of each indicator to the index value, are needed. Therefore, Principal Component Analysis (PCA) and Factor Analysis (FA) are conducted in SPSS software. Moreover, internal consistency is tested through Cronbach's Alpha in order to understand if the total list of the variables measures the respective risk dimension, including hazard, exposure, sensitivity, and adaptive capacity. Weights are assigned to the individual variables based on factor loadings and the variance of the variable explained by the respective factor.

Hazard, exposure, vulnerability, sensitivity, adaptive capacity, and risk indexes are developed based on a geometric aggregation of weighted factors obtained from PCA/FA as geometric aggregation provides partial compensability between the different indicators and allows for lower levels of information loss. The index scores are then normalized using min-max normalization, classified using natural breaks classification, and then mapped. The overall risk index is obtained by scoring the levels expressing individual risks from 1 to 5 (from very low to very high, respectively) and then summing them. Overall climate risk scores are then classified into 5 classes that include the provinces with very low, low, moderate, high, and very high overall climate risk levels based on the standard deviation classification technique in ArcGis.

As previously addressed, the thesis also aims at evaluating risks and vulnerabilities in terms of spatial planning and understanding the level of interaction between climate adaptation policy and actions and spatial planning. In this vein, adaptation action plans and mainstream spatial plans are investigated in order to understand to what extent they are interconnected, as well as to designate the extent to which climate risk and vulnerability profiles of provinces in Turkey conform with the spatial development policies. To sum up, Figure 1 outlines the framework of the research design.

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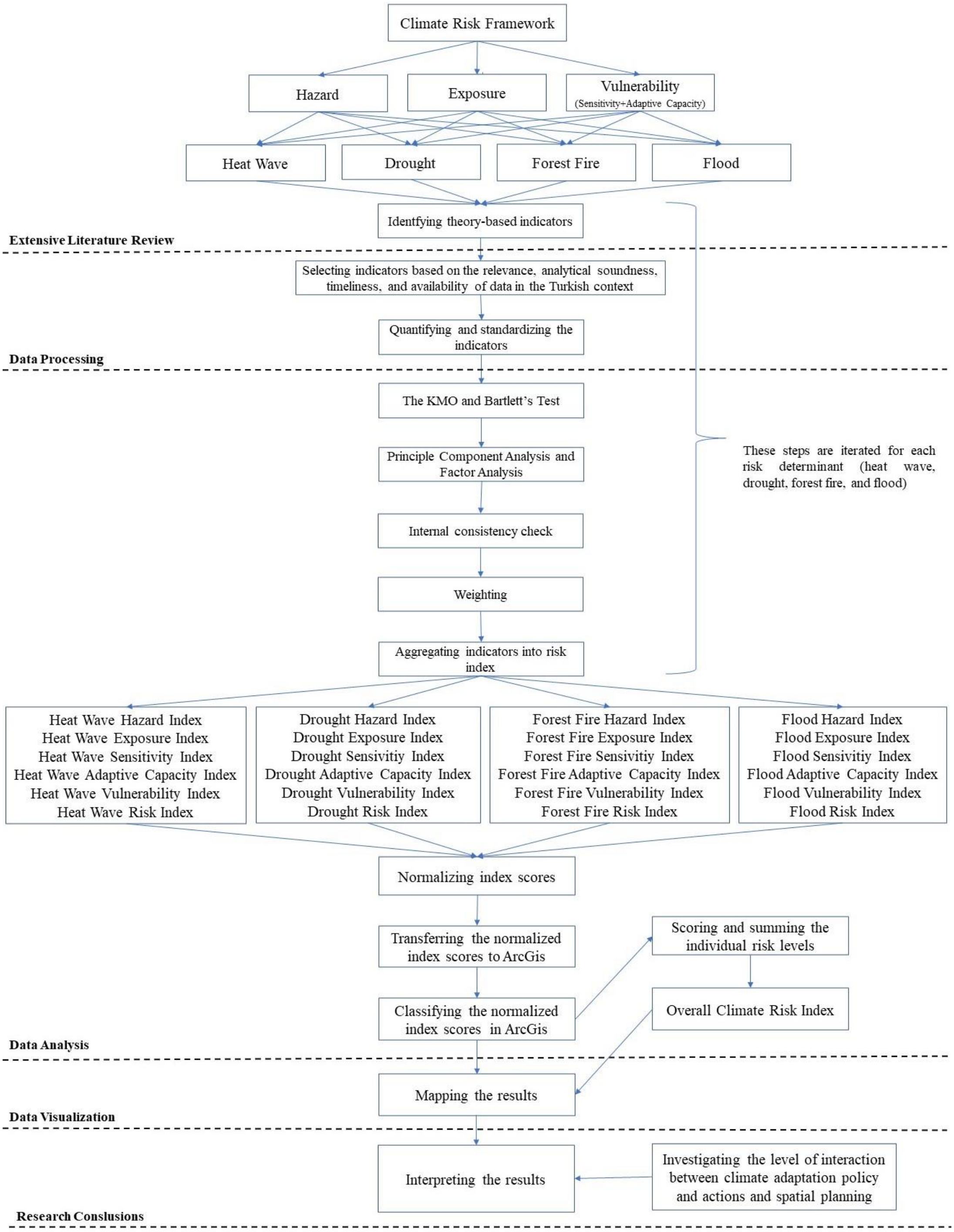

Figure 1: The Research Design Framework

1.3. Outline of the Chapters

This thesis consists of six chapters, one of which is the introduction and the last one is the conclusion. As shown in Table 2, the thesis structure follows a sequence necessary for answering the research questions specified in the previous part.

Table 2: Chapters and Their Relation to The Sub-Questions

Chapter 1	Introduction
Chapter 2	How are climate risk and vulnerability conceptualized?
Chapter 3	What are the observations, projections and impacts of climate change in Turkey?
Chapter 4	How can climate risk and vulnerability be measured?
Chapter 5	What are the risk and vulnerability levels of provinces in Turkey? How are climate change risks and vulnerability spatially distributed across provinces in Turkey?
Chapter 6	To what extent these findings are coherent with spatial development policies in Turkey? To what extent does climate adaptation planning evaluate spatial development policies? To what extent do different levels of spatial plans pay attention to climate risk, vulnerability, and adaptation of provinces?

Chapter 1 gives a general introduction of the research by focusing on the main context, aim, and research questions.

Chapter 2 focuses on the concept of vulnerability as an initial first step in the long process of adapting to climate change. This chapter covers the approaches to interpreting climate vulnerability and IPCC's evolving approach to vulnerability in terms of conceptualizing and operationalizing it. What is reviewed in this section provides insight into deciding the framework used in this research to assess climate risk and vulnerability.

Chapter 3 provides information on the climate observations and projections in Turkey, which is the case study of the thesis. In this vein, changes in temperature, precipitation, and extreme climate events in Turkey are addressed in this chapter. This knowledge is essential for understanding the changing climate conditions and what it may bring on for vulnerable systems. Chapter 3 also emphasizes the climate adaptation policy in Turkey.

Chapter 4 explains the research method and covers the main steps to conduct the climate risk and vulnerability assessment, which gives insights into the methods of selecting indicators of each risk component and collecting data, quantifying these data, standardization of data, dimension reduction, testing for internal consistency, weighting indicators, aggregating the scores of indicators through Principle Component Analysis and Factor Analysis to obtain indexes of flood, drought, forest fire, and heat risk, and finally mapping the risk and vulnerability levels of provinces.

The first part of Chapter 5 focuses on analyzing climate-related indicators of hazard component. Hazard indicators that require analyzing meteorological parameters differentiate from the rest of the components of risk in a way that they necessitate further analysis of meteorological data; therefore, it is deemed appropriate to address them as a separate part. It is followed by the climate risk and vulnerability analysis in Turkey at the provincial level based on the research method mentioned in Chapter 4. Adopting the IPCC 2014 framework, the analysis is conducted separately for heat wave risk, drought risk, forest fire risk and flood risk by considering the interaction between risk determinants, including hazard, exposure, sensitivity and adaptive capacity, and vulnerability as a function of sensitivity and adaptive capacity. The result of the analysis is also mapped for these four risk types and their risk determinants in the context of this chapter.

Chapter 6, the last chapter of the thesis, concludes the thesis. It summarizes and provides insights on the general findings of the research by discussing the extent to which the research questions and aims of the study are addressed. It also includes the evaluation of the research method, limitations of the research, and discussion for future research.

CHAPTER 2

THE CONCEPT OF VULNERABILITY IN CLIMATE CHANGE RESEARCH

2.1. The Concept of Vulnerability

Vulnerability is one of the main concepts in climate change that has its origins from geography and natural hazards research. Researchers from these different fields conceptualized vulnerability differently in various policy contexts by considering various systems exposed to various hazards (Füssel, 2007). Conceptualization of vulnerability is particularly problematic and diversified in climate change research since it requires researchers from different research traditions (Füssel, 2007).

Approaches to interpreting climate change vulnerability can be categorized into two different interpretations in the literature in treating and solving the problem. These interpretations can be categorized into outcome vulnerability and contextual vulnerability, which are also described in the literature as end-point assessment and starting point assessment (Kelly and Adger, 2000), biophysical and social vulnerability (Cutter, 1996; Cutter 2003; Füssel, 2010), outcome and contextual vulnerability (O'Brien et al., 2004a), scientific framing and a human-security framing of vulnerability (O'Brien, 2006). Independently of their different names in the literature, while the former focuses on the biophysical effects of climate change by giving less or no emphasis on any socio-economic aspects, the latter considers social aspects influencing vulnerability (Smit and Wandel, 2006). These two conceptualizations adopt different time horizons to assess vulnerability, in which end-point conceptualization of vulnerability emphasize future vulnerability, while starting-point assessment of vulnerability focuses on current vulnerability.

2.1.1. Biophysical/Outcome Vulnerability

Outcome vulnerability examines vulnerability as an outcome of the analysis on the physical features of the environment (O'Brien et al., 2004a). Outcome vulnerability is an integrated vulnerability approach focusing on both potential climate impacts and the socio-economic capacity to adapt to the negative effects of climate change (Füssel 2009, p.5). This approach considers vulnerability as being determined by the adaptive capacity and therefore future oriented.

In the context of the end-point approach, vulnerability is considered as the end-point of a series of analyses starting with projections of future emission patterns, continuing with the creation of climate scenarios, and concluding with biophysical impact analyses and the designation of adaptation choices (Kelly and Adger, 2000, p. 326). In this interpretation, vulnerability is seen as "a residual of climate change impacts minus adaptation", representing the net impacts of climate change (Kelly and Adger, 2000; O'Brien et al., 2004a). In other words, vulnerability is considered as a residual outcome of an external hazard (Füssel and Klein, 2006).

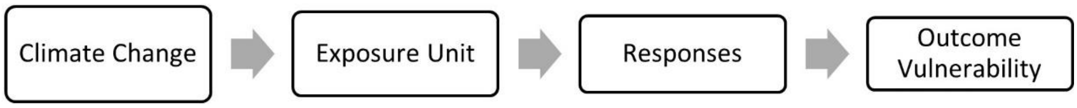

Figure 2: Outcome Vulnerability (O'Brien et al., 2007)

Figure 2 shows the linear scheme of outcome vulnerability, which corresponds to the projected impacts of climate change on the exposure unit, compensated by adaptive measures (O'Brien et al., 2007). In this sense, outcome vulnerability can be reduced either by reducing exposure factor or enhancing technical and sectoral adaptation measures.

2.1.2. Social/Contextual Vulnerability

Different than the outcome vulnerability, the starting point perspective considers vulnerability as pre-existing condition of a system, a snapshot of its internal dynamics, irrespective of the existence of an external stress. The idea behind it is that a system may be vulnerable to an external stress but still function well if it is not exposed to it (Rajesh et al., 2014). To be more precise, this approach, as a multi-dimensional process of human-climate interaction, examines vulnerability as a current lack of capacity to deal with external pressures or changes in climate (O'Brien et al., 2007), which further imply that assessing existing vulnerability serve to reduce future vulnerability to climate change (Burton et al., 2002, p.154). The rationale behind is that being exposed to climate change may escalate existing inequalities (Smit and Wandel, 2006). Vulnerability is regarded as socially constructed and a condition inherent to the social system (Soares et al., 2015). However, Shukla et al. (2016) criticize the approach that vulnerability is socially constructed because physical and ecological characteristics are equally important when determining vulnerability. That is why it is emphasized that it is deemed more appropriate to use the term "inherent vulnerability" rather than "social vulnerability" (Shukla et al., 2016).

In this interpretation, vulnerability is seen to be produced by multiple factors and processes (Kelly and Adger, 2000). Vulnerability is interpreted as a starting point to specify how vulnerability can be reduced (O'Brien et al., 2004a; Levina and Tirpak, 2006), which is mostly identified by socio-economic structure and property relations (Kelly and Adger, 2000, p. 327). Therefore, reducing vulnerability involves changing the context in which climate change takes place can help reduce vulnerability, which further results in an individual or social group to better respond to biophysical, social, economic, technological, and institutional conditions (O'Brien et al., 2007).

Figure 3 depicts contextual vulnerability in which contextual conditions, including biophysical, social, economic, technological, and institutional conditions, influence both the exposure to climate variability and change and potential responses. In that vein, responses influence both the processes and contextual conditions (O'Brien et al., 2007).

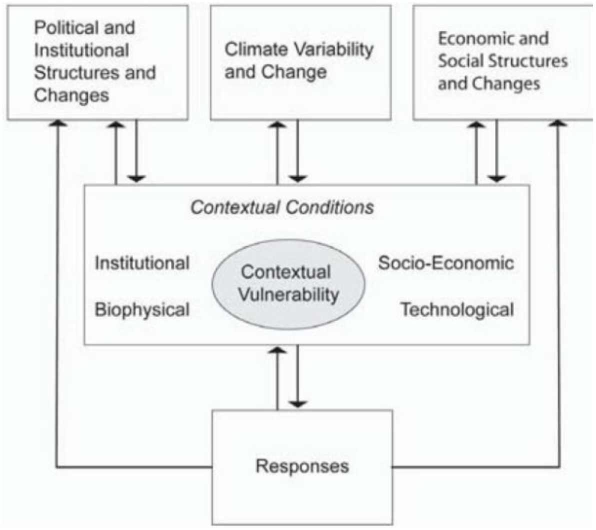

Figure 3: Contextual Vulnerability (O'Brien et al., 2007)

2.1.3. Conclusion

Outcome and contextual approaches to vulnerability comprise the two distinctive approaches when assessing vulnerability. While the former is generally adopted by natural sciences, the latter is promoted by social sciences literature. Outcome and contextual interpretations of vulnerability have different features in terms of defining vulnerability, vulnerability approach, temporal reference, the starting point of analysis, questions asked (Table 3), and the way they consider the relationship between adaptation and vulnerability (Okpara et al., 2016).

Table 3: Questions Asked by the Outcome and Contextual Vulnerability Scholars (Ford et al., 2010)

Outcome vulnerability	Contextual vulnerability
What are the optimal GHG targets for minimizing vulnerability?	Who and what are vulnerable, and why?
Which regions are most vulnerable?	How do human conditions and processes attenuate or amplify vulnerability?
What are the economic costs of not adapting?	How is vulnerability differentiated?
How would a 2 °C increase in average temperature affect vulnerability?	At what scales do determinants operate?
	What can be done to reduce vulnerability?

While in outcome vulnerability, the responsiveness of an individual or social group to climate change affects their vulnerability, in contextual vulnerability, social, economic, political, environmental, and cultural processes determine the vulnerability of an individual or social group and their responsiveness to climate change impacts. For the latter, understanding these processes is required to reduce their effects on vulnerability. While outcome vulnerability focuses on the symptoms of vulnerability, the contextual vulnerability approach center upon understanding the underlying causes of vulnerability by analyzing the current and past conditions. The two interpretations are further explained in Table 4.

Table 4: Comparison of Vulnerability Interpretations in Climate Change Domain (Fellmann, 2012)

	Outcome vulnerability (end-point interpretation)	**Contextual vulnerability (starting-point interpretation)**
Root problem	Climate change	Socio-economic vulnerability
System of interest	Biophysical, closed or at least well-defined systems	Human security or livelihood interrogation
Main discipline	Natural science	Social science
Analytical function	Descriptive, positive	Exploratory, normative
Starting point of analysis	Scenarios of future climate change	Current vulnerability to climatic stimuli
Vulnerability and adaptive capacity	Adaptive capacity determines vulnerability	Vulnerability determines adaptive capacity
Reference for adaptive capacity	Adaptation to future climate change	Adaptation to current climate variability
Meaning of vulnerability	Expected net damage for a given level of global climate change	Susceptibility to climate change and variability as determined by socio-economic factors
Illustrative research question	What are the expected net impacts of climate change in different regions?	Why are some groups more affected by climatic hazards than others? Who is vulnerable to climate change and why?
Policy context	Climate change mitigation, compensation, technical adaptation	Social adaptation, sustainable development
Illustrative policy question	What are the benefits of climate change mitigation?	How can the vulnerability of societies to climatic hazards be reduced?
Focus of results	Technologically focused on adaptation and mitigation strategies	Socially focused on increasing adaptive capacity, exploring alternative development pathways, addressing power or equity issues and constraints to respond
Approach used to inform adaptation policy	Top-down approach	Bottom-up approach
Spatial domain	Global -> local	Local -> regional
Time dimension	Future vulnerability	Current vulnerability

The current conceptualization of climate vulnerability and risk mostly grounds on the scientific works of the Intergovernmental Panel on Climate Change (IPCC). IPCC is the leading scientific United Nations body that includes scientists and government representatives from different parts of the world for the assessment of climate change. The definition of vulnerability has changed in the IPCC's assessment reports released over time. This change also manifested itself in changing approach to interpreting vulnerability. While the early definitions indicate biophysical vulnerability (Füssel, 2009; de Sherbinin, 2014), the later ones take an approach that emphasizes social vulnerability (Sharma and Ravindranath, 2019). The next part, in this vein, explains IPCC's changing approach to vulnerability.

2.2. Shifting from a Vulnerability-Based to a Risk-Based Approach in the IPCC's Assessment Reports

IPCC's approach to vulnerability shows a significant change from the report in 2001 to that in 2014 in terms of conceptualizing and operationalizing vulnerability. This changing conception in IPCC reports manifests itself especially from the third (AR3) and fourth (AR4) assessment reports to the fifth (AR5) one. These efforts have been important for the harmonization of climate change adaptation and disaster risk reduction approaches.

2.2.1. Climate Change Vulnerability Framework in the Third Assessment Report (AR3) of IPCC in 2001

The third assessment report (AR3) of IPCC (2001) defines vulnerability in the context of climate change as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity". In this context, IPCC's 2001 framework grounds on outcome vulnerability (Füssel, 2009; de Sherbinin, 2014), in which exposure, sensitivity, and adaptive capacity comprise co-factors of vulnerability to climate change. Thus, exposure (E_i), sensitivity (S_i), and adaptive capacity (A_i) are understood to be the main determinants of climate change vulnerability (V_i) in a specific area, *i*. (Equation 1).

$$Vi = f(Ei, Si, Ai) \tag{1}$$

As one of the three dimensions, exposure refers to the degree of significant climatic variations upon a system and it is commonly defined by the magnitude of climate change (IPCC, 2001). Since the exposure of a system to climate stimuli depends on the level of change in climate conditions, variability, and extremes (Füssel and Klein, 2006), exposure is represented as either “changes in climate conditions, or in climate variability, including the magnitude and frequency of extreme events” (O’Brien et al., 2004b, p. 305). Therefore, exposure is considered a manifestation of a hazard (Jurgilevich et al., 2017).

Sensitivity refers to “the degree to which the system is affected -either adversely or beneficially- by climate-related stimuli. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise)” (IPCC, 2007a). In other words, sensitivity is the degree of the negative or positive effect of climate-related stimuli upon a system. It is “the magnitude of response for a given level of climate change” (IPCC, 2001). As another dimension of vulnerability to climate change, adaptive capacity is defined as “the ability of the system to adjust to climate change, to moderate the potential damages from it, to take advantage of its opportunities and to cope with the consequences” (IPCC, 2001). IPCC (2001) defines adaptive capacity as the social and economic means to cope with the impacts of climate change. It refers to the capacities of the system to adjust to changing and varying climate change.

Exposure is seen as an external characteristic of vulnerability among these three components, whereas sensitivity and adaptive capability are internal ones. Exposure and sensitivity can be expressed through “the interaction of environmental and social forces”, while adaptive capacity is shaped by “various social, cultural, political and economic forces” (Smit and Wandel, 2006, p. 286). Therefore exposure, sensitivity, and adaptive capacity components of climate change vulnerability are inherently interdependent (Smit and Wandel, 2006; Teshome, 2016), in which higher exposure will result in higher sensitivity, while adaptive capacity can reduce the sensitivity of the system to climatic stimuli (Füssel and Klein, 2006; Teshome, 2016, p.3). Therefore, the functional relationship between vulnerability and the system’s sensitivity and exposure is positive, whereas the relationship between vulnerability and adaptive capacity is negative (Deressa et al., 2008; Pandey and Shashidhar, 2011; Fellmann, 2012).

2.2.2. Climate Change Vulnerability Framework in the Fourth Assessment Report (AR4) of IPCC in 2007

According to the definition of the fourth assessment report (AR4) of IPCC (2007b), climate vulnerability is “the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity”. The only difference of the definition from the 2001 report is the substitution of the word “or” with “and”. This change in the definition shows that sensitivity and deficiency of adaptive capacity started to be considered as co-factors of vulnerability instead of as alternatives. Therefore, vulnerability assessments include the identification of relevant aspects of climate change, characterization of the nature of exposure and sensitivity to climate change conditions, and documentation of capacity to respond and adapt to these changes (IPCC, 2007a; Ford et al., 2010). However, the 2007 report does not involve a definition for exposure but uses the same definition of sensitivity and adaptive capacity of the 2001 report. This framework also grounds on outcome vulnerability like the previous framework (Füssel, 2009, de Sherbinin, 2014; Sharma and Ravindranath,

2019) since it conceptualized vulnerability as post-hazard concept that occurs after a system is exposed to a hazard (Figure 4).

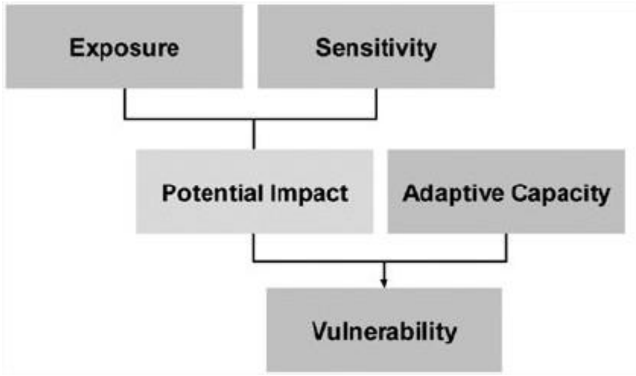

Figure 4: Vulnerability Components as presented in the IPCC 2007 Report (Fellmann, 2012)

According to the framework of vulnerability IPCC 2007 report, a system is considered vulnerable if it is exposed to climate-related impacts, sensitive to those impacts, and also has a limited capacity to adapt. By the same token, if a system is less exposed and less sensitive, or is of a high adaptive capacity, then it is deemed to be less vulnerable.

Table 5: Different Formulation of Combining Exposure, Sensitivity, and Adaptive Capacity According to IPCC's 2007 Framework

Formula	**Source**
$V = E + S + AC*$	Life Sec Adapt (2017)
$V = E + S - AC$	Antwi-Agyei et al. (2012); Liu et al. (2012); Bennett et al. (2015); Weber et al. (2015)
$V = [E + S + (1 - AC)]/3$	Ahumada-Cervantes et al. (2017)
$V = (E - AC) * S$	Hahn et al (2009)
$V = E * S * AC$	Lückenkötter et al. (2013a); Weis et al. (2016)
$V = E * S * (1 - AC)$	Das et al. (2020)
$V = (E + S)/AC$	Zarafshani et al. (2016)

Source: Prepared by the author

*: Adaptive capacity in the formula refers to the lack of adaptive capacity in the corresponding report

IPCC's 2007 framework has been largely adopted by the scholars to assess climate change vulnerability. However, the formula used to calculate the vulnerability index differs based on how scholars operationalize the three components of vulnerability. Although acknowledging vulnerability as a function of exposure, sensitivity, and adaptive capacity, different formulations of vulnerability assessments have been adopted by the scientific community in the related literature (Table 5). The indicators to assess climate vulnerability are therefore used by the researchers in these studies based on the three components of vulnerability. In this respect, Table 6 shows the indicators found to be used for the assessments prepared by the scientific community that adopts IPCC 2007 framework.

Table 6: Combination of Indicators of Vulnerability Assessments adopting IPCC's 2007 Framework (Prepared by the author)

Exposure	Change in climate variables	-Increase in hot days/year (Rannow et al., 2010; Greiving et al., 2011; Holsten and Kropp, 2012; Lung et al., 2013; Kumar et al., 2016) -Change in mean temperature (Gbetibouo et al., 2010; Greiving et al., 2011; Kumar et al., 2016; Quintão et al., 2017; Feyissa et al., 2018) -Mean of daily mean summer temperature (Lung et al., 2013) -Change in Annual Maximum or Minimum Temperature (Piya et al., 2019) -Number of tropical nights (Lung et al., 2013) - Increase in days/year with heavy rain (Rannow et al., 2010; Greiving et al., 2011; Holsten and Kropp, 2012; Kumar et al., 2016) -Increase in precipitation (Rannow et al., 2010; Kumar et al., 2016; Quintão et al., 2017; Piya et al., 2019) -Decrease in summer precipitation (Rannow et al., 2010; Greiving et al., 2011; Lung et al., 2013) -Change in total annual precipitation (Gbetibouo et al., 2010) -# of consecutive days per year with daily precipitation<1mm (Lung et al., 2013) -Frequency of climate-related disasters (Gbetibouo et al., 2010; Piya et al., 2019) - Decrease of frost days/year (Tmin < 10 ◦C) (Rannow et al., 2010) -Change in climatic water balance (Holsten and Kropp, 2012) -Change in relative humidity (Greiving et al., 2011; Holsten and Kropp, 2012) -Change in snow cover days (Greiving et al., 2011; Holsten and Kropp, 2012) -Change in storm days with daily maximum wind speed (Holsten and Kropp, 2012)
Sensitivity	Physical and economic	-Percentage of built-up area (Rannow et al., 2010; Handayani, et al., 2017; Krkoška Lorencová et al., 2018) -Population density (Lung et al., 2013; Kumar et al., 2016; Handayani, et al., 2017; Feyissa et al., 2018) -Vegetation cover (Feyissa et al., 2018) -Rural population density (Gbetibouo et al., 2010; Krkoška Lorencová et al., 2018) -Area covered by road (Kumar et al., 2016) -Land use change (Kumar et al., 2016) -Percentage of livable houses (Kumar et al., 2016; Handayani, et al., 2017) -Fraction of flood prone area (Rannow et al., 2010) -Percentage of flooded area (Lung et al., 2013) -Mean water depth of flooded area (Lung et al., 2013) -% of area covered by streets and other infrastructure (Rannow et al., 2010) -Percentage of arable land (Rannow et al., 2010) -Percentage of irrigated land (Gbetibouo et al., 2010) -Land degradation index (Gbetibouo et al., 2010) -Small-scale farming operations (Gbetibouo et al., 2010) -The extent of the winter sport infrastructure (Holsten and Kropp, 2012) -Water retention capacity of the agricultural soils (Holsten and Kropp, 2012) -Percentage of commercial & industrial areas (Lung et al., 2013)

Table 6 (continued)

	Social	-Percentage of vulnerable people (Rannow et al., 2010; Holsten and Kropp, 2012; Lung et al., 2013; Kumar et al., 2016; Handayani, et al., 2017; Quintão et al., 2017; Krkoška Lorencová et al., 2018) -Percentage of households composed of one adult (Lung et al., 2013) -Number of slums (Kumar et al., 2016) -Infant mortality (Quintão et al., 2017) -HIV prevalence (Gbetibouo et al., 2010) -Under five mortality rates (Feyissa et al., 2018)
	Environmental	-Forest proportion (%) (Rannow et al., 2010; Lung et al., 2013) -Mean fuel type combustibility (Lung et al., 2013) -Wildland accessibility by roads (Lung et al., 2013) -Increased fluctuation of groundwater levels (Kumar et al., 2016) -Flow accumulation of runoff water (Holsten and Kropp, 2012) -Number of species/habitats endangered by climate change (Rannow et al., 2010; Holsten and Kropp, 2012) -Percentage of area protected by nature conservation law (Rannow et al., 2010) -Loss of lakes and wetland area (Kumar et al., 2016)
Adaptive Capacity	Social	-Literacy rate (Gbetibouo et al., 2010; (Kumar et al., 2016; Quintão et al., 2017; Feyissa et al., 2018 -Educational level (Holsten and Kropp, 2012; Lung et al., 2013; Handayani, et al., 2017; Quintão et al., 2017) -Participation in climate change and sustainability initiatives on municipal level
	Economic	-GDP per capita (Greiving et al., 2011; Lung et al., 2013) -GINI coefficient (Lung et al., 2013) -Unemployment rate (Greiving et al., 2011; Feyissa et al., 2018) -Access to credit (Gbetibouo et al., 2010) -Percentage of households with access to banking facilities (Kumar et al., 2016) -Total household savings (Piya et al., 2019) -Dependency ratio (Greiving et al., 2011; Piya et al., 2019) -Percentage of people below poverty (Gbetibouo et al., 2010; Handayani, et al., 2017; Quintao et al., 2017) -Available income of private households (Holsten and Kropp, 2012) -% of households who own their homes (Kumar et al., 2016) -% of households owning any kind of asset (Kumar et al., 2016) -Share of farmers members of farmers associations (Gbetibouo et al., 2010) -Farm income (Gbetibouo et al., 2010) -Farm holding size (Gbetibouo et al., 2010) -Share of agricultural GDP (Gbetibouo et al., 2010) -Farm assets (Gbetibouo et al., 2010; Gbetibouo et al., 2010) -R&D expenditure per capita (Greiving et al., 2011; Kruse et al., 2011; Lung et al., 2013)
	Provision of Basic Facilities	-Infrastructure index (Gbetibouo et al., 2010) -Health infrastructure (Lung et al., 2013; Quintão et al., 2017; Feyissa et al., 2018) -Hospital beds and doctors per person (Greiving et al., 2011; Handayani, et al., 2017) -% of areas with road access (Greiving et al., 2011; Kumar et al., 2016; Feyissa et al., 2018) -% of households having drinking water and wastewater connection (Kumar et al., 2016; Handayani, et al., 2017; Feyissa et al., 2018) -Percentage of area under lakes (Kumar et al., 2016) -Internet use (Lung et al., 2013)
	Institutional	-Status of financial budget of municipality (Holsten and Kropp, 2012) -National adaptation strategies (Greiving et al., 2011)

2.2.3. Risk-Based Framework in the Fifth Assessment Report (AR5) of IPCC in 2014

Different than the previous two, the fifth assessment report (AR5) of IPCC (2014c) adopts a risk management framework which was previously suggested in the IPCC Special Report on Managing Risks from Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) in 2012 (IPCC, 2012). With this new framework, the focus started to be given on risk rather than vulnerability in terms of climate change adaptation, which leads to a transition from a vulnerability-based framework to a risk-based framework in adapting to climate change, which bridges and harmonizes the literatures of disaster risk management with climate change adaptation (Jurgilevich et al., 2017; Connelly et al., 2018). In fact, disaster risk management arena has been giving increasing importance to climate change-related risk and vulnerability. Hyogo Framework for Action 2005-2015, the first globally adopted framework of disaster risk reduction, highlights the importance of vulnerability reduction and of integrating disaster risk reduction strategies with climate change adaptation (UNISDR, 2005). The Sendai Framework for Disaster Risk Reduction 2015–2030 also puts an emphasis on addressing vulnerability to understand disaster risk as one of the priorities for action (UNDRR, 2015), since understanding vulnerability, a core component of risk, has a critical role to assess the risk and to take the necessary risk reduction measures (Schneiderbauer et al., 2017).

In accordance with the new framework, risk is defined as “the potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values” (IPCC, 2014b). In this vein, climate-related hazards, together with vulnerability and exposure of human and natural systems, comprise co-factors of risk of climate-related impacts, as it shown in Figure 5 (IPCC, 2014b, p.3). Exposure and vulnerability are mainly characterized by socioeconomic processes, while hazard is the result of a change in the climate system (IPCC, 2014b). Hazard, in this vein, is defined as “the potential occurrence of a natural or human-induced physical event that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources" (IPCC, 2014b). Climate-related hazards range from extreme weather events such as heat waves, droughts, forest fires, and floods to slow-onset changes such as sea level rise.

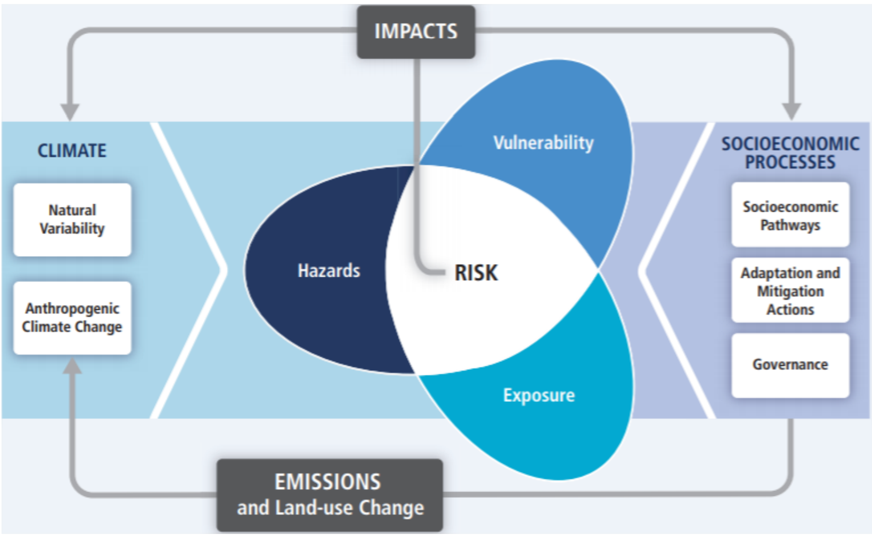

Figure 5: Risk-Based Framework in the Fifth Assessment Report (AR5) of IPCC in 2014

In SREX, the emphasis is given to "reducing exposure and vulnerability and increasing resilience" (IPCC, 2012 p.4); therefore, exposure factor was separated from the vulnerability concept. According to the 2014 report, exposure is defined as "the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected" (IPCC, 2014b, p.5). This definition points out the spatiality of the exposure factor, where hazard occurs and results in an adverse impact on a vulnerable system (Jurgilevich et al., 2017). Therefore, exposure is considered a spatial element, unlike previous frameworks which consider exposure as a "manifestation of a hazard" (Jurgilevich et al., 2017).

As it is mentioned earlier, the IPCC 2014 report adopts this framework and defines vulnerability as "the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts including sensitivity or susceptibility to harm and lack of capacity to cope and adapt" (IPCC, 2014b, p.1048). Therefore, the 2014 report takes vulnerability independent from exposure and hazard as being fundamentally different from the 2007 report in terms of assessing vulnerability. In other words, vulnerability is considered to be characterized by sensitivity and adaptive capacity, which are internal factors of vulnerability (Figure 6). The focus is on the system's internal state whether or not the system is exposed to a hazard (Sharma and Ravindranath, 2019). Unlike the previous frameworks that adopted end-point approach, the 2014 framework grounds on starting point approach due to considering vulnerability as the pre-existing state of a system.

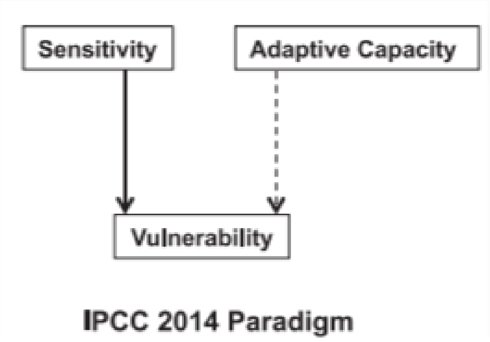

Figure 6: Vulnerability Components as presented in the IPCC 2014 Framework (Sharma and Ravindranath, 2019)

The IPCC 2014 report (IPCC, 2014c) defines sensitivity as the "degree to which a system or species is affected, either adversely or beneficially by climate variability or change. The effect may be direct (e.g., change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise)". Sensitivity, therefore, represents the internal weaknesses of a system. Adaptive capacity, on the other hand, is defined as "the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences" (IPCC, 2014c), which focuses on the internal strengths of a system. Vulnerability, in this vein, has a positive functional relationship with sensitivity and a negative functional relationship with adaptive capacity. Therefore, vulnerability increases as sensitivity increases and adaptive capacity decreases, or vice versa. Due to the direct relationship between sensitivity and vulnerability and the inverse relationship between adaptive capacity and vulnerability, the function of vulnerability is considered as below (Equation 2). However, the functional relationship between sensitivity and adaptive capacity is hard to measure since they are "practically non-observable, non-measurable and non-quantifiable" (Sharma et al., 2018, p. 17).

$$V = f(S, 1/AC) \tag{2}$$

Risk assessments have been conducted in various disciplines from health science to disaster risk management (Connelly et al., 2018). However, the mathematical formula used to calculate risk index differs based on how scholars operationalize the factors that lead to risk. Different formulations of risk assessments have been adopted by the scientific community in the corresponding literature (Table 7).

Table 7: Different Formulations of Combining the Factors of Risk (Prepared by the author)

Formula	**Source**
$R = H * V$	Johnson et al. (2016); Life Sec Adapt (2017)
$R = H + E + V;\ V = S - AC$	Ortega-Gaucin et al., 2021
$R = H * (E + S)/AC$	Zarafshani et al., 2016
$R = H * E * S(1 - AC)$	Das et al., 2020
$R = H * E * S/AC$	Rana and Routray, 2016; Salam et al., 2021
$R = H * E * V$	Liu et al., 2016; Allen et al., 2018; Connelly et al. (2018); KC et al., 2021; Kim et al., 2021

This thesis employs the IPCC's 2014 framework of climate risk and vulnerability. The use of the 2014 approach is still recent and is not thoroughly covered in the literature. There are still limited examples that adopt the IPCC 2014 framework.

2.2.4. Conclusion

The recent conceptual understanding of climate vulnerability and risk mostly grounds on the scientific works of the IPCC. IPCC's definition, conceptualization, and operationalization of vulnerability indicate a significant change from the assessment report in 2007 (AR3) to that in 2014 (AR5) which tends to harmonize climate change adaptation and disaster risk-reduction approaches (Table 8).

Table 8: The Changing Vulnerability Frameworks of IPCC

	IPCC 2007 Framework	**IPCC 2014 Framework**
Conceptualization of vulnerability	Post-hazard: the adverse impact after a system is exposed to a hazard, reduced by adaptation actions (outcome vulnerability)	Pre-hazard: a pre-existing state of a system (contextual vulnerability)
Focus	The focus is on the adverse impacts of hazard on the system	The focus is on the system itself
Components of vulnerability	Exposure, sensitivity, and adaptive capacity	Sensitivity and adaptive capacity
External/internal factors	Both external (exposure) and internal factors (sensitivity and adaptive capacity) are considered	Vulnerability conceptualized as the current internal state of a system

Source: Adapted from Jurgilevich et al. (2017), Connelly et al. (2018), Sharma et al. (2018), Sharma and Ravindranath (2019)

Connelly et al. (2018) states that the transition from a vulnerability-based to a risk-based framework is influential as the former promotes inaction. The rationale behind is that acknowledging people and places as vulnerable may lead to a passive attitude toward climate change. Moreover, the latter avoids uncertainty associated with the future climate projections and climate models as exposure is delinked from vulnerability, as it is mentioned above. Therefore, the latter has been found as a win-win strategy with or without further changes in climate (Sharma et al., 2018) and more robust than the former as it minimizes the chances of maladaptation, while the former embodies uncertainty due to the exposure component it employs (Sharma and Ravindranath, 2019). This thesis adopts the IPCC's 2014 framework of risk in the climate risk assessment which is still recent and is not thoroughly represented in the literature.

CHAPTER 3

CLIMATE OBSERVATIONS, PROJECTIONS, AND ADAPTATION POLICY IN TURKEY

This chapter consists of two parts. The first part focuses on climate observations based on historical data and projections, including changes in temperature, precipitation, and extreme climate events in Turkey are addressed. Knowledge of the changing climate conditions and the future states is vital to comprehend the hazard dimension of risk. The second part of the chapter, on the other hand, emphasizes the climate adaptation policy in Turkey with a particular focus on contemporary arrangements that have taken place.

3.1. Observed and Projected Changes in Climate In Turkey

Turkey locates in Mediterranean Basin, which is among the fastest warming regions in the world. This makes the country extremely prone to climate-related threats (MedECC, 2020). Ocean acidification increased risk of forest fires, droughts, and heat waves, and modified precipitation regimes are the several impacts of climate change on the Mediterranean Basin (MedECC, 2020), which has been acknowledged as one of the most vulnerable regions in the world (Milano et al., 2013). Therefore, observations and projections for climate change are highly significant in order to respond to the climate crisis, namely, to avoid or at least minimize the negative impacts of climate change. In this context, the following parts will be focusing on the observed and projected impacts of climate change in Turkey.

In his research, Şen (2013) finds that temperatures have increased in almost all regions of Turkey, in which the most increase is observed in the summer season while warm seasons expand. Precipitation has increased in the northeastern part; however, there has not been a significant change over Turkey in general. The other finding of the study is that mountain glaciers in Turkey have been retreating 10 meters per year. Timing of the peak discharges has shifted to about 7-10 days earlier. Moreover, sea-level has risen by 3.8-7.7 mm per year. Lastly, the number of natural hazards has been increasing as positively correlated with increasing temperatures (Figure 7). Future climate projections for Turkey indicate that temperatures will continue to increase, precipitation will decrease, heat waves and drought will exacerbate in terms of frequency and length (Türkeş, 2013b; Türkeş, 2014; Türkeş, 2019; UNDP, 2021 March 15).

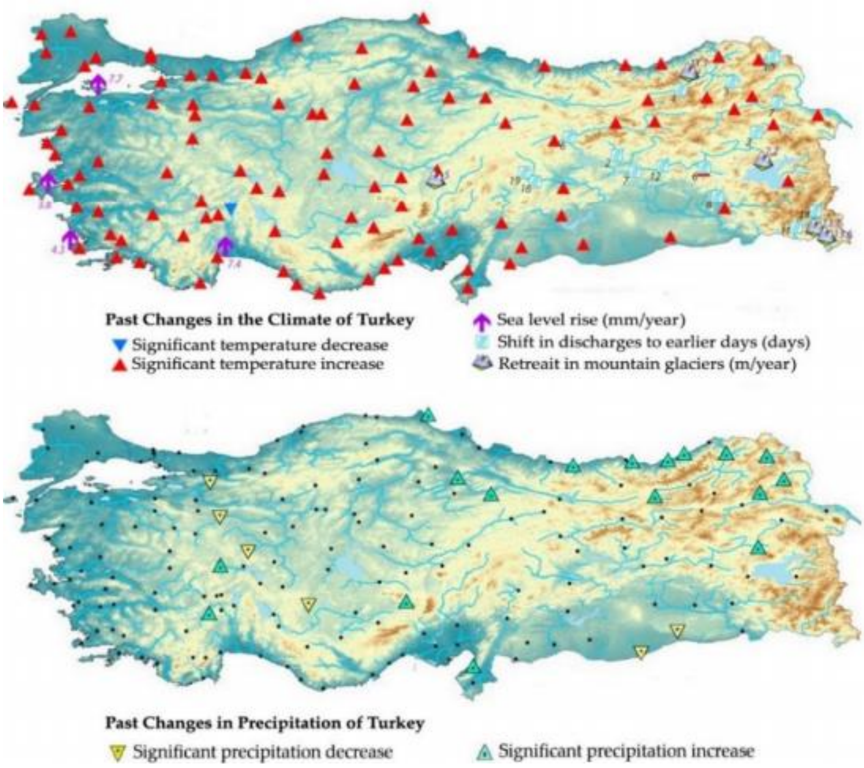

Figure 7: Past Changes in the Climate of Turkey (Şen, 2013)

3.1.1. Observed and Projected Changes in Temperature

As mentioned above, studies indicate that temperatures have increased in almost all regions of Turkey (Şen, 2013; MoEU, 2018; Türkeş, 2019). The most increase is observed in summer season while warm seasons expand. In the last 50 years, Turkey's annual average temperatures have increased from 12.5°C to 14.5°C. There is an increasing trend in annual average temperatures of 4°C/100 years (Figure 8) (Turkish State Meteorological Service, 2021).

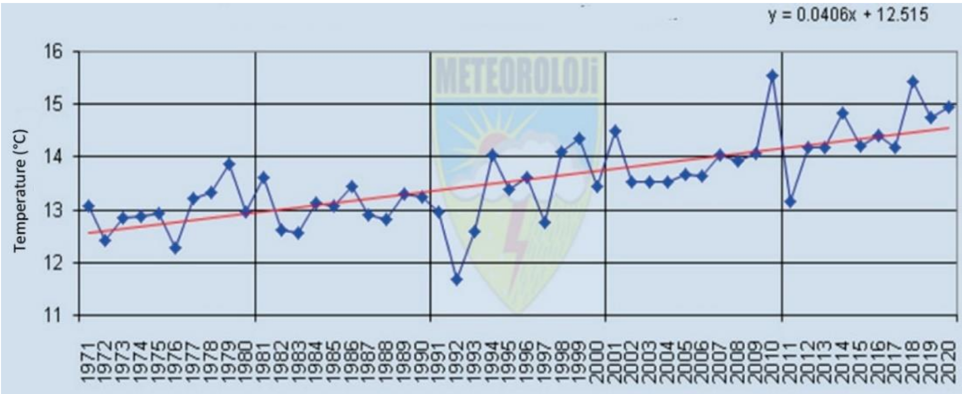

Figure 8: Trend of Annual Average Temperatures in Turkey over the period 1971-2020, 220 Stations (Turkish State Meteorological Service, 2021)

Figure 9 demonstrates the mean temperature anomaly relative to the 1981-2010 period average temperature in Turkey. Especially after 1998, there has been an increase in prevalence of positive anomalies, except for the year 2011. Moreover, the average temperature in 2020 was more than 1.4°C above the 1981-2010 average, which made 2020 stand out as the third warmest year on record (Turkish State Meteorological Service, 2021).

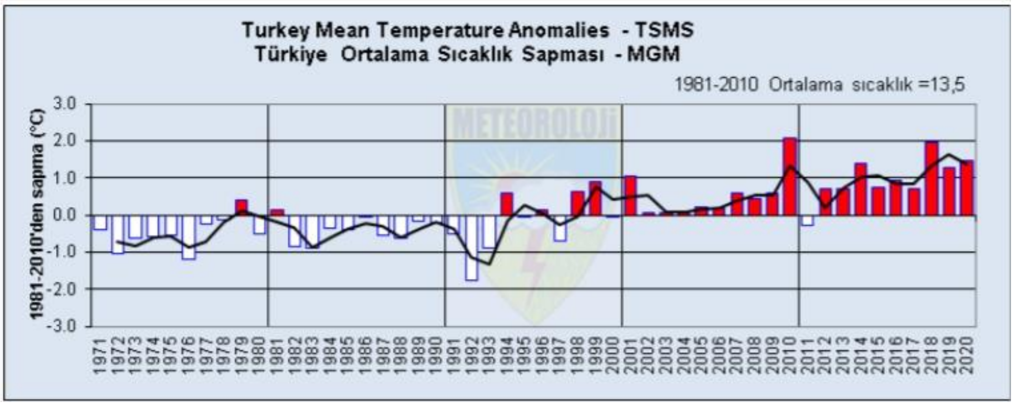

Figure 9: Mean Temperature Anomalies in Turkey over the period 1971-2020 relative to 1981-2010 (Turkish State Meteorological Service, 2021)

In addition, Türkeş (2019) examines the spatial distribution pattern of trends in average, annual average maximum, and annual average minimum temperatures for 1950-2010 period as indicated in Figure 10 (Türkeş, 2019). According to the findings, there is a significant positive trend in annual average, annual average maximum, and annual average minimum air temperatures for most of the stations in Turkey.

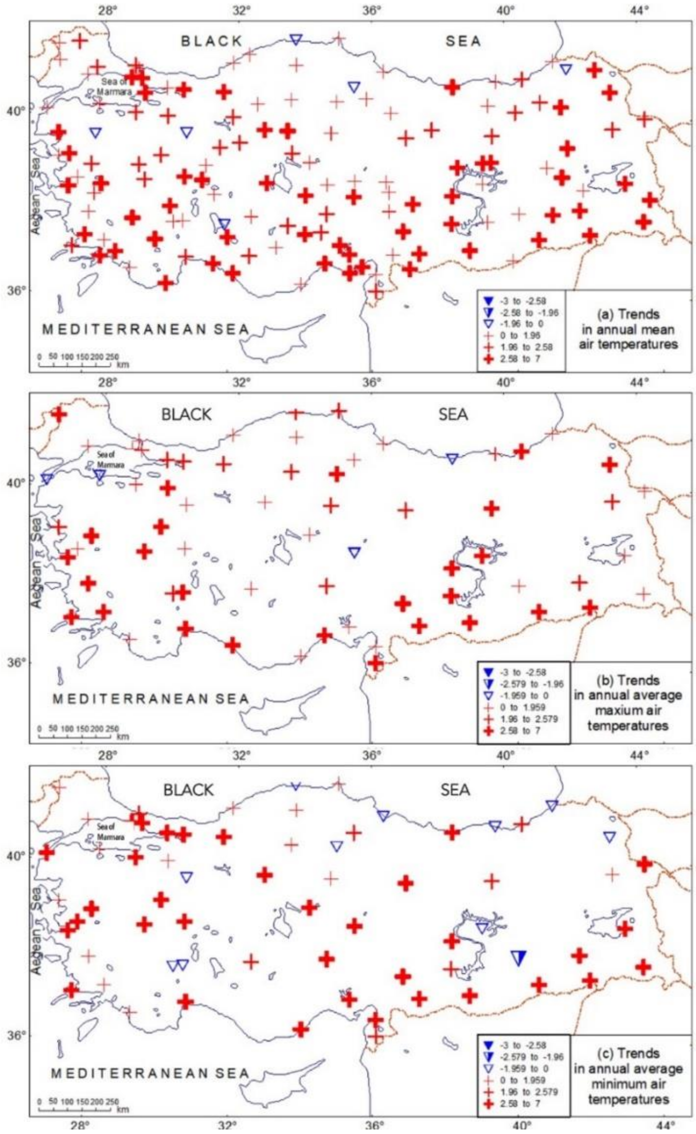

Figure 10: Long-Term Trends of Annual Mean, Annual Average Maximum, and Annual Average Minimum Temperatures in 1950-2010 period, respectively (Türkeş, 2019)

According to 4th Assessment Report of IPCC, Mediterranean Basin will experience warmer temperatures, expanding drought, and increasing number of heat waves (IPCC, 2013). Turkey's Seventh National Communication to the UNFCCC states that the annual mean temperature is projected to increase ranging from 1.5°C to 2.6 °C during the 2016-2099 period based on the RCP4.5 scenario and ranging from 2.5°C to 3.7 °C based on the RCP8.5 scenario (MoEU, 2018, Turkish State Meteorological Service, 2015) (Figure 11).

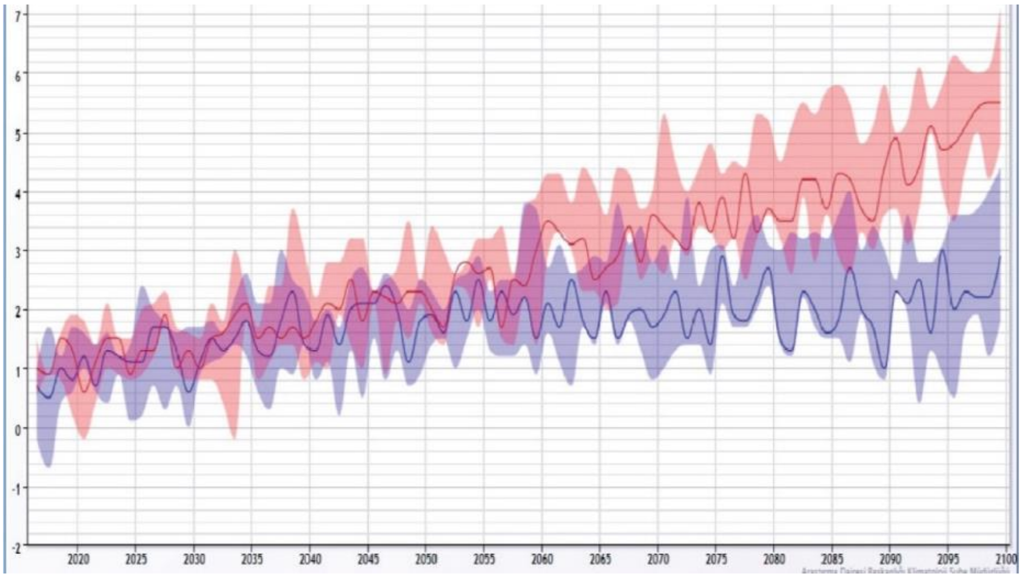

Figure 11: Probable Band of Annual Mean Temperature Anomaly based on RCP4.5 scenario (blue line) and RCP8.5 scenario (red line) (Turkish State Meteorological Service, 2015)

According to the project Enhancing Climate Adaptation Action in Turkey, which has been conducted with the collaboration of the Ministry of Environment, Urbanization and Climate Change (MoEUCC) and the United Nations Development Program Country Office Turkey, temperature will increase 5-5.5 °C at an accelerating pace by 2100 in Turkey, based on the RCP8.5 scenario. When regional projections are considered, temperature in the eastern and southeastern parts of Turkey is projected to increase 6 °C by 2100 (UNDP, 2021 March 15) (Figure 12).

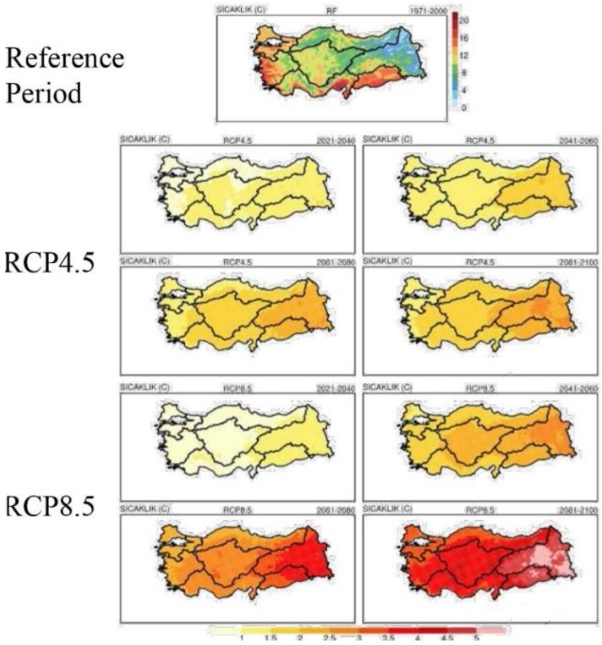

Figure 12: Temperature Projections for Turkey (UNDP, 2021 March 15)

3.1.2. Observed and Projected Changes in Precipitation Patterns

Annual areal precipitation anomaly shows an erratic rainfall pattern, as it is shown in Figure 13. Therefore, this irregular pattern does not allow a statistically significant trend formation.

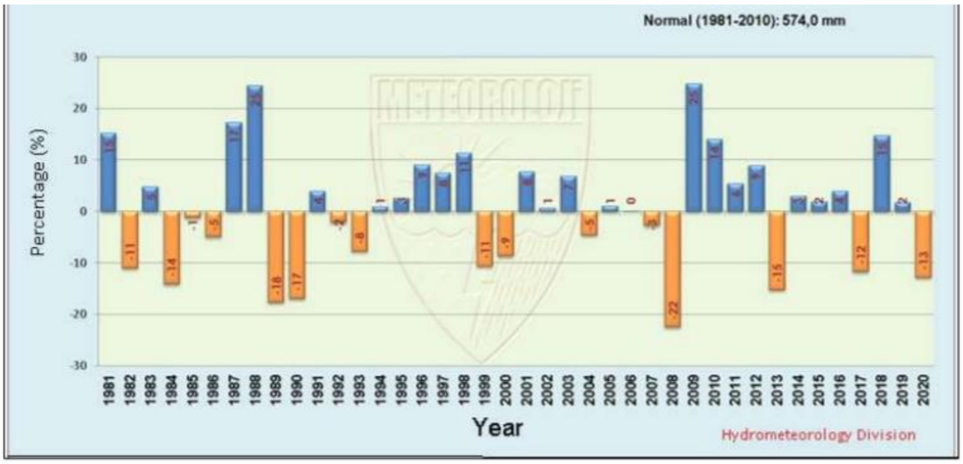

Figure 13: Annual Areal Precipitation Anomaly in Turkey relative to 1981-2010 period (Turkish State Meteorological Service, 2021)

When the spatial distribution of annual total precipitation for the 1950-2010 period in Turkey is examined, there is a decreasing trend, especially in the western and southern region. However, an increasing trend manifests itself in the northern corridor, part of central and eastern Anatolia (Türkeş, 2019) (Figure 14).

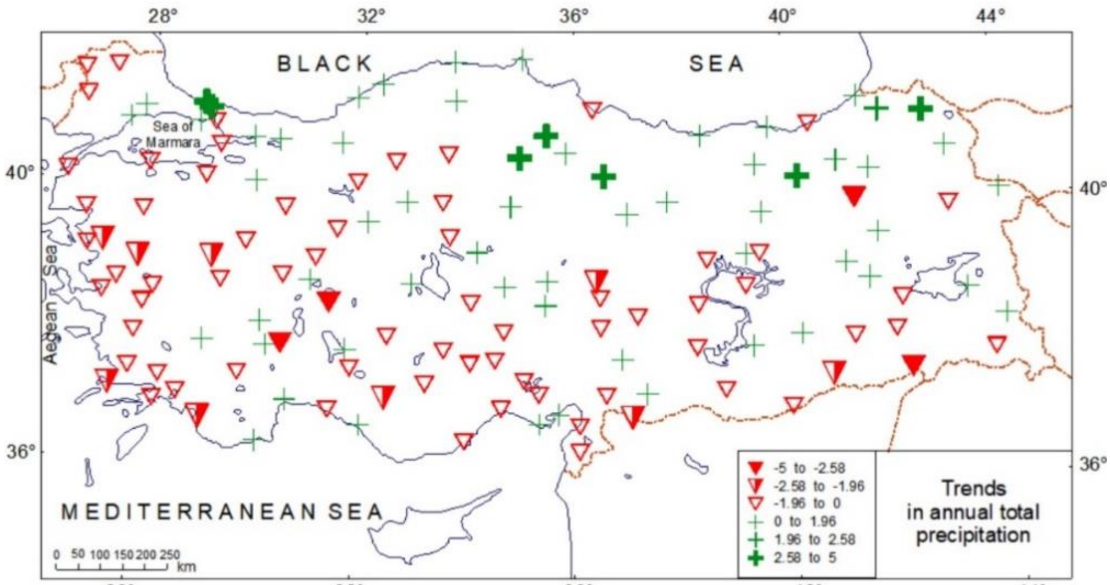

Figure 14: Annual Total Precipitation Trends in Turkey for 1950-2010 period (Türkeş, 2019)

Annual precipitation is projected to decrease particularly in the southern parts, but to increase in the north and northeastern parts of Turkey (Şen, 2013; MoEU, 2018). The decrease during winter season in the southern and southeastern regions of Turkey is projected to vary in the range of 20% to 60% in the period of 2071-2100 (Önol and Semazzi, 2009). The north and the northeastern parts as the regions that already receive the most precipitation in Turkey can be considered to continue keeping their position in that sense (Figure 15).

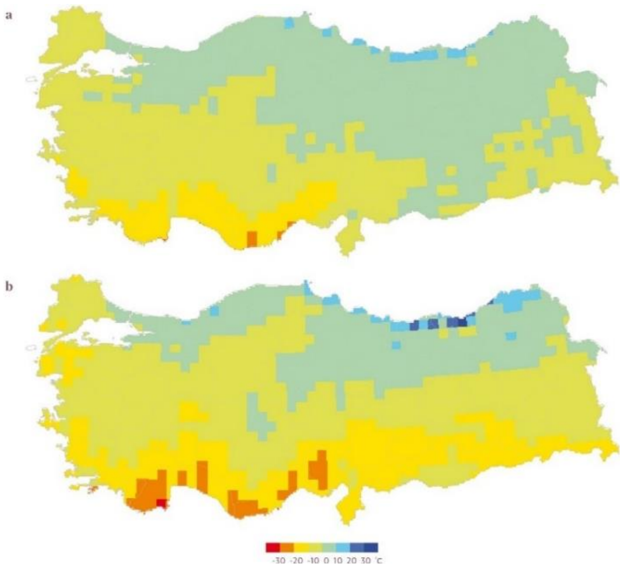

Figure 15: Projected Precipitation Changes relative to the 1961-1990 Period: (a) 2041-2070 period, (b) 2071-2099 period (Şen, 2013)

A recent study has similar findings to Şen's research (2013), indicating that precipitation will decrease 15-20 percent by 2100 in Turkey, based on RCP8.5 scenario. When regional projections are considered, precipitation is projected to decrease by 25 percent in the southern and southwestern parts by 2100 (UNDP, 2021 March 15) (Figure 16).

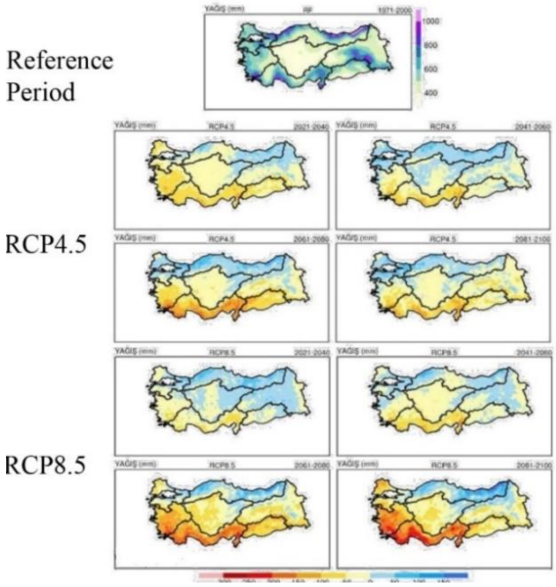

Figure 16: Precipitation projections for Turkey (UNDP, 2021 March 15)

Turkey’s Seventh National Communication to the UNFCCC highlights that the annual total precipitation anomaly is projected to rank among 3% and 6% during 2016-2099 period based on RCP4.5 scenario and in the range of +3% and -12% based on RCP8.5 scenario (MoEU, 2018) (Figure 17).

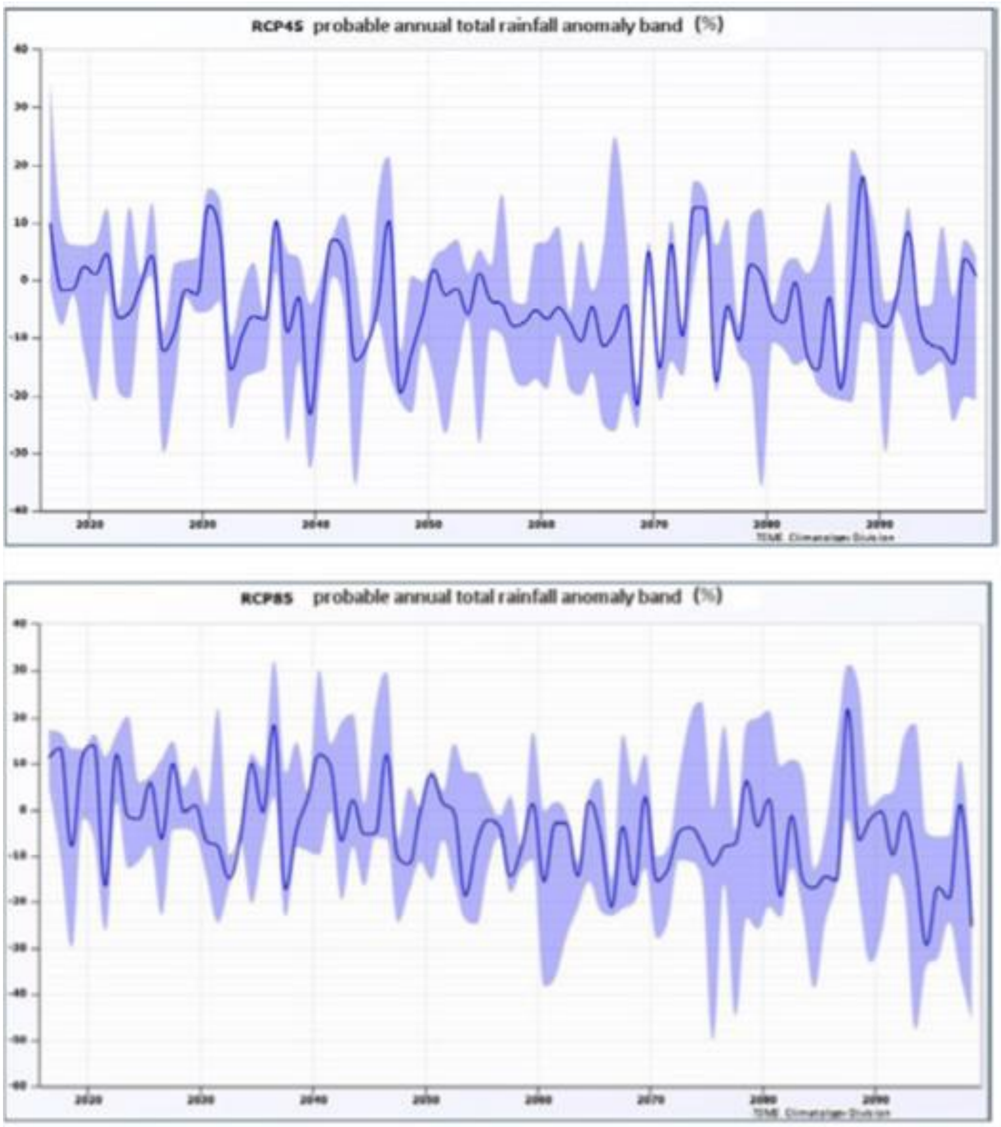

Figure 17: Change in Annual Total Precipitation Anomaly based on RCP4.5 scenario and RCP8.5 scenario, respectively (MoEU, 2018)

The changes in the projected precipitation patterns are considerably important as it is highly influential on the availability of future water resources (Önol and Semazzi, 2009). Turkey is geographically located in the Mediterranean climate zone with an arid and semi-arid climatic condition. In his research, Türkeş (1999) highlights the vulnerability of Turkey to drought and desertification. He finds that approximately 60% of land area in Turkey experiences annual moisture deficit and is vulnerable to desertification (Türkeş, 2013a) (Figure 18). According to his findings, Konya Basin and Iğdır region have semi-arid climatic conditions, while the inner part and south-east region of Turkey have dry sub-humid conditions. Moist sub-humid climatic conditions are predominant in the western part and surroundings of dry sub-humid area. Black sea region, receiving the greatest amount of precipitation in Turkey, has humid and very humid climatic condition (Türkeş, 2013a). Between very arid and sub-humid climate zones is considered more exposed to the impacts of severe changes in climate (Türkeş, 2019).

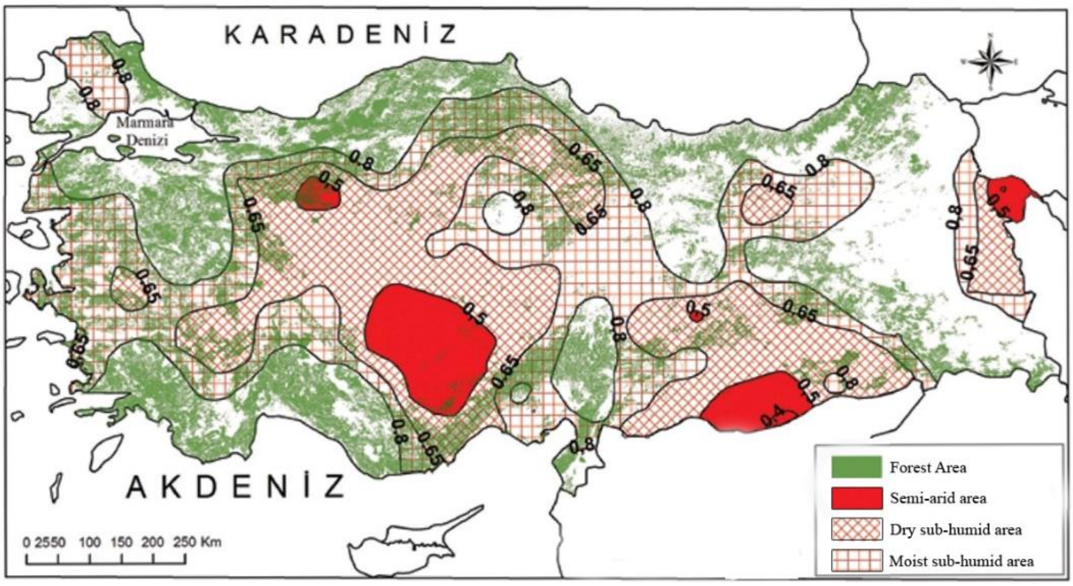

Figure 18: Geographical Distribution of Annual Aridity Index

Source: Türkeş, 2013a (legend added by the author)

Based on RCP4.5 and RCP8.5 scenarios of IPCC, Türkeş et al. (2019) reveal that precipitation is projected to decrease in 2021-2050 period relative to the reference period 1971-2000, which may bring extreme precipitation events to increase and **droughts** to prolong. Drought frequency and intensity are projected to increase due to the projected increase in temperatures and changing precipitation patterns for some parts of Turkey. Therefore, future climate condition is expected to be intensively drier in Turkey, leading to extreme vulnerability to climate change, particularly to increased droughts (Kostopoulou and Jones, 2005; MoEU, 2018; Türkeş et al., 2019). Moreover, it is projected that there will be a conspicuous increase in the number of consecutive dry days (MoEu, 2018). Another research affirms this finding, in which meteorological drought is expected to increase at a slow pace by the mid-2030s, which will exacerbate between 2040 and 2100, thus leading to a more severe drought conditions under the RCP8.5 scenario (UNDP, 2021 March 15) (Figure 19).

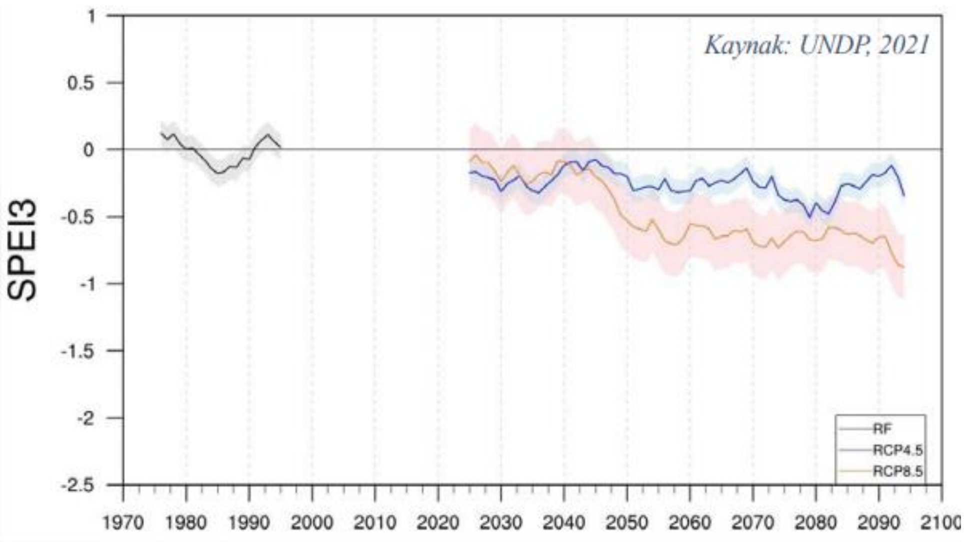

Figure 19: Standardized Precipitation Evapotranspiration Index (SPEI) Results for Turkey (UNDP, 2021 March 15) [where SPEI ≥ 2 very severe wet, 1.5≤SPEI<2 severe wet, 1≤ SPEI<1.5 moderate wet, -0.99≤ SPEI ≤0.99 close to normal, -1.5<SPEI ≤-1 moderate drought, -2<SPEI ≤-1.5 severe drought, SPEI ≤ -2 very severe drought]

3.1.3. Changes in Extreme Climate Events

Changes in the mean climate are not the only issue regarding climate change. Changes in the frequency and severity of extreme climate events are also directly related to climate change. IPCC (Seneviratne et al., 2012) defines extreme weather or climate event as “the occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends (tails)” of the range of historical measurements. A climate event may not be extreme itself; however, the combination of climate or weather events may lead to climate extremes, for example, droughts and floods. Climate change is highly influential on changes in the “frequency, intensity, spatial extent, duration, and timing” of extremes (Seneviratne et al., 2012). There is a substantial change in climate extremes, including decreases in cold days and nights, increases in warm days and nights, increases in the duration of warm spells as well as in the number of days with heavy precipitation (Jones et al., 2008).

In Turkey, as one of the highly vulnerable countries to climate change in the Mediterranean Basin, there is a significant increase in the number of extreme climate events. Evidence is growing that some extreme events are likely to occur more frequent, longer and more intense, and more widespread by 2100 in Turkey. As demonstrated in Figure 19, the number of extreme events has been increasing, especially for the last twenty years (Figure 20). 2020 is the year with the highest number of extreme events, in which 984 events occurred.

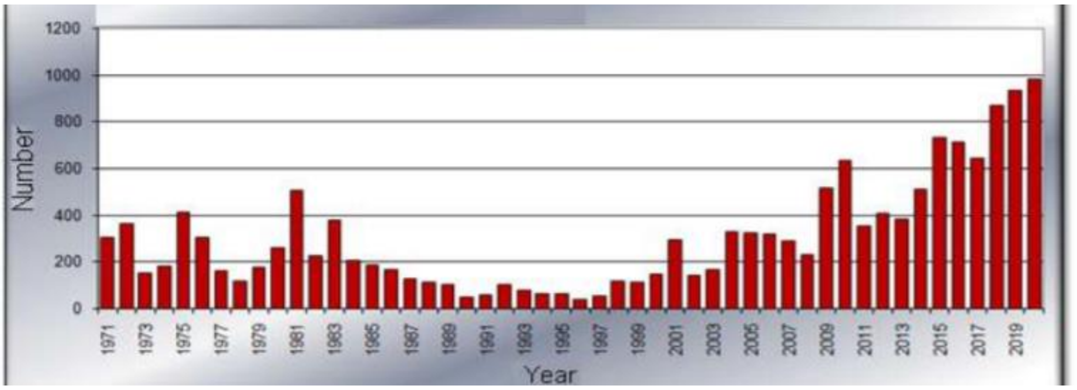

Figure 20: Annual number of extreme events in Turkey in 1971-2019 (Turkish State Meteorological Service, 2021)

When considering the distribution of extremes, heavy rain and floods, storms, and hail comprise 30%, 27%, and 23% of the total number of extremes occurred in 2020, respectively. The rest includes lightning bolt with 7%, heavy snow with 5%, frost, and landslide with 2%. Avalanche, forest fire, heat wave, and fog are responsible for the remaining 1% (Turkish State Meteorological Service, 2021). In this context, the following headings will cover climate extremes in Turkey.

3.1.3.1. Changes in Maximum and Minimum Temperatures

In Turkey, warm days are getting warmer and more frequent, while cold days are decreasing due to anthropogenic factors of climate change. In their research, Erlat and Türkeş (2015) focus on the change in the annual number of record maximum and record minimum air temperatures based on the data obtained from 81 stations in Turkey in 1950-2014 period. Their findings show that the annual number of record minimum temperatures has decreased since the 1950s. In addition, particularly after the 2000s, record maximum temperature frequency has an increasing trend (Figure 21). It is important to highlight that half of the record maximum events since 1950 occurred during the 2000-2014 period (Erlat and Türkeş, 2015).

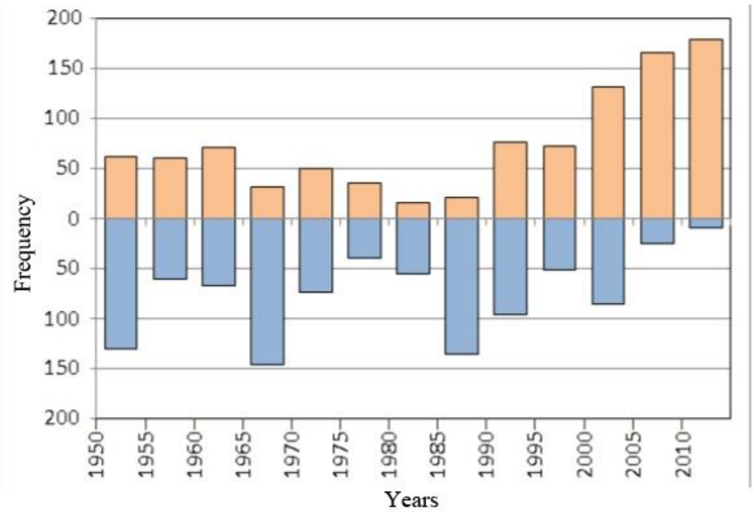

Figure 21: Frequency of the Annual Number of Record Maximum and Record Minimum Temperatures in 1950-2014 Period (Erlat and Türkeş, 2015)

The Seventh National Communication of Turkey to the UNFCCC (MoEU, 2018) also affirms these findings in which the number of cold days, cool days, and cool nights have been decreasing while that of summer days, warm days, warm nights, and tropical nights have been increasing. The magnitude of the increasing trend of warm days is 14 days/100 years, while that of summer days is 39 days/100 years, and that of warm nights is 15 days/100 years (MoEU, 2018). On the other hand, the magnitude of the decreasing trends of cold days is 6 days/100 years, while that of cool nights is 15 days/100 years (MoEU, 2018).

Based on extreme temperature records of 165 meteorological stations in the period 1961–2008, Toros (2012) observed that daily maximum and minimum temperatures have been increasing in Turkey, in which warming is characterized more by maximum than minimum temperatures. Figure 22 demonstrates the geographical distribution of Mann-Kendall test results of increasing and decreasing trends for summer temperature extremes over Turkey, where the maps indicate TX90th index (warm days), TX95th index (hot days), and TX99th index (extremely hot days), respectively. As the first map summarizes, the majority of the stations show an upward trend of the TX90th percentile (warm days), while those in the eastern part indicate a statistically insignificant increasing trend between the years 1970 and 2006. The second map that shows trend of hot days has similar results to the one showing warm days. For the last one, which demonstrates the trend for extremely hot days, there is a significant increasing trend in the southern, southwestern and central parts of Turkey have mainly influenced extreme warm days (Toros, 2012).

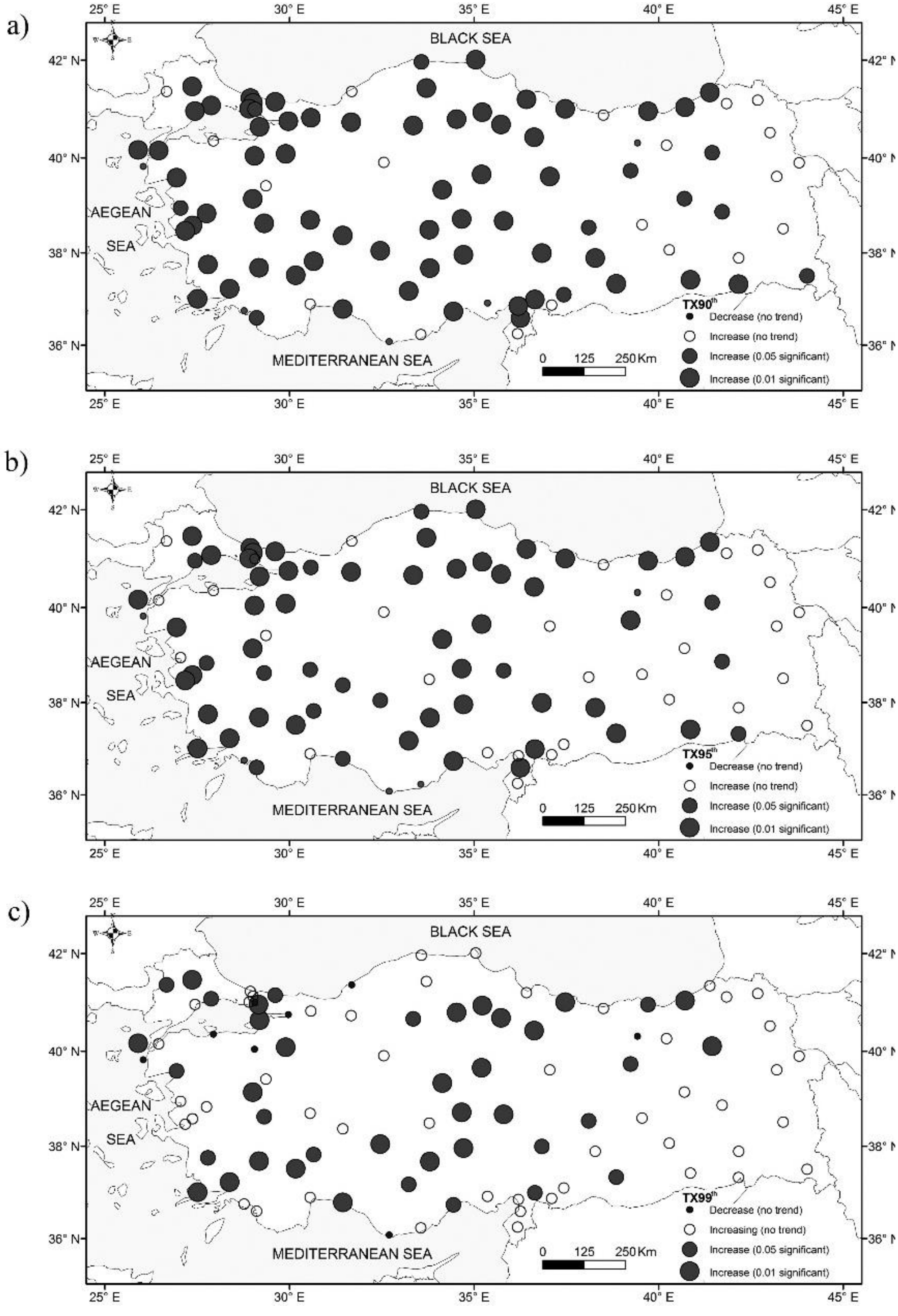

Figure 22: Trends in the daily maximum temperature during 1970-2016 period where a) TX90th index (warm days), b) TX95th index (hot days), c) TX99th index (extremely hot) (Toros, 2012)

According to Erlat et al. (2021) there is a significant increasing trend in heat wave indices in Turkey. In the same vein, **heat waves** are becoming more common and more frequent, especially after 1950s (Erlat et al., 2021). There is an increase in the number, length, and intensity of heat wave across the eastern Mediterranean region (Kostopoulou and Jones, 2005; Kuglitsch, 2010; IPCC, 2012; IPCC, 2013, Erlat et al., 2021). Moreover, the number and length of hot extremes is projected to rise and the number of cold extremes to decline in the Mediterranean region (Jones et al., 2008; IPCC, 2012; IPCC, 2013). Based on the RCP8.5 scenario, the number of heat waves is projected to increase gradually in Turkey (Figure 23). The increase will be at least six days more by 2030, and at least 12 days more by the end of the century than the reference period of 1971-2000 (UNDP, 2021 March 15). In addition, it is projected that heat waves realized every 10 years in the reference period will be seen every 2-3 years after the 2040s, and heat waves occuring every 100 years in the reference period will happen every 9 years by the end of the century (UNDP, 2021 March 15).

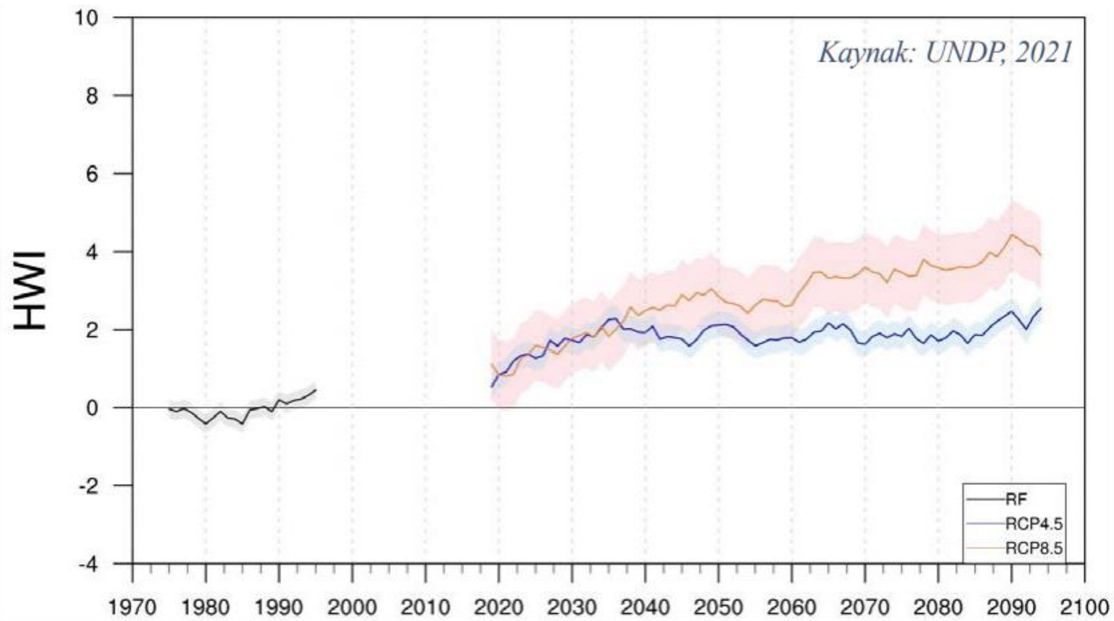

Figure 23: Heat wave intensity (HWI95) index results for Turkey (UNDP, 2021 March 15)

Drought condition is the key factor that exacerbates **forest fires**. In general, there are several factors that leads to an increase in forest fire risk, namely increasing temperatures, decreasing precipitation -thus decreasing soil moisture-, and the potential fuel the area has, which are of substantial direct or indirect relationship with climate variability and climate change. Therefore, like in any other part of the world, climate change is highly influential in increasing the risk of forest fires in Turkey. Figure 24 shows the number of forest fires and area burned between 1937 and 2021. Over the period from 1937 and 2021, the total forest area burnt as a result of 117,287 fires is 1.85 million hectares, according to the data obtained from forestry statistics and strategic plans of the General Directorate of Forestry (Ministry of Agriculture and Forestry, 2021). Moreover, there is an increasing trend in the number of forest fires (Figure 24).

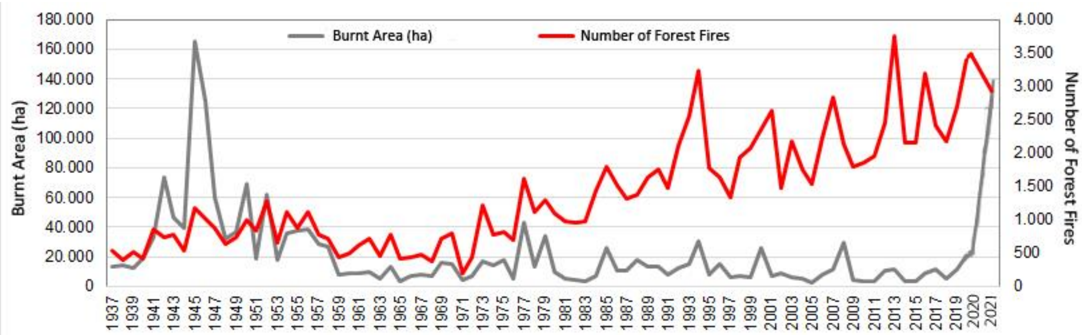

Figure 24: Number of Forest Fires and Area Burnt in Turkey, 1937-2021

[Adapted from Tolunay (2021) based on the data from Ministry of Agriculture and Forestry (2021)]

Figure 25 demonstrates the decadal average number of forest fires and annual forest area burned, respectively. In this vein, there is an increasing trend in the decadal average number of forest fires, while the ten-year average burned forest areas have not changed much in the last 60 years (Tolunay, 2022).

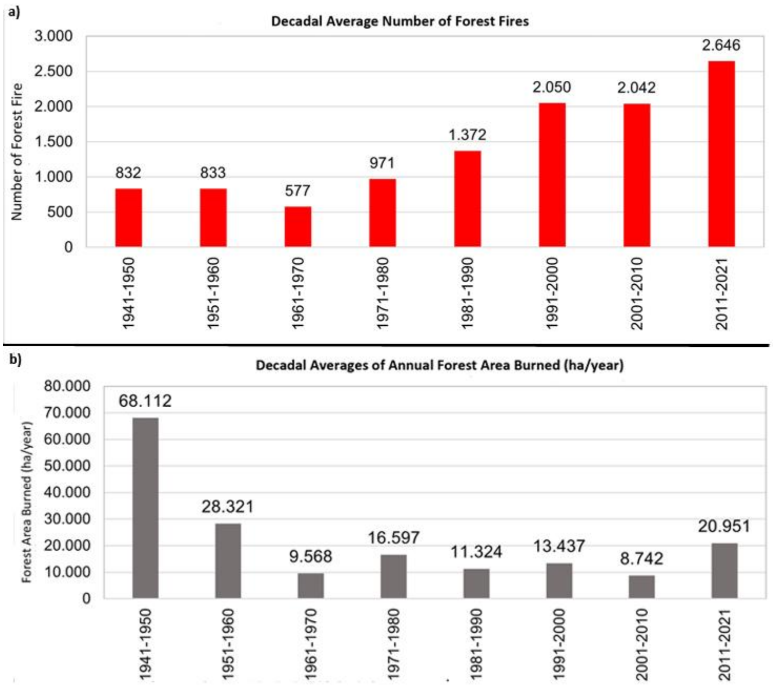

Figure 25: Decadal Average Number of Forest Fires (a), and Decadal Averages of Annual Forest Area Burned (b) (Tolunay, 2022)

In the same vein, forest fires are expected to decrease by mid-2030, followed by a dramatic increase after the 2040s, under the RCP8.5 scenario (UNDP, 2021 March 15) (Figure 26).

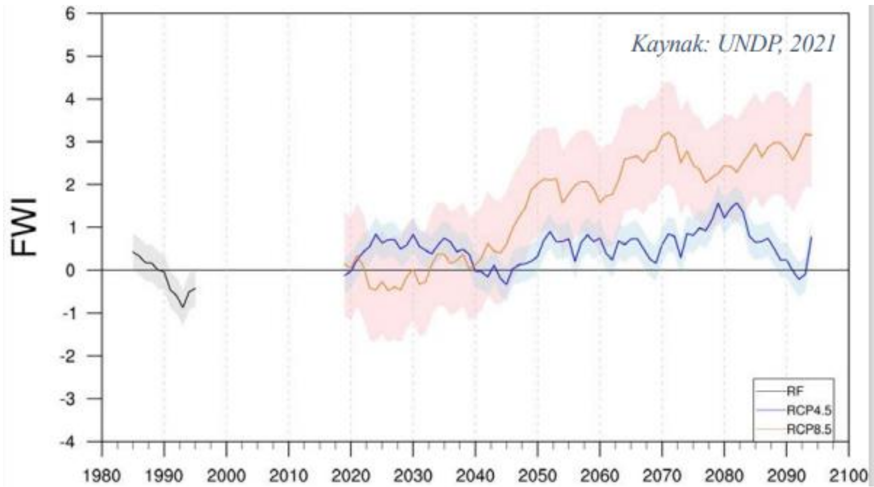

Figure 26: Fire Weather Index Results for Turkey (UNDP, 2021 March 15)

[where WFI<5.2 very low, 5.2 - 11.2 low, 11.2 - 21.3 moderate, 21.3 - 38.0 high, 38.0 – 50 very high, ≥50 extreme]

3.1.3.2. Changes in the Number of Tropical Days and Tropical Nights

The number of tropical days shows a slight decreasing trend in the 1950-1975 period, followed by a significant increasing trend after that period (Türkeş, 2019). Moreover, there is an increasing trend in the number of tropical nights in Turkey for the 1950-2016 period relative to the average and standard deviation of the 1961–1990 reference period, in which the increase is more rapid, particularly after the 1980s, as indicated in Figure 27 (Erlat and Türkeş, 2017).

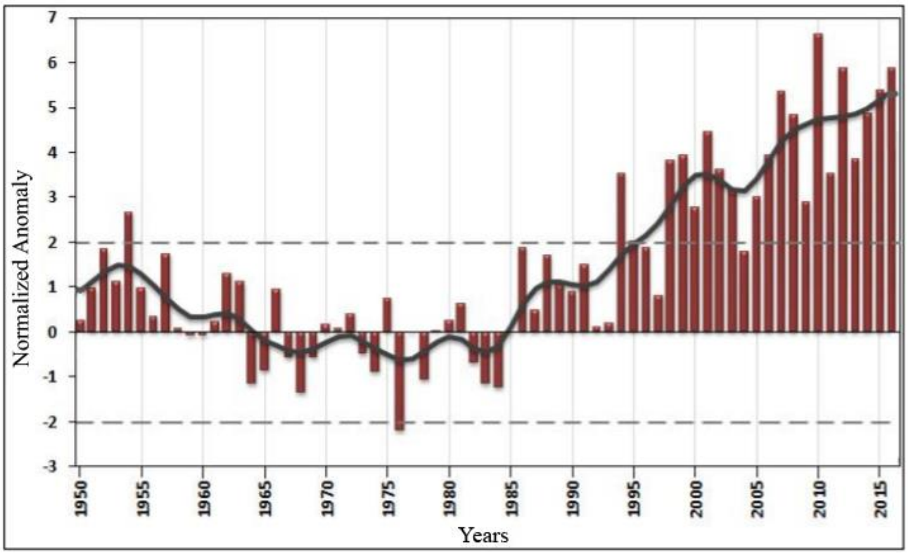

Figure 27: Normalized annual anomalies of the average number of tropical nights in Turkey, 1950-2016 (Erlat and Türkeş, 2017)

According to the Seventh National Communication of Turkey under the UNFCCC, the number of tropical nights has been increasing except for Euphrates Basin. The magnitude of the significant increasing trend is 37 days/100 years and coastal stations make a substantial contribution to this trend (MoEU, 2018). When the spatial distribution of long-term trends in the annual number of tropical nights of Turkey in the 1950–2016 period is examined, the Mediterranean coast is at the forefront, as demonstrated in Figure 28 (Türkeş, 2013a).

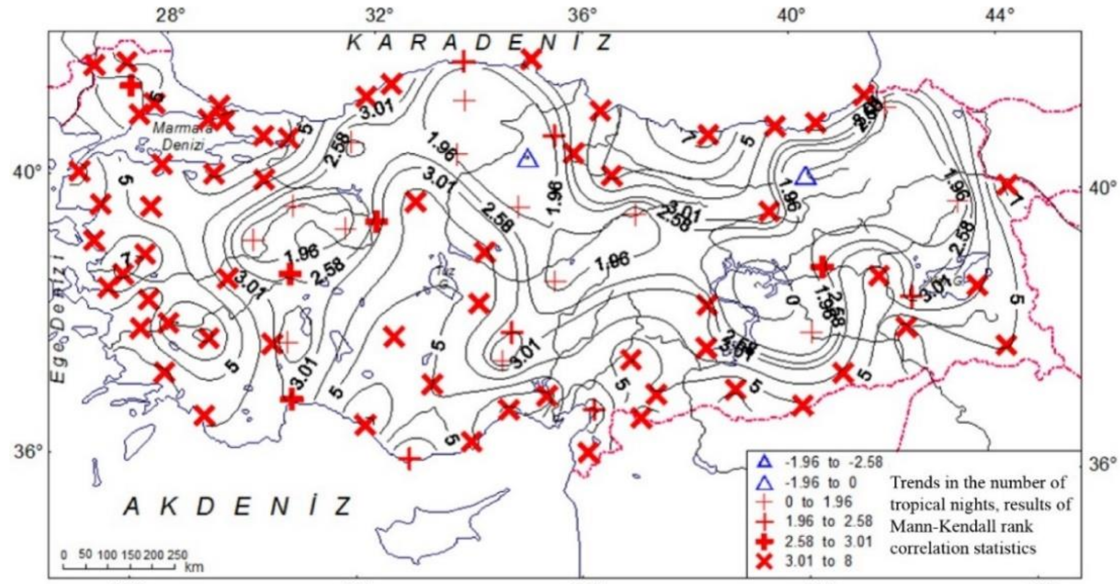

Figure 28: Long-Term Trends in the Annual Number of Tropical Nights in 1950–2016 period (Türkeş, 2013a)

3.1.3.3. Increase in Days with Heavy Precipitation

Extreme precipitation events have become more common in many regions of Turkey. There is an increasing trend in the number of days with heavy precipitation and that of with extreme precipitation at majority of the stations -except Aegean and southeastern Anatolia regions- with a magnitude of 17 days/100 years and 119 mm/100 years, respectively. Moreover, the trend in one-day maximum precipitation increases by 17 mm/100 years (MoEU, 2018). For the future projections based on RCP8.5 scenario, extreme precipitation in Turkey is considered to increase 1.5 percent which equals approximately 5.5 days by 2100, as shown in Figure 29 (UNDP, 2021 March 15).

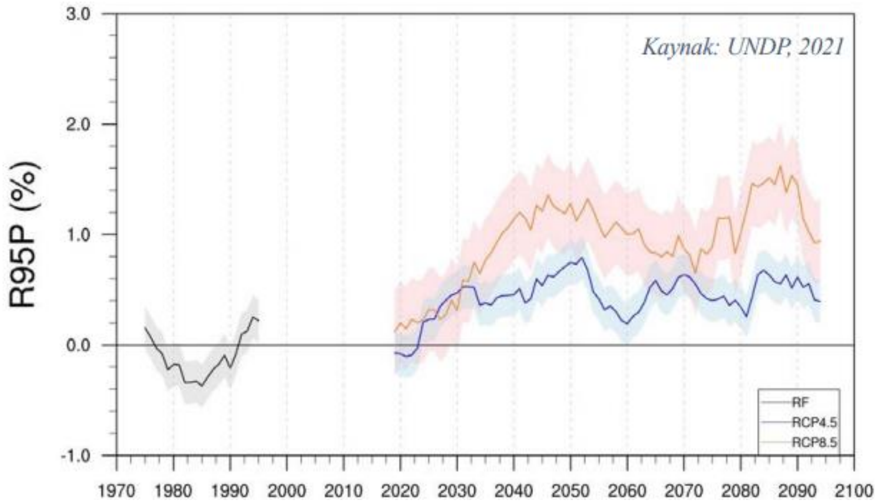

Figure 29: Extreme Precipitation Index (R95P-very wet days) Results for Turkey

Heavy precipitation also increases the risk of landslides which stems from the saturation of the ground and the slope instability. Moreover, changes in precipitation patterns lead to frequent occasions of irregular precipitation, which increases flood risk (Rannow et al., 2010; Lung et al., 2013; Holsten et al., 2013). The flood risk can be stronger, especially in urban areas which are mostly characterized by impervious surfaces. There has been an increasing trend in flood events since the early 2000s (Figure 30). In the last 10 years, approximately 100 or more flood events have occurred each year (Turkish State Meteorological Service, 2021).

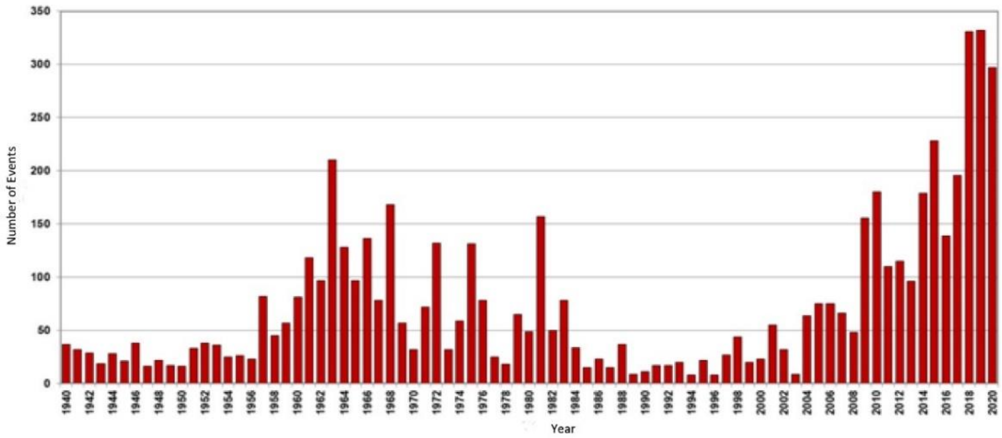

Figure 30: Number of Flood Events, 1940-2020 (Turkish State Meteorological Service, 2021)

Moreover, increases that may occur in the precipitation in the Eastern Black Sea Region are projected to cause an increase in both flood and landslide events. The number of flood events is expected to decrease in the southern regions but increase in the northern regions of Turkey (Sen et al, 2013).

3.2. Policy, Legal and Institutional Framework of Climate Change Adaptation in Turkey

Governments are increasingly adopting policy and other measures to address climate change issues, but progress varies substantially among countries. Every country is affected by the climate-related impacts at different levels. With a population of more than 84 million, Turkey is among the countries most severely affected by the adverse impacts of climate change. In this context, policy, legal and institutional framework of climate change adaptation is increasingly important to take urgent action to combat climate change and its impacts.

Turkey has a National Climate Change Adaptation Strategy and Action Plan (NASAP) covering the period of 2011-2023, which is coordinated by the Ministry of Environment, Urbanization, and Climate Change. Having focused on five focus areas, including water resources management, agricultural sector and food security, ecosystem services, biodiversity and forestry, natural disaster risk management, and public health (MoEU, 2011), NCCAP sets climate adaptation priorities and responsibilities in Turkey.

Turkey has recently made some institutional and legislative arrangements to combat climate change. The Paris Agreement, signed by Turkey in 2015, was ratified by the Turkish Parliament on 6 October 2021 after a 6-year delay. With this ratification, a new era in climate policy that contributes to global efforts against climate change has begun. In this context, Turkey is expected to submit an adaptation communication that includes actions to adapt to the impacts of climate change and update it regularly.

The Ministry of Environment and Urbanization, the leading institution responsible for planning and coordinating local and international activities in terms of mitigation, adaptation, and implementation, was renamed the Ministry of Environment, Urbanization and Climate Change (hereby MoEUCH) on 29 October 2021 with a Presidential Decree. In this vein, the ‘Climate Change Presidency’ and its affiliated ‘Climate Change and Adaptation Coordination Board’ have been established. The Presidency is responsible for the determination of plans, policies, and strategies related to climate change; conducting studies to determine national, local, and sectoral climate change adaptation needs; preparing modeling and risk assessment studies to identify the impacts of climate change, preparing risk maps and having them prepared. The affiliated Board, which consists of 22 members from 11 ministries, public institutions, private sector, and NGO representatives, aims to take necessary actions to combat the adverse impacts of climate change, determine corresponding policies, and ensure cooperation and coordination between public and private sector institutions and organizations.

Moreover, two general directorates with critical roles in combating climate change, ‘The General Directorate of Combating Desertification and Erosion’ and ‘the Turkish State Meteorological Service’, which were affiliated with the Ministry of Agriculture and Forestry, have been subordinated to the MoEUCH.

Furthermore, the Ministry establishes some project collaborations to address climate adaptation. Enhancing Adaptation Action in Turkey Project which is funded under IPA-II and conducted by the partnership of the MoEUCH and UNDP, is of critical importance for addressing climate vulnerability and risks in Turkey at the sectoral and urban level for the first time and for having direct linkages with NASAP. It is a four-year project initiated at the end of 2019. In this vein, vulnerability assessments are conducted in priority areas of ecosystems, infrastructure, economic, social, and cross-cutting issues at national and local levels in the context of the project which is expected to contribute to the preparation of a comprehensive platform for sharing of climate change data between all stakeholders. Turkey’s NASAP is planning to be revised as one of the expected outputs of Enhancing Adaptation Action in Turkey

Project. The project is conducted based on three main components (Iklimeuyum.org, n.d.). The first component is the “adaptation toolbox”, which aims to enhance the decision-making process of the central government for (i) updating national strategy and action plan for climate change adaptation, (ii) considering climate change adaptation in planning and investment decisions for priority sectors, and (iii) providing efficient tools for financing climate change adaptation and impact assessment. The second component is the “Solution Catalog for Cities”, which aims to increase the capacity for urban adaptation planning capacity including (i) preparing climate change adaptation action plan for four pilot cities (Muğla, Sakarya, Konya, and Samsun) and ensuring that these cities have the means of mainstreaming it through urban governance, (ii) providing cities with a typology framework which enable them to exchange knowledge and experience, and (iii) providing efficient tools for financing climate change adaptation and impact assessment. The last component is the “network”, which aims to develop a network among national institutions and with the EU to (i) support efficient collaborations between Turkish stakeholders from the public, private, academia, and civil society, (ii) increase the number of Turkish cities that have memberships to European urban networks, (iii) strengthen the ties between EU and Turkish research and expert institutions, (iv) organize training to further support the climate change adaptation experts in Turkey, and (iv) give adequate support to the grant component during design, implementation, and evaluation (Iklimeuyum.org, n.d.). Therefore, the expected outputs of the project are (Iklimeuyum.org, n.d.):

- Assessing climate change impact and vulnerability assessment for priority sectors (urban area, agriculture, social development, energy, industry, transportation and communication, public health, tourism and cultural heritage, biodiversity and ecosystem services, water resources)
- Revising the National Climate Change Adaptation Strategy and Action Plan (NASAP)

- Developing monitoring, evaluating, reporting and notification system to be used for NASAP
- Generating financing strategies for NASAP
- Establishing guidelines of adaptation planning for priority sectors
- Analyzing capacity and needs of stakeholders for capacity building and cooperation in order to strengthen adaptation to climate change
- Establishing a National Adaptation Platform
- Preparing “Urban Adaptation Strategy and Action Plans” for the four metropolitan cities including Muğla, Sakarya, Konya, and Samsun within the scope of the project and establishing monitoring and evaluation systems and developing financing strategies regarding implementation.

In addition to national efforts, MoEUCH draws attention to the necessity of addressing the adaptation to the effects of climate change at the local level and the responsibility of local governments to take precautions for meteorological disasters due to climate change, especially in cities and rural areas in Turkey. The circular dated January 22, 2019, on “Climate Change and Disaster Measures” sent by the Ministry to all governorates and municipalities highlights that there has been an increase in the number and severity of disasters, especially floods and overflows in recent years due to climate change and local governments, which have the ability and responsibility to intervene in the problem are expected to take immediate measures.

3.3. Conclusion

The impact of climate change has increasingly manifested itself more severely in Turkey, like in any other part of the world. As specified by the broad scientific community, Turkey has experienced not only high temperatures and changing precipitations but also increasing number of climate-related impacts. Being located in the Mediterranean Basin, Turkey is one of the countries that will be substantially affected by climate change (IPCC, 2013, p.1266).

Table 9: Summary of Observed and Projected Changes in Climate Extremes in Turkey

Climate Extremes	Observed Changes	Projected Changes
Temperature Extremes	-The annual number of record minimum temperatures has decreased since 1950s. Particularly after 2000s, record maximum temperature frequency has an increasing trend (Erlat and Türkeş, 2015). -Daily maximum and minimum temperatures have been increasing (Toros, 2012) -There is an increasing trend in the number of tropical nights for 1950-2016 period (Erlat and Türkeş, 2017).	The number of heat waves is projected to increase gradually in Turkey (UNDP, 2021 March 15).
Precipitation Extremes	There has been a substantial increase in extreme precipitation events in Turkey (MoEU, 2018).	Extreme precipitation in Turkey is considered to increase 1.5 percent which equals to approximately 5.5 days by the end of the century (UNDP, 2021 March 15).
Droughts	Approximately 60% of land area in Turkey experiences annual moisture deficit and is vulnerable to desertification (Türkeş, 2013a)	Future climate condition is expected to be intensively drier in Turkey, which leads to increased droughts (Kostopoulou and Jones, 2005; Türkeş et al., 2019; UNDP, 2021 March 15)
Floods	There has been an increasing trend in flood events since the early 2000s (Turkish State Meteorological Service, 2021).	The number of flood events is expected to decrease in the southern regions, but to increase in the northern regions of Turkey (Sen et al, 2013)
Forest Fires	There is an increasing trend in the number of forest fires (Ministry of Agriculture and Forestry, 2021).	Forest fires is expected to decrease by mid-2030, followed by an increase after 2040s, under RCP8.5 scenario (UNDP, 2021 March 15)

Source: Prepared by the author

Various research highlight that there is a significant change in the frequency and severity of extreme climate events, which is also highly influential in Turkey. Increasing extreme precipitation, longer and more intensive heat events, more frequent floods, landslide and mass movement events, more severe drought conditions and increasing number of forest fires comprise a significant part of the climate problem with many adverse impacts in Turkey. In the same vein, the climate of Turkey is expected to experience significant changes in the coming decades. The projections for Turkey indicate increasing temperatures and erratic rainfall patterns and increasing number of extreme climate events (Türkeş, 2013b; Türkeş, 2014; MoEU, 2018; Türkeş, 2019; UNDP, 2021 March 15). Table 9 shows the summary of observed and projected changes in climate extremes in Turkey.

The change in the frequency and severity of extreme climate events in Turkey has triggered the policy, legal and institutional side of the climate challenge and the importance of adaptation in reducing climate-related risks and vulnerabilities has recently started to be realized. In this context, some regulatory and institutional arrangements have been realized. Paris Agreement was ratified by Turkish parliament after a 6-year-delay, which launched a new climate policy era in Turkey. The ratification of the Agreement opens the way for Turkey to begin taking practical actions toward meeting its commitments related to the global climate problem and achieving its goals in line with the Agreement. Moreover, National Climate Change Adaptation Strategy and Action Plan is being revised by the partnership of the MoEUCH and UNDP. The partnership aims to assess vulnerabilities and risks for different sectors.

CHAPTER 4

METHOD OF THE RESEARCH

Because the change in climate will be incorporated into social, cultural and economic stresses, which will alleviate or exacerbate vulnerability to climate change (Ford et al., 2010), action to address climate risk and vulnerability is urgently needed (Bulkeley, 2013, p.143). Knowledge of vulnerability is the initial step in the long process of adapting to climate change (Bierbaum et al., 2007; Holsten, 2013). In order to develop an adaptation strategy and measure, the initial step is to identify what and who are vulnerable to what stress, in what way, as well as what is the capacity to adapt to changing conditions (Downing and Patwardhan, 2005; Kasperson et al., 2005; Ford et al., 2010; Schneiderbauer et al., 2017). Since many different entities may be at risk, structuring the vulnerability problem needs defining the purposes and scope of the analysis (Kasperson et al., 2005, p. 268).

For climate risk assessments, hazard, exposure, and vulnerability (vulnerability as a function of sensitivity and adaptive capacity) components are considered and the risk is therefore calculated based on the interaction of these three factors adopting the IPCC 2014 framework as indicated in Figure 31 (IPCC, 2014b). Risk is defined as the product of the impacts from hazardous events and the probability that each event occurs. The impact of a hazardous event is determined by system's vulnerability and exposure. In this study, (1) the hazard is considered as a latent damaging physical event or trend for a system (e.g., human population, infrastructure, agricultural livelihood, biodiversity, water resources, and forest-based livelihoods); (2) exposure refers to the presence of the system components in places and settings that could be adversely affected by the hazard; (3) vulnerability is the function of sensitivity and adaptive capacity of that system to the hazard.

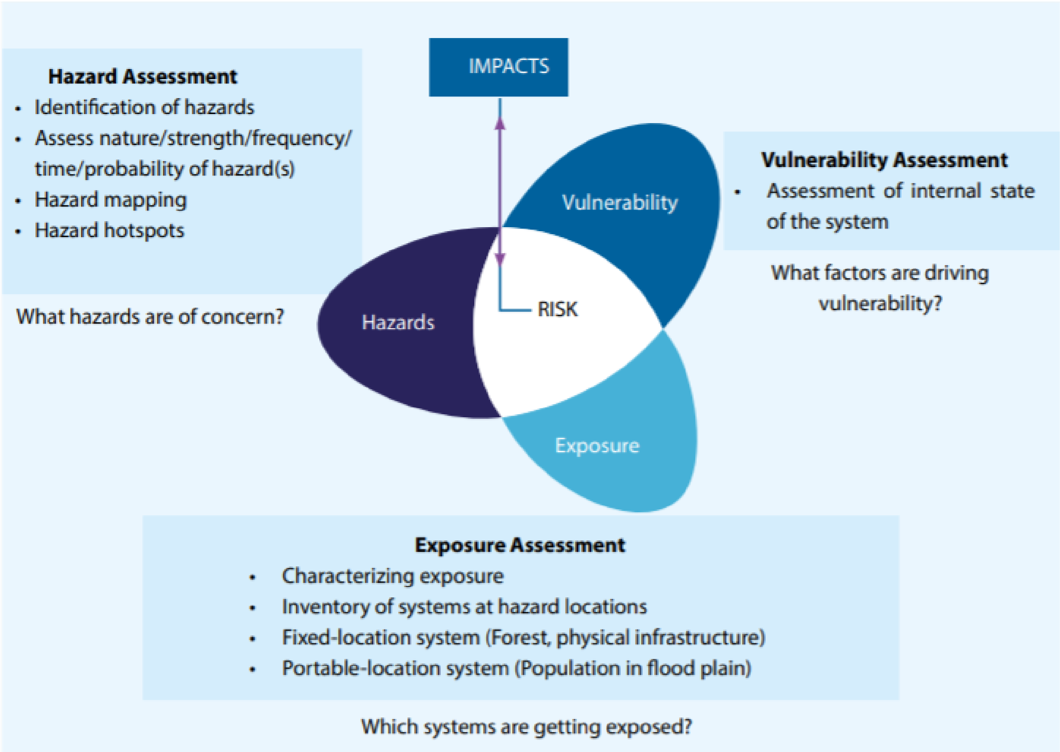

Figure 31: Risk Assessment Framework based on Risk-Based Approach in the Fifth Assessment Report (AR5) (Sharma et al., 2018).

Since risk is a multidimensional concept, it cannot be directly measured. That is why measurable and observable indicators are required to determine climate-related risk. Indicators help simplify, quantify, and measure relevant information in order to determine an overall climate risk condition rather than focusing separately on each dimension creating risk at larger spatial scales. Indicator studies are easy to implement and can be helpful not only to increase comprehension of the dimensions of risk and to quantify them (Eriksen and Kelly, 2007; O'Brien et al., 2007), but also to serve policy purposes since indicators enable complex data in different fields to be synthesized into a single number (Hinkel, 2011). The synthesis of indicators comprises a basis for the analyses, determining priorities for adaptation strategies (Downing et al., 2005), and directing spatial development policies.

In this study, the indicator approach is used to construct the climate risk and vulnerability index for the provinces in Turkey. The indicator approach is found appropriate to quantify risk and vulnerability in which selected indicators are combined systematically in order to reveal the risk and vulnerability levels of the provinces in Turkey. The indicator approach is a widely used method adopted for quantifying the risk and developing a better understanding of the internal factors contributing to vulnerabilities.

Figure 32 below shows the flowchart of the main steps to conduct the climate risk and vulnerability assessment. This process, in brief, includes selecting indicators of each risk component and collecting data, quantifying these data, standardization of data, dimension reduction, testing for internal consistency, weighting indicators, aggregating the scores of indicators through PCA/FA to prepare the indexes of flood, drought, forest fire, and heat risk, and finally mapping the risk and vulnerability levels of provinces.

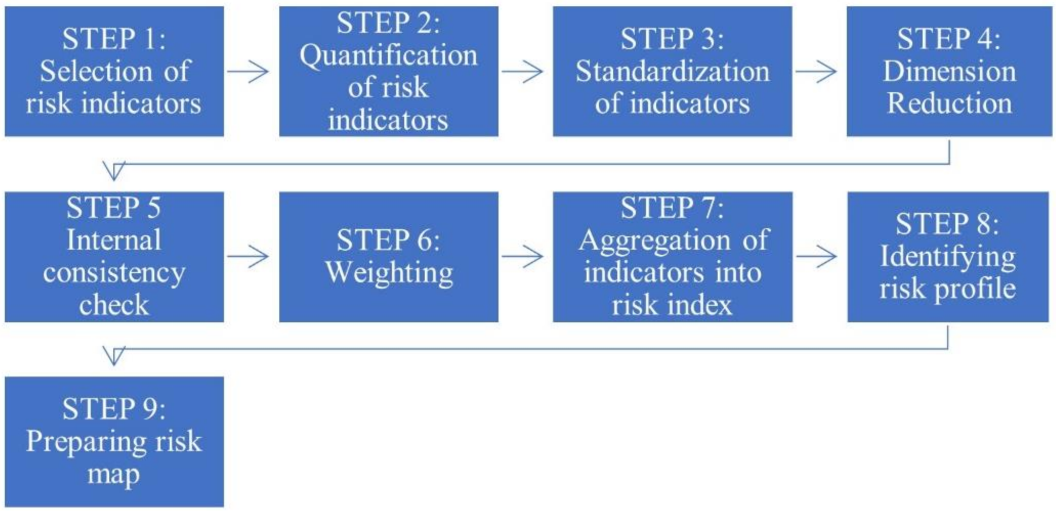

Figure 32: Steps for Climate Change Risk Assessment

4.1. Selection of Risk Indicators

Climate-related risks are increasing in frequency and severity, and they are expected to continue due to climate change. In this study, heat wave risk, flood risk, drought risk, and forest fire risk as the major risk types relevant to climate change are investigated, adopting the risk framework suggested by the IPCC (2014b). As it was mentioned before, the risk is a function of hazard, exposure, and vulnerability. Therefore, it is important to specify hazards, the presence of various systems that could be adversely affected, and vulnerability that contribute to risk.

Tapia et al. (2016) conceptualized risk induced by climate change to manage complexity within a climate change risk analysis. In their conceptualization, risk is considered as a tri-dimensional space where climate change threats (hazard), elements at risk (exposure), and vulnerability interface. In this study, this conceptualization is adapted from Tapia et al. (2016), as indicated in Figure 33.

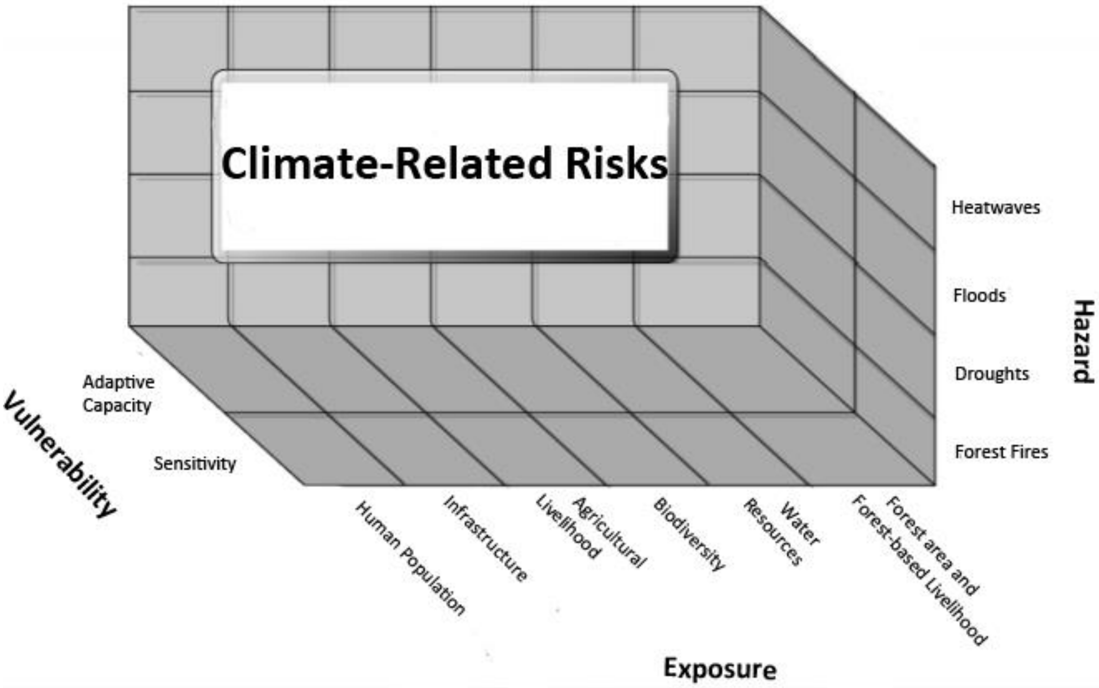

Figure 33: Risk as a Tri-Dimensional Space

Source: Adapted from Tapia et al. (2016)

Although in theory, each small cube could be characterized by the interaction among the dimensions, in practice, lack of data and inability to access data make this characterization complicated. Therefore, the tri-dimensional construct is considered separately based on the most relevant climate change hazards (heat wave, drought, forest fire, and flood) and elements that may be exposed in the first place in order to operationalize the risk analysis (Table 10). Specifying the system under consideration and the boundaries is necessary for the context-specific nature of adaptation (Fünfgeld and McEvoy, 2011). According to Ionescu et al. (2008), it is important to specify the vulnerable entity as well as the climate-related stimuli that makes the entity vulnerable. In this study, climate-related stimuli are heat wave, drought, forest fire, and flood, and the entities exposed are grouped based on corresponding stimuli.

Table 10: Most Relevant Climate Related Stimuli and Elements Exposed

Climate-Related Stimuli	**Exposed System**
Heat wave	Human population Infrastructure
Drought	Rural population Agricultural Livelihood Biodiversity Water Resources
Forest Fire	Forest-based Livelihood Biodiversity
Flood	Human population Infrastructure

Before the indicator selection, scientific literature on climate risks are reviewed, and theories, methodological approaches, empirical findings, and discussions are followed to better understand climate risks. Studies that adopt the risk-based framework of IPCC are given particular emphasis. Indicators are identified as a result of scientific literature review, in which hundreds of scientific articles, institutional reports, and case studies are reviewed.

Hazard is directly related to climatic parameters and can be expressed by temperature, precipitation, and occurrence of extreme events. Hazard indicators, in this thesis, cover indicators of meteorological parameters, indicators that address frequency and intensity of hazard, and indicators that exacerbate hazard. Exposure indicators encompass indicators related to natural and human systems located where hazard occurs (e.g., population settled in the flood-prone area). Sensitivity and adaptive capacity indicators, on the other hand, represent the internal weaknesses (e.g., poverty produces sensitivity to flood hazard) and internal strengths of a system (e.g., the redundancy of critical infrastructure systems enables better responding to climate-related impacts), respectively.

The procedures for indicator selection can be built by means of two general approaches, namely deductive and inductive approaches (Adger et al., 2004). In the deductive approach, a theory or conceptual framework is emphasized to select indicators based on relationships to be measured. In the inductive approach, statistical and empirical generalizations are used for the selection of indicators. In this study, deductive approach is used for the selection of indicators.

After a comprehensive review of risk and vulnerability studies, existing information and data on the shortlisted indicators are reviewed for Turkish provinces. Data sources are identified, and the list is then revised based on the relevance, analytical soundness, timeliness, and availability of data in the Turkish context.

The second criterion for indicator selection is the context of indicators. As discussed in the second chapter, the 2014 framework of IPCC considers vulnerability as independent from hazard. This approach does not allow addressing the question "vulnerability to what?"; without responding this question it becomes difficult to pinpoint the actions for reducing the vulnerability of a system. Moreover, a factor that makes a system vulnerable to a hazard may not produce vulnerability to another (Schneiderbauer et al., 2017); therefore, the "one size fits all" approach fails to contextualize vulnerability. However, considering vulnerability with reference to a hazard is "contextual and practical" in responding to the question of "vulnerability to what?" (Sharma and Ravindranath, 2019, p. 4). Therefore, this study employs hazard-relevant indicators for vulnerability assessment.

The third criterion for indicator selection focuses on spatial levels. The indicators are narrowed down so as to cover provincial or regional levels. As a result, 92 indicators (21 for heat wave, 22 for drought, 21 for forest fire, and 28 for flood risk) are deductively selected and grouped into hazard, exposure, sensitivity, and adaptive capacity, based on data availability in the Turkish context and literature review discussions. The data for indicators are retrieved from secondary sources, namely the relevant institutions and organizations, through official correspondences or in person. The following tables indicate the rationale behind indicator selection and data sources for heat wave, drought, forest fire, and flood risk, respectively.

First, selected indicators for heat wave, drought, forest fire, and flood risks are shown in Table 11, Table 12, Table 13, and Table 14, respectively. The indicators are provided with their relevance as they are discussed in the literature to highlight the reason why they are selected. These tables also show the data source, temporal coverage, and data level of corresponding risk indicators, categorized under hazard, exposure, sensitivity, and adaptive capacity components.

Table 11: Selected Indicators and Rationale Behind Their Selection and Data for Heat wave Risk (Prepared by the author)

Dimension	Indicator	Description	Reference	Variable	Unit	Data Source	Temporal Coverage	Data Level
Hazard	Increase in hot days/year (Tmax>30°C)	Climate change results in increase in the number of combined tropical nights (minimum temperature above 20 °C) and hot days (maximum temperature above 30 °C), which leads to more frequent extreme heat events.	Hübler et al. (2008), Rannow et al. (2010), WHO (2012), Lung et al. (2013), Holsten et al. (2013), Choi (2018), Hong et al. (2018)	Increase in number of days where Tmax>30°C	Coefficient of trend	Turkish Meteorological Service	1971-2018	Province
	Increase in number of tropical nights (TN>20°C)			Increase in number of days where TN>20°C	Coefficient of trend	Turkish Meteorological Service	1971-2018	Province
	Increase in annual maximum temperature			Annual maximum temperature in °C	Coefficient of trend	Turkish Meteorological Service	1971-2018	Province
	Increase in annual mean temperature			Increase in annual mean temperature	Coefficient of trend	Turkish Meteorological Service	1971-2018	Province
Exposure	Continuous urban land cover	The risk increases when the land use has a large share of built-up area. Densely built-up areas with a significant proportion of sealed surfaces increase the intensity of the heat island effect.	Lückenkotter et al. (2013b), Li et al. (2016), Krkoška Lorencová et al., (2018), Carter et al. (2018)	Share of land covered by continuous urban fabric in the total land area	%	Corine Database	2018	Province
	Urbanization rate	Population living in urban areas is highly exposed to heat wave since these areas have high proportion of built-up areas.	Sun et al. (2016), Vahmani et al. (2019), Tuholske et al. (2021)	Share of urban population in the total provincial population	%	Health Statistics Yearbook	2018	Province
	Urban rail system	Urban rail system is exposed to heat wave, this leads to track buckling and warping, sagging of overhead lines, and electrical failure.	Dobney et al. (2008), Rowan et al. (2013), Magill (2014), Ferranti et al. (2016), Otto et al. (2019)	The length of urban rail system	km	Railturkey.org	2018	Province
Sensitivity	Share of children (0-4 years old) and elderly population (over 65 years old)	Children are particularly sensitive to heat waves because they hardly regulate their body heat. Also heat waves may lead to renal disease, fever, and imbalance of electrolytes and exacerbate allergies for children.	Leonardi et al. (2016), Knowlton et al. (2009), Xu et al. (2012), UNICEF (2014), UNICEF (2021)	The number of 0-4 years of children and the number of people above 65 years old divided by the total population	%	TurkStat	2018	Province
		Population above the age of 65 have particularly sensitive to heat waves due to changes in the thermo-regulatory systems and due to the use of drugs that may affect homeostasis. Heat waves leads to higher -cardiovascular and respiratory-related mortality of elderly.	Conti et al. (2005), Fouillet et al. (2006), Knowlton et al. (2009), Reid et al. (2009), Baccini (2011), Swart et al. (2012), Climate Just (2014),					
	Share of refugees	Displaced people are one of the most sensitive groups to the impacts of climate change. The living conditions and lack of access of essential services are increasing their sensitivity to the climatic impacts (Ahmed et al., 2021). Climate change exacerbates other drivers of displacement such as poverty, food insecurity, water shortages, and resource scarcity that communities dependent on for survival (Huntjens and Nachbar, 2015). A potential conflict between refugees and citizens of the host country may arise to compete over natural resources and land rights (UNHCR, September 21, 2021).	Huntjens and Nachbar (2015), Swain (2015), UN News (April 22, 2021), Ahmed et al. (2021), UNHCR (September 21, 2021)	Share of Syrian refugees under temporary protection in the total population	%	The Directorate General of Migration Management of Turkey	2018	Province
	Change in landcover	Increase in the artificial areas intensifies heat island effect. When these areas tend to increase over time, this may exacerbate the heat and increase sensitivity to heat waves.	Carter et al. (2018), Kamali Maskooni et al. (2020), Li et al. (2020)	Change in the share of artificial surface cover	%	Corine Database	2012-2018	Province
	One-person households	Older people are sensitive to heat wave when they live alone since they become isolated which may be fatal during heat wave, thus they have a higher risk of death compared with people with social contacts.	Semenza et al. (1996), Tomassini et al. (2004), Toulemon and Barbieri (2008); Reid et al. (2009)	Share of one-person households	%	Turkstat, Statistics on Family	2018	Province
	Poverty	The impact of heatwave manifest itself more severely on the poor people who hardly afford health insurance or air conditioning, thus poverty increases sensitivity to heat wave.	Moser (1998), Morello-Frosch et al. (2009), Füssel (2010), IPCC (2014c), Hallegatte et al. (2020)	Share of households declaring to fail on meeting basic needs	%	Turkstat Well-being Index	2015	Province
	Unemployment	Unemployment increases sensitivity and indicates a high level of vulnerability to climate change	De Oliveira Mendes (2009), Juhola et al. (2013), Tapia et al. (2017)	Share of unemployed workers in the total labor force	%	Turkstat Well-being Index	2015	Province
	Dependency Ratio	Higher dependency ratio increases sensitivity. The burden of supporting and providing the social services needed by children and elderly people, who are often economically dependent, is larger on the economically active population and the entire economy, when there is a high dependence ratio.	Vincent and Cull (2010), Sewando et al. (2016)	Ratio of the population under 15 and over 65 years of age to the population between 19-64 years old	Unit rate	Turkstat	2018	Province
Adaptive Capacity	Urban green spaces	Urban green spaces are particularly important to reduce heat island effect. Green spaces can improve resilience of cities to heat-related impacts by providing a cooling effect especially during times with high temperatures	Mundoli et al. (2014), Carter et al. (2018)	Urban green space per area of continuous and discontinuous urban fabric	Unit rate	Corine Database	2018	Province
	High education	Education is an important aspect of adaptive capacity. Higher education strengthens adaptive capacity and reduces vulnerability as people with high education are likely to earn higher income and recover quickly.	Greiving et al. (2011), Holsten and Kropp (2012), Muttarak and Lutz (2014), Striessnig et al. (2016), Asbridge et al. (2021)	Proportion of higher education graduates	%	Turkstat	2018	Province
	Civic engagement	Public participation is important in improving adaptive capacity. Well-networked people have higher capacity to adapt.	Marshall et al. (2010), de Coninck et al. (2018), Hügel and Davies (2020), Khatibi et al. (2021)	Share of persons interested in union/association activities	%	Turkstat Well-being Index	2015	Province
	Level of interest in environmental issues	Level of interest in environmental issues can improve adaptive capacity since individuals that have a higher level of interest in environmental issues help mobilize local knowledge and resources.	Added by the author	Rate of interest in environmental issues	%	Turkstat, Life Satisfaction Statistics	2013	Province
	GDP per capita	Higher GDP per capita implies higher adaptive capacity as it increases the ability to cope with the consequences of climate change.	Swanson et al. (2007), Füssel (2010), Jongman et al. (2015), Weiler (2019)	GDP divided by population	TRY	Turkstat	2018	Province
	Saving deposit per capita	Higher saving deposit per capita indicates higher adaptive capacity, therefore lower vulnerability.	Smit et al. (2001), Swanson et al. (2007), Thathsarani & Gunaratne (2018)	Saving deposit divided by population	TRY	Turkstat Well-being Index	2015	Province
	Access to hospitals	Improved access to hospitals indicates higher adaptive capacity and lower vulnerability.	Greiving et al. (2011), Juhola et al. (2013), Handayani (2017)	The number of hospitals per hectare of land area	Unit rate	Openstreetmap	2021	Province

Table 12: Selected Indicators and Rationale Behind Their Selection and Data for Drought Risk (Prepared by the author)

Dimension	Indicator	Description	Reference	Variable	Unit	Data Source	Temporal Coverage	Data Level
Hazard	Increase in annual maximum temperature	The increase in the annual maximum temperature and the number of hot days contributes to the increase in drought risk. The magnitude of individual hazards can be intensified when drought and heatwave occur simultaneously.	Rannow et al. 2010), Dai (2012), Blanka et al. (2013), Shukla et al. (2015), Kong et al. (2020), Ashraf et al. (2021)	Annual maximum temperature in °C	Coefficient of trend	Turkish Meteorological Service	1971-2018	Province
	Increase in hot days/year (Tmax>30°C)			Increase in number of days where Tmax>30°C	Coefficient of trend	Turkish Meteorological Service	1971-2018	Province
	Decrease in annual total precipitation	Because of their thermodynamic relationship, temperature and precipitation are closely linked to each other at various timeframes. Changes in climate lead to substantial irregular precipitation pattern, which increases drought risk.		Decrease in annual total precipitation in millimeters	Coefficient of trend	Turkish Meteorological Service	1971-2018	Province
	Decrease in days/ year with heavy precipitation			Decrease in the number of days where precipitation exceeds 10 mm	Mann- Kendall Test Score	Turkish Meteorological Service	1971-2018	Province
	Drought conditions	Drought indices show drought conditions of a region; therefore, used as a drought hazard indicator.	Vicente-Serrano et al. (2012), Jain et al. (2015)	Bagnouls-Gaussen drought index results	Index value	Cebeci et al., 2019	2000-2016	Province
Exposure	Rural population	Higher proportion of rural population shows higher dependence on natural resources-based economies. Population living in rural areas could be adversely affected by drought.	Cutter et al. (2003), KC et al. (2015), Vincent (2004), Das et al. (2020),	Share of rural population in the total provincial population	%	Health Statistics Yearbook	2018	Province
	Agricultural workers	Agricultural workers are exposed to drought as their main livelihood is dependent on agriculture which is highly affected from drought.	Cutter et al. (2003), KC et al. (2015), Das et al. (2020)	The number of agricultural workers	#	Social Security Institution	2018	Province
	Irrigated land	Irrigated lands are exposed to drought due to the water sources used for irrigation. Both surface water and groundwater supplies decrease especially during prolonged drought, which further shorten the duration of the availability of water resources.	World Bank (2005), Meza et al. (2021), Wallender et al. (2022)	The totality of irrigated agricultural land area	ha	General Directorate of State Hydraulic Works	2018	Province
	Number of species	The biodiversity in local ecosystems is severely impacted by temperature and precipitation changes. For example, habitat conditions might alter, ecosystem services may disappear, patterns of biodiversity and species' distribution may vary, and species can become extinct.	Walther et al. (2002), Root et al. (2003), Thuiller et al., (2005), CCSP (2008), Holsten et al. (2013), Mundoli et al. (2014)	The number of species identified	#	Ministry of Agriculture and Forestry	2019	Province
	Wetland area	Wetlands suffers from and are exposed to drought which may erode many wetlands.	Dollar et al. (2013), Stirling et al. (2020), Marambanyika et al. (2021)	The area of wetland	ha	Corine Database	2018	Province
Sensitivity	Species in Red List	Species at high risk of global extinction are particularly sensitive to climate change.	Lung et al. (2013), Holsten et al. (2013)	Number of critically endangered (CR), endangered (EN), and vulnerable (VU) species according to IUCN classification divided by the protected area	Unit rate	Ministry of Agriculture and Forestry, Ministry of Environment and Urbanization	2019	Province
	Agricultural GDP	The agricultural sector is highly sensitive to drought which adversely affects agricultural production.	Cutter et al. (2003), Das et al. (2020)	Share of agriculture in GDP	%	Turkstat	2018	Province
	Poverty	The impact of climate change manifests itself more severely on the poor people. The higher the proportion of poor people, the lower the adaptive capacity thus higher the vulnerability and risk	Moser (1998), Füssel (2010), IPCC (2014c), Hallegatte et al. (2020)	Share of households declaring to fail on meeting basic needs	%	Turkstat Well-being Index	2015	Province
	Unemployment	Unemployment reduces adaptive capacity and indicates a high level of vulnerability to climate change	De Oliveira Mendes (2009), Juhola et al. (2013), Tapia et al. (2017)	Share of unemployed workers in the total labor force	%	Turkstat Well-being Index	2015	Province
	Dependency ratio	Higher dependency ratio increases sensitivity. The burden of supporting and providing the social services needed by children and elderly people, who are often economically dependent, is larger on the economically active population and the entire economy, when there is a high dependence ratio.	Vincent and Cull (2010), Sewando et al. (2016)	Ratio of the population under 15 and over 65 years of age to the population between 19-64 years old	ratio	Turkstat	2018	Province
Adaptive Capacity	Water treatment	Treated wastewater has an important role for recycling and reuse in the arid and semi-arid regions which experience increasing water shortages. The reuse of wastewater helps conserve water resources.	Qadir et al. (2007), Pedrero et al. (2010), de Stefano et al. (2015), Ungureanu et al. (2020)	Amount of water treated	Thousand m^3	TurkStat, Municipal Water Statistics	2018	Province
	High education	Education is an important aspect of adaptive capacity. Higher education strengthens adaptive capacity and reduces vulnerability as people with high education are likely to earn higher income and recover quickly.	Greiving et al. (2011), Holsten and Kropp (2012), Muttarak and Lutz (2014), Striessnig et al. (2013), Asbridge et al. (2021)	Share of higher education graduates	%	Turkstat	2018	Province
	Civic engagement	Public participation is important in improving adaptive capacity. Well-networked people have higher capacity to adapt.	Marshall et al. (2010), de Coninck et al. (2018), Hügel and Davies (2020), Khatibi et al. (2021)	Share of persons interested in union/ association activities	index value	Turkstat Well-being Index	2015	Province
	Level of interest in environmental issues	Level of interest in environmental issues can improve adaptive capacity since individuals that have a higher level of interest in environmental issues help mobilize local knowledge and resources.	Added by the author	Rate of interest in environmental issues	%	Turkstat, Life Satisfaction Statistics	2013	Province
	GDP per capita	Higher GDP per capita implies higher adaptive capacity as it increases the ability to cope with the consequences of climate change.	Swanson et al. (2007), Füssel (2010), Jongman et al. (2015), Weiler (2019)	GDP divided by population	TRY	Turkstat	2018	Province
	Saving deposit per capita	Higher saving deposit per capita indicate higher adaptive capacity, therefore lower vulnerability.	Smit et al. (2001), Swanson et al. (2007), Thathsarani & Gunaratne (2018)	Saving deposit divided by population	TRY	Turkstat Well-being Index	2015	Province
	R&D investments	The ability to create new technologies is a critical component of adaptive capacity. Regions that invest in R&D have a higher adaptive capacity	Juhola et al. (2013), Swart et al. (2012)	R&D and Innovation Performance Index	index value	Belgin&Apaydin Avsar, 2019	2018	Province

Table 13: Selected Indicators and Rationale Behind Their Selection and Data for Forest Fire Risk (Prepared by the author)

Dimension	Indicator	Description	Reference	Variable	Unit	Data Source	Temporal Coverage	Data Level
Hazard	Increase in annual maximum temperature	Drought and forest fires are highly connected, in which drought increases the risk of forest fires as dry trees and shrubs serve as fuel for fires. Increases in temperatures and changes in precipitation result in drought and increase the danger of forest fires.	Westerling and Bryant (2008), Jones et al. (2008), Girardin et al. (2009), Holden et al. (2007), Littell et al. (2009), IPCC (2012), Abatzoglou and Kolden (2013) Jolly et al. (2015), Holden et al. (2018)	Annual maximum temperature in °C	Coefficient of trend	Turkish Meteorological Service	1971-2018	Province
	Increase in hot days/year			Increase in number of days where Tmax>30°C	Coefficient of trend	Turkish Meteorological Service	1971-2018	Province
	Decrease in annual total precipitation			Decrease in annual total precipitation in millimeters	Coefficient of trend	Turkish Meteorological Service	1971-2018	Province
	Decrease in days/year with heavy precipitation			Decrease in number of days where precipitation exceeds 10 mm	Coefficient of trend	Turkish Meteorological Service	1971-2018	Province
	Drought conditions			Bagnouls-Gaussen drought index results	Index value	Cebeci et al., 2019	2000-2016	Province
	Forest fires	Provinces with frequent occurrence of forest fire events indicate the frequency of the forest fire hazard.	Westerling and Bryant (2008)	The number of forest fires	Unit rate	Ministry of Agriculture and Forestry	2013-2018	Province
Exposure	Forest area	Forest areas with their high fuel availability increase exposure to forest fires	Rannow et al. (2010), Lung et al. (2013)	Forest extent	hectare	Corine Database	2018	Province
	Population of forest villages	Population settled in forest villages could be adversely affected by forest fires as they are heavily dependent on high usage of forest areas and resources for a living.	Kurtulmuşlu and Yazıcı (2000)	Population living in forest villages	#	Ministry of Agriculture and Forestry	2018	Province
	Number of species	Species are exposed to and affected by forest fires due to changes in habitat structure and the composition of species and decrease in wildlife diversity because loss of native habitat	Kinnaird and O'Brien (1998), Myers (2006)	The number of species identified	#	Ministry of Agriculture and Forestry	2019	Province
Sensitivity	Species in Red List category	Species at high risk of global extinction are particularly sensitive to forest fire.	Lung et al. (2013), Holsten et al. (2013)	Number of critically endangered (CR), endangered (EN), and vulnerable (VU) species according to IUCN classification divided by the protected area	Unit rate	Ministry of Agriculture and Forestry, Ministry of Environment and Urbanization	2019	Province
	Forest village poverty rates	Higher poverty rates in forest villages increases sensitivity. Due to their limited access to alternative sources of income, low levels of productive assets, low levels of social capital (such as membership in cooperatives), and high levels of vulnerability, the poor are more dependent on the forest. They thus have a restricted ability to diversify their sources of income and transition to higher-return economic pursuits, including agriculture and owning livestock.	World Bank (2017)	Poverty rates of forest villages	%	World Bank	2017	NUTS 1
	Dependency ratio	Higher dependency ratio increases sensitivity. The burden of supporting and providing the social services needed by children and elderly people, who are often economically dependent, is larger on the economically active population and the entire economy, when there is a high dependence ratio.	Vincent and Cull (2010); Sewando et al. (2016)	Percentage of the population under 15 and over 65 years of age to the population between 19-64 years old	Unit rate	Turkstat	2018	Province
Adaptive Capacity	Silvicultural activities	Silviculture can help moderate climate-related stresses and increase forest capacity to resist.	Anderson and Palik (2011),	Annual average area of silvicultural activities divided by the total forest area	Unit rate	Ministry of Agriculture and Forestry	2017-2019	Province
	Area protected by nature conservation laws	Protected areas are influential in buffering the impacts of extreme climate events in maintaining ecosystem integrity and provision of ecosystem services.	IUCN (2012), WWF (2015)	The proportion of area protected by nature conservation law	%	Ministry of Agriculture and Forestry, Ministry of Environment and Urbanization	2018	Province
	High education	Education is an important aspect of adaptive capacity. Higher education strengthens adaptive capacity and reduces vulnerability as people with high education are likely to earn higher incomes and recover quickly.	Greiving et al. (2011), Holsten and Kropp (2012), Muttarak and Lutz (2014), Striessnig et al. (2013), Asbridge et al. (2021)	Share of higher education graduates	%	Turkstat	2018	Province
	Civic engagement	Public participation is important in improving adaptive capacity. Well-networked people have higher capacity to adapt.	Marshall et al. (2010), de Coninck et al. (2018), Hügel and Davies (2020), Khatibi et al. (2021)	Share of persons interested in union/ association activities	index value	Turkstat Well-being Index	2015	Province
	Level of interest in environmental issues	Level of interest in environmental issues can improve adaptive capacity since individuals that have a higher level of interest in environmental issues help mobilize local knowledge and resources.	Added by the author	Rate of interest in environmental issues	%	Turkstat, Life Satisfaction Statistics	2013	Province
	GDP per capita	Higher GDP per capita implies higher adaptive capacity as it increases the ability to cope with the consequences of climate change.	Swanson et al. (2007), Füssel (2010), Jongman et al. (2015), Weiler (2019)	GDP divided by population	TRY	Turkstat	2018	Province
	Saving deposit per capita	Higher saving deposit per capita indicates higher adaptive capacity, therefore lower vulnerability.	Smit et al. (2001); Swanson et al. (2007); Thathsarani & Gunaratne (2018)	Saving deposit divided by population	TRY	Turkstat Well-being Index	2015	Province
	R&D investments	The ability to create new technologies is a critical component of adaptive capacity. Regions that invest in R&D have a higher adaptive capacity	Swart et al. (2012), Juhola et al. (2013)	R&D and Innovation Performance Index	index value	Belgin & Apaydin Avsar, 2019	2018	Province
	Access to road network	Settlements with high spatial isolation have lower capacity to adapt climate-related impacts.	Greiving et al. (2011), de Sherbinin et al. (2014), Kumar et al. (2016), Feyissa et al. (2018)	Road lengths per km2	Unit rate	Openstreetmap	2020	Province

Table 14: Selected Indicators and Rationale Behind Their Selection and Data for Flood Risk (Prepared by the author)

Dimension	Indicator	Justification	Reference	Variable	Unit	Data Source	Temporal Coverage	Data Level
Hazard	Increase in annual total precipitation	Changes in precipitation patterns lead to frequent occasions of irregular precipitation, which increases flood risk.	Rannow et al. (2010), Lung et al. (2013), Holsten et al. (2013)	Change in number of days where precipitation exceeds 10 mm	Coefficient of trend	Turkish Meteorological Service	1971-2018	Province
	Increase in days/ year with heavy precipitation	Extreme precipitation may increase the intensity and frequency of flooding.	Schiermeier (2011), Trenberth (2011), Zolina (2012), Swain et al. (2020), Tabari (2020)	Annual total precipitation in millimeters	Coefficient of trend	Turkish Meteorological Service	1971-2018	Province
	Continuous urban land cover	Built-up areas with a significant proportion of impervious surfaces increase surface runoff due to changing the hydrology and geomorphology of streams.	Gill et al. (2007), Morello-Frosch et al. (2009), Kron (2012), Kazmierczak et al. (2015), Pistocchi 2015), OECD (2018), Asbridge et al. (2021)	Share of continuous urban fabric in the total provincial area	%	Corine Database	2018	Province
	Number of occurrences of flood events	Areas with frequent occurrence of flood events increases flood hazard.	Deressa et al. (2008); Lung et al. (2013)	Number of occurrences of flood events divided by the flood-prone area	Unit rate	Disaster and Emergency Management Presidency, EEA	1950-2018	Province
Exposure	Population settled in flood-prone area	The indicator shows the presence of people living in flood-prone area; therefore, they could be adversely affected by flood hazard.	Carter et al. (2018)	Share of population living in flood-prone area divided by the total population	%	GEOSTAT, EEA	2018	Province
	Road network in flood-prone areas	Flooding may damage the road infrastructure that creates difficulties in accessing emergency services and evacuation, thus, disruptions endanger community functioning. Any road segment located within flood-prone area indicates the exposure of the system to flood hazard.	Carter et al. (2018), Dong et al. (2020), Papilloud et al. (2020)	The length of major road network in flood-prone area divided by the total length of road network	%	Openstreetmap, EEA	2021	Province
	Rail network in flood-prone area	Floods may have a large direct and indirect negative influence on a railway network, causing infrastructure and rail operations to be disrupted. Any rail segment located within flood-prone area indicates exposure to flood hazard.	Cheetham et al. (2016), Carter et al. (2018), Koks et al. (2019), Ottoo et al. (2019), Bešinović (2020)	The length of rail network in flood-prone area divided by the total length of rail network	%	Openstreetmap, EEA	2021	Province
	Power plants, airports, and ports in flood-prone area	Airports, ports, and power stations are classified as critical infrastructures whose failures could bring serious consequences and intensifies the flood impact. Their presence within flood-prone area indicates exposure to flood hazard.	Pant et al. (2016), Carter et al. (2018), Murdock et al. (2018), de Brujin et al. (2019), de Vivo et al. (2021)	The number of power plants, airports, and ports in flood prone area divided by the total number of these facilities	%	Arcgis database, The Centre for Humanitarian Data, EEA	2018	Province
	Hospitals in flood-prone area	Hospitals are classified as critical infrastructures under threat of flooding. They become especially critical during flooding as they serve as emergency services. Their presence within a flood-prone area indicates exposure to flood hazard.	Janius et al. (2018), Koneswaran et al. (2022), Yazdani et al. (2022)	The number of hospitals in flood prone area divided by the total number of hospitals	%	Openstreetmap, EEA	2021	Province
Sensitivity	Share of children (0-4 years old) and elderly population (over 65 years old)	Children are sensitive to floods which can severely affect them both physically and physiologically. They can hardly protect themselves from a flood event. Elderly population is sensitive to floods in several ways. They tend to live alone in particular types of homes that are sensitive to floods. They have limited mobility to evacuate their properties during flood. Also, they have limited resources to cope and recover from flood.	Kazmierczak and Cavan (2011), Climate Just (2014), Tapia et al. (2016), Mallett & Etzel (2018), UNICEF (2021) Knowlton et al. (2009), Baccini (2011), Swart et al. (2012), Climate Just (2014), Breil et al. (2018)	The number of 0-4 years of children and the number of people above 65 years old divided by the total population	%	TurkStat	2018	Province
	Share of refugees	Displaced people are one of the most sensitive groups to the impacts of climate change. The living conditions and lack of access to essential services increase their sensitivity to flooding. Shelters for refugees are generally not resistant to natural hazards. Refugees with limited knowledge of the official language are also more vulnerable.	Huntjens and Nachbar (2015), Swain (2015), Breil et al. (2018), UN News (April 22, 2021), Ahmed et al. (2021)	Share of Syrian refugees under temporary protection in the total population	%	The Directorate General of Migration Management of Turkey	2018	Province
	Share of low-quality houses	Access to safe living conditions is critical for increasing people's resilience. Poor housing conditions increase flood sensitivity.	Kazmierczak et al. (2015), Breil et al. (2018), O'hare and White (2017)	Share of households having problems with quality of dwellings	%	Turkstat Well-being Index	2015	Province
	Poverty	Poverty produce sensitivity to flood hazard as they hardly afford insurance coverage and recover a damaged property. The higher the proportion of poor people, the higher the sensitivity to flood hazard.	Moser (1998), KC et al. (2015), Füssel (2010), IPCC (2014c), Hallegatte et al. (2020)	Share of households declaring to fail on meeting basic needs	%	Turkstat Well-being Index	2015	Province
	Unemployment	Unemployment reduces adaptive capacity and indicates a high level of vulnerability to climate change since unemployed people may have limited capacity to replace or repair a damaged property or afford home insurance.	De Oliveira Mendes (2009), Juhola et al. (2013), Tapia et al. (2017), Asbridge et al. (2021)	Share of unemployed workers in the total labor force	%	Turkstat Well-being Index	2015	Province
	Dependency Ratio	Higher dependency ratio increases sensitivity. The burden of supporting and providing the social services needed by children and elderly people, who are often economically dependent, is larger on the economically active population and the entire economy, when there is a high dependence ratio.	Vincent and Cull (2010), Sewando et al. (2016)	Percentage of the population under 15 and over 65 years of age to the population between 19-64 years old	Unit rate	Turkstat	2018	Province
Adaptive Capacity	Flood control zone	Flood risk management strategies may play a key role in protecting lives and livelihoods and minimizing losses.	Jongman et al. (2015), Ward et al. (2017)	The area of flood control zone divided by the flood-prone area	Unit rate	State Hydraulic Works, EEA	2018	Province
	Urban green spaces	Green spaces can reduce the rate of water runoff during an extreme precipitation event, thus excess water does not lead to flood events. Therefore, the higher the percentage of green space increases adaptive capacity.	Ripl (1995), Gill et al. (2007), Kazmierczak et al. (2015), Carter et al. (2018),	Share of urban green spaces in the total urban area	%	Corine Database	2018	Province
	Access to road network	Road networks are considered critical networks. Settlements with high spatial isolation have lower capacity to adapt climate-related impacts. Higher road density offers more route options for evacuation and other critical services. The redundancy of road network, thus, increases adaptive capacity.	Greiving et al. (2011), Shepard et al. (2011), de Sherbinin et al. (2014), Rogelis (2015), Kumar et al. (2016), Feyissa et al. (2018), Asbridge et al. (2021)	Road lengths per km2 of surface area	Unit rate	Openstreetmap	2021	Province
	Access to railroad	The redundancy of critical infrastructure systems increases adaptive capacity since the system can still function, which is especially vital during flood hazard. The redundancy of rail network, thus, increases adaptive capacity.	Cheetham et al. (2016), Carter et al. (2018), Koks et al. (2019), Ottoo et al. (2019), Bešinović (2020)	Road lengths per 100 km2 of surface area	Unit rate	Openstreemap	2021	Province
	Access to airports and ports	The redundancy of critical infrastructure systems enables better responding to climate-related impacts and increases adaptive capacity since the system can still function, which is especially vital during flood hazard. The redundancy of airports and ports, thus, increases adaptive capacity.	Pant et al. (2016), Carter et al. (2018), Murdock et al. (2018), de Brujin et al. (2019), de Vivo et al. (2021)	Number of airports and ports per 100 km2 of surface area	Unit rate	The Centre for Humanitarian Data	2018	Province
	Access to energy	The redundancy of critical infrastructure systems enables better responding to climate-related impacts and increases adaptive capacity as the system can still function, which is especially vital during flood hazard. Improved access to energy indicates higher adaptive capacity and lower vulnerability as population may still reach energy during flood hazard.	Perera et al. (2015), Carter et al. (2018), de Brujin et al. (2019)	Installed power in MW per 10,000 persons	MW	Energy Market Regulatory Authority	2018	Province
	Access to hospitals	The redundancy of critical infrastructure systems enables better responding to climate-related impacts and increases adaptive capacity since the system can still function, which is especially vital during flood hazard. Improved access to hospitals indicates higher adaptive capacity as population may still get necessary medical support during flood hazard.	Greiving et al. (2011), Juhola et al. (2013), Handayani (2017), Carter et al. (2018), Janius et al. (2018), Koneswaran et al. (2022), Yazdani et al. (2022)	The number of hospitals per 100 km2 of land area	Unit rate	Openstreetmap	2021	Province
	High education	Education is an important aspect of adaptive capacity. Higher education strengthens adaptive capacity and reduces vulnerability as people with high education are likely to earn higher incomes and recover quickly.	Greiving et al. (2011), Holsten and Kropp (2012), Muttarak and Lutz (2014), Striessnig et al. (2013), Asbridge et al. (2021)	Share of higher education graduates	%	Turkstat	2018	Province
	Civic engagement	Public participation is important in improving adaptive capacity. Well-networked people have higher capacity to adapt.	Marshall et al. (2010), de Coninck et al. (2018), Hügel and Davies (2020), Khatibi et al. (2021)	Share of persons interested in union/ association activities	index value	Turkstat Well-being Index	2015	Province
	Level of interest in environmental issues	Level of interest in environmental issues can improve adaptive capacity since individuals that have a higher level of interest in environmental issues help mobilize local knowledge and resources.	Added by the author	Rate of interest in environmental issues	%	Turkstat, Life Satisfaction Statistics	2013	Province
	GDP per capita	Higher GDP per capita implies higher adaptive capacity as it increases the ability to cope with the consequences of climate change.	Swanson et al. (2007), Füssel (2010), Jongman et al. (2015), Weiler (2019)	GDP divided by population	TRY	Turkstat	2018	Province
	Saving deposit per capita	Higher saving deposit per capita indicate higher adaptive capacity, therefore lower vulnerability since savings can enable people to replace or repair a damaged property or afford home insurance.	Smit et al. (2001), Swanson et al. (2007), Thathsarani & Gunaratne (2018), Asbridge et al. (2021)	Saving deposit divided by population	TRY	Turkstat Well-being Index	2015	Province
	R&D investments	The ability to create new technologies is a critical component of adaptive capacity. Regions that invest in R&D have a higher adaptive capacity	Swart et al. (2012), Juhola et al. (2013)	R&D and Innovation Performance Index	index value	Belgin & Apaydin Avsar, 2019	2018	Province

4.2. Quantification of Risk Indicators

This step includes quantification of indicators of four types of climate risks mentioned above. For each indicator, the quantification process is explained below.

Several ways are followed when quantifying indicators. Data related to temperature and precipitation (e.g., increase in hot days/year, increase in the number of tropical nights, increase in annual mean temperature, decrease in annual total precipitation, increase in days/year with heavy precipitation, increase in annual maximum temperature) are quantified and analyzed using Mann-Kendall Test and Sen's Slope Estimator to find out the overall trend of temperature and precipitation for all 81 provinces for the time period, 1971 to 2018. The data is processed using MAKESENS 1.0 software, an Excel macro prepared by Salmi et al. (2002). Mann Kendall Test (Mann, 1945; Kendall, 1975) is a non-parametric statistical test commonly used for the analysis of the trend in temperature and precipitation time series. Mann Kendall Test is used to detect if there is an upward or downward trend over time, while Sen's method uses a linear model to estimate the slope of the trend. This test is found appropriate for two reasons. First and most importantly, the test is of low sensitivity to missing values and outliers; and second, it is a non-parametric test and does not require the data to be distributed normally (Tabari et al., 2011, p.130). Although parametric trend tests are more powerful, they necessitate the data to be normally distributed and are of high sensitivity to outliers. According to this test, the null hypothesis H0 assumes that there is no trend, while alternative hypothesis H1 assumes that there is a trend. Mann-Kendall test provides a Z value, in which positive Z and negative Z values show monotonic increasing and decreasing trends, respectively. In this context, when the Z value is between -1.96 and 1.96 (alpha $\leq$ 0.05), it can be inferred that there is no trend; thus, the null hypothesis will be accepted (Sahu et al., 2020).

Therefore, quantification and analysis of climate-related data are found appropriate to be presented separately in the second part of Chapter 5. The quantification technique for the rest of the indicators is addressed below. Indicators that are commonly used in different risk types were explained only within the first risk type in which they are included in order to avoid redundancy.

Heat wave Risk Indictors:

- **Urbanization rate:** The data for **s**hare of the urban population in the total population is retrieved from Health Statistics Yearbook prepared by the Ministry of Health.

- **Continuous urban land cover:** This indicator represents the share of the continuous urban fabric in the total provincial land area. The data is retrieved from Corine Database. It is calculated for each province by dividing continuous urban land cover by the total provincial area and then multiplying by 100.

$$Share\ of\ continuous\ urban\ land\ cover = \frac{Continuous\ urban\ land\ cover}{Total\ Land\ Area} * 100$$

- **Urban rail system:** This indicator represents the length of continuous urban fabric in the total provincial land area. The related data is retrieved from Railturkey.org website

- **Share of children and elderly population (0-4 years old, and over 65 years old):** 0-4 years old children and over 65 years old elderly population data is retrieved from TurkStat the Results of Address Based Population Registration System. It is calculated for each province by dividing 0-4 years old children and elderly over 65 years old population by the total provincial population formulated as below.

$$Share\ of\ Children\ and\ Elderly\ Population = \frac{Children\ and\ elderly\ population}{Total\ Provincial\ Population} * 100$$

- **Share of refugees:** This indicator refers to the share of Syrian refugees under temporary protection in the total provincial population, whose data is obtained from The Directorate General of Migration Management of Turkey. It is calculated for each province by dividing the number of Syrian refugees under temporary protection by the total provincial population formulated as below.

$$Share\ of\ Refugees = \frac{Syrian\ refugees\ under\ temporary\ protection}{Total\ Provincial\ Population} * 100$$

- **Change in landcover:** This indicator indicates the change in the built-up area based on CORINE data. The change in built-up area is calculated by dividing the change in artificial surface cover between 2012 and 2018 by the total land area of the province then multiplying by 100.

$$Change\ in\ Landcover = \frac{Change\ in\ artificial\ sırface\ cover\ (hectar)}{Total\ land\ area\ (hectar)} * 100$$

- **One-person households:** The data used for this indicator is the share of one-person households in the total number of households in the province, which is sourced from Turkstat Statistics on Family.

$$One\text{-}person\ Households = \frac{\#\ of\ one - person\ households}{Total\ number\ of\ households} * 100$$

- **Poverty:** The data used for this indicator is the share of households declaring to fail meeting basic needs, which is obtained from Turkstat Well-Being Index for Provinces report conducted in 2015.

- **Unemployment:** The data for the unemployment rate is obtained from Turkstat Well-Being Index for Provinces report conducted in 2015.

- **Dependency Ratio:** The data of dependency ratio is obtained from Turkstat the Results of Address Based Population Registration System for 81 provinces in Turkey. It refers to the total age dependency ratio, which equals to the sum of child and elderly dependency ratio.

- **Urban green spaces:** This indicator indicates the ratio of the area of urban green spaces to the continuous and discontinuous urban fabric, whose data is sourced from CORINE. It is calculated for each province by dividing the area of urban green space by the area of continuous and discontinuous urban fabric, formulated as below.

$$\text{Ratio of urban green spaces} = \frac{Area\ of\ urban\ green\ space\ (ha)}{Area\ of\ continuous\ and\ discontinuous\ urban\ fabric\ (ha)}$$

- **High education:** This indicator indicates the ratio of the population with high education to the total population aged 15 years and above. The data is retrieved from TurkStat National Education Statistics database. It is calculated for each province by dividing the total number of graduates from universities and other higher educational institutions, master including 5- or 6-years faculties, and doctorate by the population aged 15 years and over.

$$\text{Ratio of High Education} = \frac{Graduates\ with\ bachelor's, master's, and\ doctorate\ degree}{Total\ Population\ aged\ 15\ years\ and\ above} * 100$$

- **Civic engagement:** This indicator refers the share of people interested in union/association activities. Although unions and associations are intended to be narrowed down to those focusing on the environment or climate change, the data is not available. The data for civic engagement is obtained from the "TurkStat Well-being Index for Provinces" report conducted in 2015.

- **Level of interest in environmental issues:** Related data is acquired from the "TurkStat Life Satisfaction Statistics" report prepared in 2015.

- **GDP per capita:** The related data that include GDP per capita of 81 provinces is sourced from TurkStat Gross Domestic Product by Provinces press release.

- **Saving deposit per capita:** The related data is obtained from TurkStat Well-Being Index for Provinces report.

- **Access to hospitals:** Access to hospitals is represented by the number of hospitals per 100 km2 of land area in the province. The data for hospitals is sourced from Openstreetmap (2021) and they are intersected with the provincial boundaries and then the data of flood-prone areas in Turkey in Arcgis 10.7.

$$Access\ to\ Hospitals = \frac{Number\ of\ hospitals}{Total\ land\ area\ (km2\ )} * 100$$

<u>Drought Risk Indictors:</u>

- **Drought conditions:** In their study, Cebeci et al. (2019) calculate Bagnouls-Gaussen drought indices by using average total monthly precipitation amounts and average monthly temperature data of 81 meteorological stations in Turkey between the period 2000-2016. In this sense, the drought conditions indicator is represented by Bagnouls Gaussen drought index, which was sourced from Cebeci et al. (2018).

- **Share of rural population:** This indicator shows the share of the rural population in the total provincial population, which is retrieved from Health Statistics Yearbook prepared by Ministry of Health.

- **Agricultural workers:** This indicator indicates the number of agricultural workers in the province. The data is retrieved from the Social Security Institution. This refers to the sum of the number of active insured persons in the agricultural sector within the scope of article 4-1/a of act 5510 and of article 4-1/a of act 5510 Social Insurance and Universal Health Insurance Law.

- **Irrigated agricultural land:** This indicator represents the area of irrigated agricultural land in the province. The data for the irrigated area is sourced from the General Directorate of State Hydraulic Works.

- **Number of species:** This indicator represents the number of species identified according to the Noah's Ark National Biodiversity Database prepared by the Ministry of Agriculture and Forestry, which is the data source of this indicator.

- **Wetland area:** This indicator represents the area of wetlands in the province, whose data is obtained from Corine.

- **Species in Red List:** This indicator represents the number of species in Red List per 100 hectares of the protected area. The Noah's Ark National Biodiversity Database prepared by the Ministry of Agriculture and Forestry addresses the number of critically endangered (CR), endangered (EN), and vulnerable (VU) species according to the IUCN classification, which is the data source of this indicator. It is calculated by dividing the number of species in Red List by the area protected by nature conservation law which includes Gene Conservation Forests-in situ, Wetland of Local Importance, National Parks, Protection Forests, Ramsar sites, Urban Forests, Nature Monuments, Nature Conservation Areas, Nature Parks, seed orchard-ex situ, Seed Stands-in situ, Nationally Important Wetlands, Wildlife Conservation Areas, Natural Sites, and Special Environmental Protection Area. The related data is retrieved from the Ministry of Agriculture and Forestry and the Ministry of Environment and Urbanization. There have been some problems processing the data. Since these areas are governed by two different ministries, some areas may have two conservation statuses at once. It is not possible to distinguish the mentioned areas from each other; therefore, these areas are accounted as they are. In addition, the areas within the borders of more than one province are divided by the number of provinces that they are included in and distributed into the respective provinces. Therefore, the species in Red List is quantified by dividing the number of species in Red List in the province by the total protected area of the province, then multiplying by 100.

$$\textit{Species in Red List:} = \frac{\#\ of\ species\ in\ Red\ List}{Protected\ area\ (hectar)} * 100$$

- **Agricultural GDP per agricultural worker:** The data for agricultural GDP per agricultural worker is sourced from TurkStat Gross Domestic Product by Provinces press release for the former, and Social Security Institution for the latter.

$$\textit{Agricultural GDP per agricultural worker} = \frac{Agricultural\ GDP\ (TRY)}{Number\ of\ agricultural\ workers}$$

- **Water treatment:** This indicator refers to the amount of water treated. The data is retrieved from TurkStat Municipal Water Statistics 2018 report.

- **R&D investments:** The data for R&D investments is obtained from the research article conducted by Belgin and Apaydın Avşar (2019), who measured Turkey's R&D and innovation performance at the regional and provincial level. In this sense, the data used for this indicator is R&D and Innovation Performance Index values for 81 provinces.

Forest Fire Risk Indictors:

- **Forest fires:** This indicator refers to the number of forest fire events for each of the 81 provinces from 2013 to 2018. The data on forest fire events in 81 provinces is obtained from the Ministry of Agriculture and Forestry of Turkey.

- **Forest area:** This indicator refers to the amount of forest area in a province. The data for forest area is obtained from the Ministry of Agriculture and Forestry.

- **Population of forest villages:** This indicator refers to the population living in forest villages. The data for the population living in forest villages is retrieved from the Ministry of Agriculture and Forestry.

- **Forest village poverty rates:** This indicator refers to the forest village poverty rate which is sourced from World Bank (2017) at NUTS-1 level.

- **Silvicultural activities:** The indicator of silvicultural activities is represented by the annual average area of silvicultural activities divided by the total forest area in the province. The former is retrieved from the Ministry of Agriculture and Forestry.

$$Silvicultural\,Activities = \frac{Annual\ average\ area\ of\ silvicultural\ activities\ (hectar)}{Total\ forest\ area\ (hectar)} * 100$$

- **Area protected by nature conservation laws:** The data used for this indicator include Gene Conservation Forests-in situ, Wetland of Local Importance, National Parks, Protection Forests, Ramsar sites, Urban Forests, Nature Monuments, Nature Conservation Areas, Nature Parks, seed orchard-ex situ, Seed Stands-in situ, Nationally Important Wetlands, Wildlife Conservation Areas, Natural Sites, and Special Environmental Protection Area. The related data were retrieved from the Ministry of Agriculture and Forestry and the Ministry of Environment and Urbanization. There have been some problems processing the data. Since these areas are governed by two different ministries, some areas may have two conservation statuses at once. It is not possible to distinguish the mentioned areas from each other; therefore, these areas are accounted as they are. In addition, the areas within the borders of more than one province are divided by the number of provinces that they are included in and distributed into the respective provinces. The share of area protected by nature conservation law is calculated for each province by dividing the sum of the protected areas by the total provincial area.

$$\%\ of\ Area\ Protected = \frac{The\ sum\ of\ the\ protected\ areas\ (hectar)}{Total\ Land\ Area\ (hectar)} * 100$$

- **Access to road network:** Access to road network is represented by the indicator of total road lengths per km^2 of provincial land area. The major road network is retrieved from Openstreetmap (2021). ‘Motorway’, ‘motorway_link’, ‘primary’, ‘primary_link’, ‘secondary’, ‘secondary_link’, ‘tertiary’, ‘tertiary_link’, ‘trunk’, and ‘trunk_link’ classes are selected as the major roads. It is calculated for each province, by dividing the total road length in the province by the land area of that province.

$$Access\ to\ Road\ Network = \frac{Total\ road\ length\ (km)}{Total\ land\ area\ (km2\ )}$$

<u>Flood Risk Indictors:</u>

- **Number of occurrences of flood events:** This indicator refers to the number of flood events divided by the flood-prone area in the province. The data of flood events in 81 provinces for the time period January 1950-June 2018 is obtained from the Disaster and Emergency Management Presidency of Turkey. Potential flood-prone area extent is sourced from European Environment Agency (EEA). It represents the area that is flooded once every 100 years, covering the river channel, active floodplain where flooding still occurs, and former floodplain where flooding is restricted due to flood protection.

$$Number\ of\ Occurrences\ of\ Flood\ Events = \frac{\#\ of\ flood\ events}{Flood\ prone\ area\ (ha)}$$

- **Population settled in flood-prone area:** This indicator indicates the population living in the corresponding province that would be exposed to flooding in the event of a 1 in 100-year fluvial flood. Potential flood-prone area extent is sourced from European Environment Agency. It represents the area that is flooded once every 100 years, covering the river channel, active floodplain where flooding still occurs, and former floodplain where flooding is restricted due to flood protection. Population data is obtained as 250m GEOSTAT population grids sourced from EUROSTAT. This data is intersected with the provincial boundaries and then the data of flood-prone areas in Turkey in Arcgis 10.7 (Figure 34).

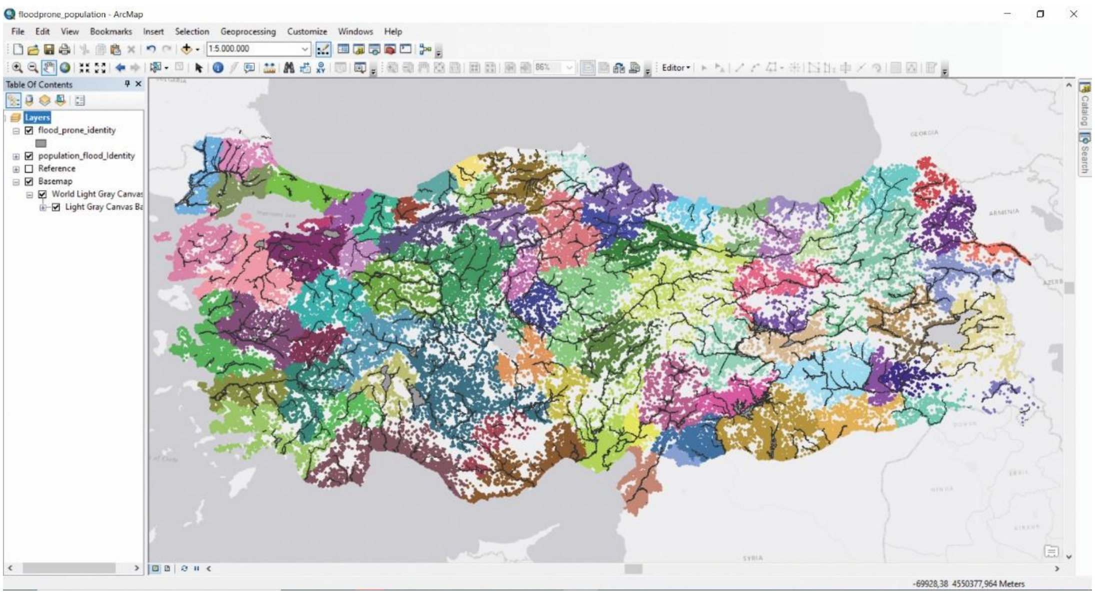

Figure 34: Intersecting Population Data with Flood Prone Areas in ArcGis 10.7

The measure of the population in flood-prone area is transformed into a rate based on the total population living in the province. Therefore, the indicator of the population settled in the flood-prone area is finalized by dividing the population living in flood prone area by the total population living in the corresponding province, then multiplying by 100.

$$\textit{Population Settled in Flood-Prone Area} = \frac{Population\ living\ in\ flood\ prone\ area}{Total\ population} * 100$$

- **Road network in flood-prone areas:** This indicator indicates the total length of the major road infrastructure in the corresponding province that would be exposed to flooding in the event of a 1 in 100-year fluvial flood. Potential flood-prone area extent is sourced from European Environment Agency. It represents the area that is flooded once every 100 years, covering the river channel, active floodplain where flooding still occurs, and former floodplain where flooding is restricted due to flood protection. The major road network is retrieved from Openstreetmap (2021). ‘Motorway’, ‘motorway_link’, ‘primary’, ‘primary_link’, ‘secondary’, ‘secondary_link’, ‘tertiary’, ‘tertiary_link’, ‘trunk’, and ‘trunk_link’ classes are selected as major roads. Selected major roads are intersected with the provincial boundaries and then the data of flood-prone areas in Turkey in Arcgis 10.7 (Figure 35).

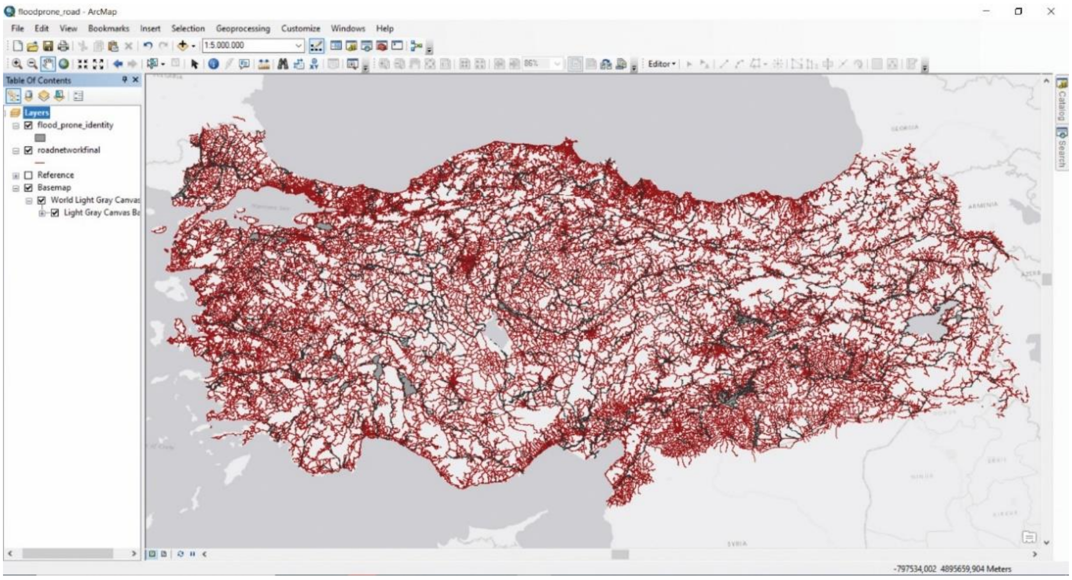

Figure 35: Intersecting Major Road Networks with Flood Prone Areas in ArcGis 10.7

The measure of road network in flood-prone area is transformed into a rate based on the total length of the road network in the province. Therefore, the indicator of major road infrastructure in flood-prone area is finalized by dividing the length of major road infrastructure in flood-prone area by the total length of major road infrastructure in the corresponding province, then multiplying by 100.

$$\textit{Road Network in Flood-Prone Area} = \frac{Length\ of\ road\ network\ exposed\ to\ flooding\ (km)}{Total\ length\ of\ road\ network\ (km)} * 100$$

- **Rail network in flood-prone area:** This indicator indicates the total length of the rail network in the corresponding province that would be exposed to flooding in the event of a 1 in 100-year fluvial flood. Potential flood-prone area extent is sourced from European Environment Agency. It represents the area that is flooded once every 100 years, covering the river channel, active floodplain where flooding still occurs, and former floodplain where flooding is restricted due to flood protection. The rail network is obtained from

Openstreetmap (2021). ‘Funicular’, ‘light_rail’, ‘rail’, ‘subway’, and ‘tram’ classes are selected from the data set. Selected segments of the rail network are intersected with the provincial boundaries and then the data of flood prone areas in Turkey in Arcgis 10.7 (Figure 36).

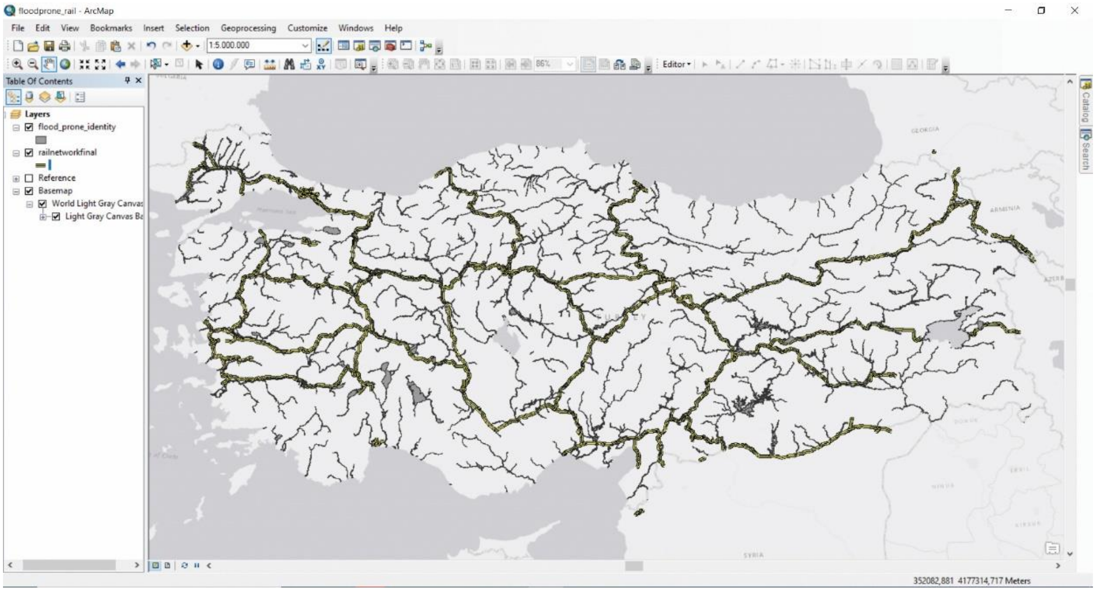

Figure 36: Intersecting Rail Network with Flood Prone Areas in ArcGis 10.7

The measure of the rail network in the flood-prone area is transformed into a rate based on the total length of rail network in the province. The indicator of rail network in flood-prone area is measured by dividing the length of rail network in flood-prone area by the total length of rail network in the corresponding province, then multiplying by 100.

$$\textit{Rail Network in Flood-Prone Area} = \frac{Length\ of\ rail\ network\ exposed\ to\ flooding\ (km)}{Total\ length\ of\ rail\ network\ (km)} * 100$$

- **Power plants, airports, and ports in flood-prone area:** This indicator indicates the total number of power plants, airports, and ports in the province that would be exposed to flooding in the event of a 1 in 100-year fluvial flood. Potential flood-prone area extent is sourced from European

Environment Agency. It represents the area that is flooded once every 100 years, covering the river channel, active floodplain where flooding still occurs, and former floodplain where flooding is restricted due to flood protection. For power plants, the data is obtained from Arcgis database and ‘coal’, ‘gas’, ‘geothermal’, ‘hydro’, ‘oil’, ‘solar’, and ‘wind’ are included in the dataset. For airports, the data is sourced from The Centre for Humanitarian Data and includes ‘airport’, ‘airfield’, ‘airstrip’. Finally for ports, the data is received from The Centre for Humanitarian Data. These point data are intersected with the provincial boundaries and then the data of flood-prone areas in Turkey in Arcgis 10.7 (Figure 37).

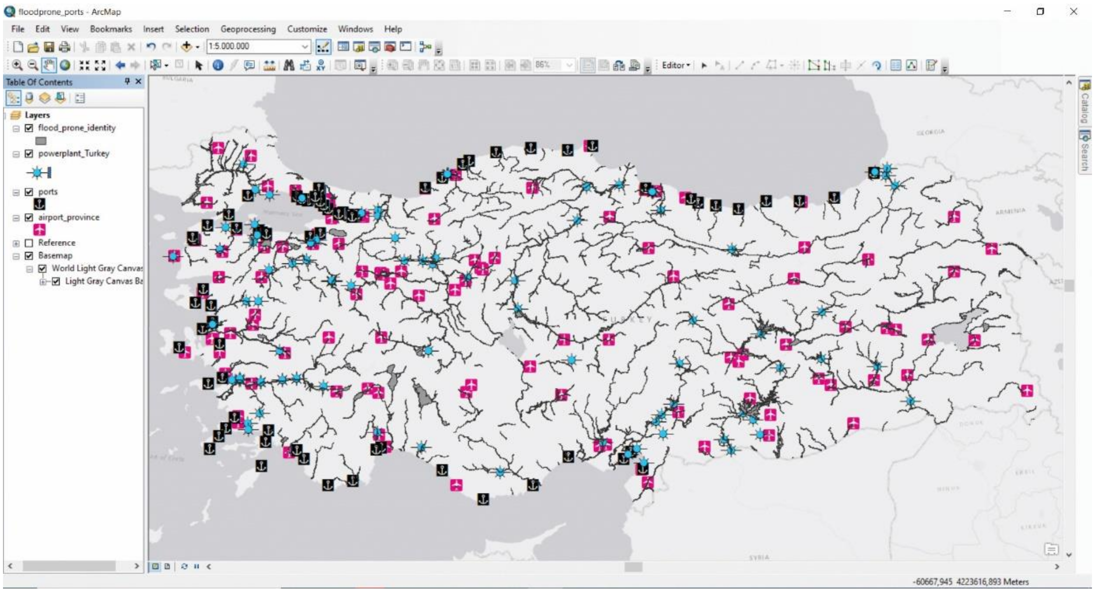

Figure 37: Intersecting Airports, Ports, and Power Plants with Flood Prone Areas in ArcGis 10.7

The measure of power plants, airports, and ports in the flood-prone area is transformed into a rate based on the total number of these facilities in the province. The indicator of power plants, airports, and ports in flood-prone area is measured by dividing the number of power plants, airports, and ports in the flood prone area by the the total number of these facilities in the corresponding province, then multiplying by 100.

$$\textit{Power Plants, Airports, and Ports in Flood-Prone Area} = \frac{\#\ of\ those\ exposed\ to\ flooding}{Total\ number\ of\ these\ facilities} * 100$$

- **Hospitals in flood-prone area:** This indicator shows the total number of hospitals in the province that would be exposed to flooding in the event of a 1 in100 year fluvial flood. Potential flood-prone area extent is sourced from European Environment Agency. It represents the area that is flooded once every 100 years, covering the river channel, active floodplain where flooding still occurs, and former floodplain where flooding is restricted due to flood protection. The data for hospitals is sourced from Openstreetmap (2021) and they are intersected with the provincial boundaries and then the data of flood-prone areas in Turkey in Arcgis 10.7 (Figure 38).

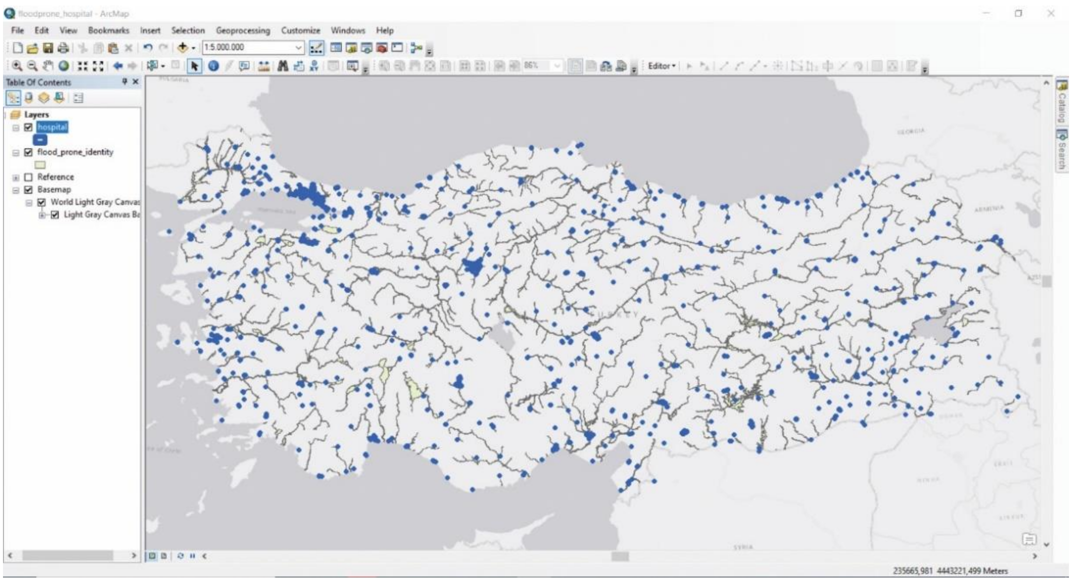

Figure 38: Intersecting Hospitals with Flood Prone Areas in ArcGis 10.7

The measure of hospitals in flood-prone area is transformed into a rate based on the total number of hospitals in the province. The indicator of hospitals in flood-prone area is measured by dividing the number of hospitals in flood-prone area by the total number of hospitals in the corresponding province, then multiplying by 100.

$$\text{Hospitals in Flood-Prone Area} = \frac{Number\ of\ hospitals\ exposed\ to\ flooding}{Total\ number\ of\ hospitals} * 100$$

- **Share of low-quality houses:** This indicator shows the share of households having problems with the quality of dwellings in the total number of households in the province, which is sourced from TurkStat Well-being Index.

- **Flood control zone per flood-prone area:** This indicator represents the flood-control zone per 1 hectare of flood-prone area. Potential flood-prone area extent was sourced from European Environment Agency. It represents the area that is flooded once every 100 years, covering the river channel, active floodplain where flooding still occurs, and former floodplain where flooding is restricted due to flood protection. The data for flood control zone is obtained from The General Directorate of State Hydraulic Works. This indicator is computed by dividing the area of flood control zone by flood-prone area in the related province.

$$\text{Flood control zone per flood prone area} = \frac{Flood\ control\ zone\ (ha)}{Flood - prone\ area\ (ha)}$$

- **Access to railroad:** Access to railroad is represented by the data of total railroad lengths per 100 km^2 of provincial land area. The data is obtained from Openstreetmap (2021) and ‘funicular’, ‘light_rail’, ‘rail’, ‘subway’, and ‘tram’ classes are selected from the data set. The indicator is measured by dividing the length of total railroad in the province by the province’s total land area and then the result is multiplied by 100.

$$\text{Access to Railroad} = \frac{Total\ railroad\ length\ (km)}{Total\ land\ area\ (km2\ )} * 100$$

- **Access to airports and ports:** This indicator is represented by the data of the number of airports and ports 100 km^2 of provincial land area. For airports, the data is sourced from The Centre for Humanitarian Data and includes ‘airport’, ‘airfield’, ‘airstrip’. For ports, the data is received from The Centre for Humanitarian Data. The indicator is measured by dividing the number of airports and ports in the province by the total land area of the province and then the result is multiplied by 100.

$$\text{Access to Airports and Ports} = \frac{\#\ of\ airports\ and\ ports}{Total\ land\ area\ (km2\ )} * 100$$

- **Access to energy:** This indicator shows the installed power per 10,000 population. The data for installed power is sourced from the Republic of Turkey Energy Market Regulatory Authority (2018) and population data from TurkStat (2018). The indicator is measured by dividing the installed power in the province by the province’s total population and then the result is multiplied by 10,000.

$$\text{Access to energy} = \frac{installed\ power\ (MW)}{Total\ population} * 10000$$

To sum up, in this study, heat wave risk, flood risk, drought risk, and forest fire risk are considered in order to develop a climate risk-based framework (Figure 39).

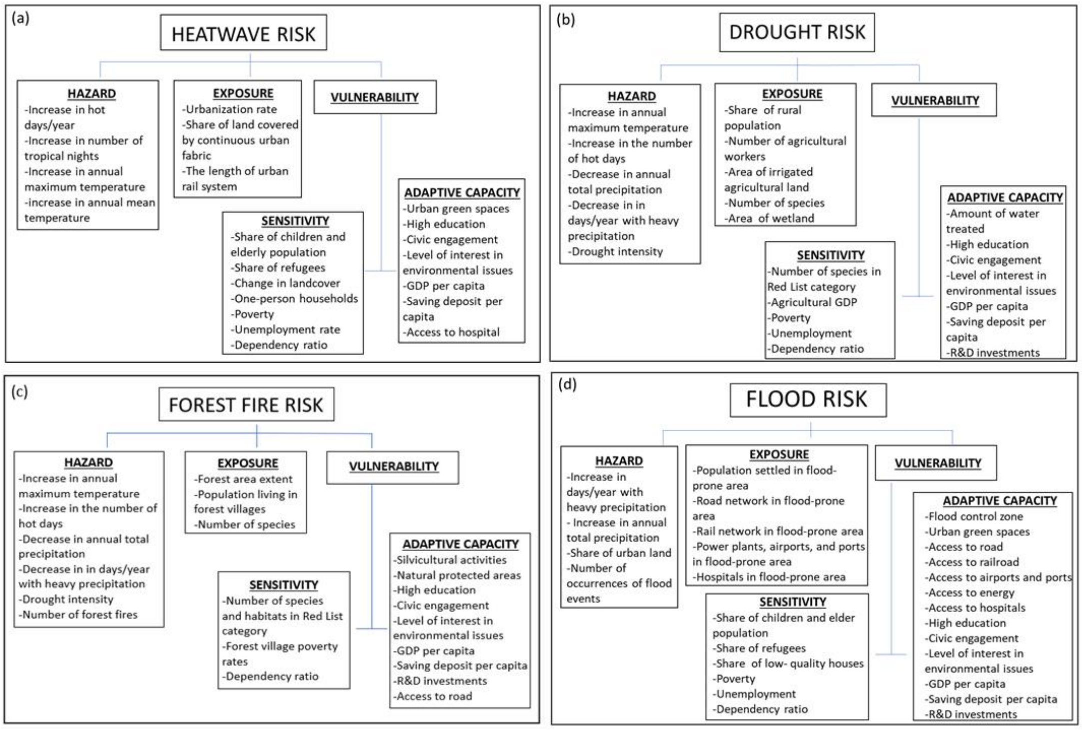

Figure 39: Chosen Indicators for a: heat wave risk, b: drought risk, c: forest fire risk, d: flood risk

4.3. Standardization of Indicators

Collected data is inserted into Excel and SPSS to prepare a database to calculate indices for hazard, exposure, sensitivity, and adaptive capacity. However, the actual value of each data has different units of measurement, e.g., the population density is measured in population per km^2, precipitation in millimeters, area in km^2. Therefore, it is necessary to converting all the values into dimensionless units in order to aggregate them. Standardization, in this vein, is widely accepted as an important step before proceeding to an aggregation process to avoid potential errors that may stem from the aggregation of variables with different means (Jones and Andrey 2007). Z-score transformation is conducted in SPSS as a standardization method to make the variable scale-free.

4.4. Dimension Reduction

The quantitative assessment of climate risk is vital to deal with climate hazard consequences. Climate risk assessment is investigated by incorporating the dimensions of hazard, exposure, and vulnerability (sensitivity and adaptive capacity) since quantifying climate risk necessitates hazard, exposure, and vulnerability information according to the risk-based framework of IPCC (2014b). Indicators are validated through multivariate analysis (correlation and principal components analysis). Multicollinearity is removed to avoid double counting when these indicators are aggregated, which makes the dataset suitable for calculating a composite risk index.

PCA is a method used to reduce a large set of factors to a smaller set so as to cover as much variation as possible (Nardo et al., 2005). It is a dimension reduction technique that creates components to interpret a relatively large series of data in a smaller number of components, which, in this study, allows the identification of the individual risk components (hazard, exposure, adaptive capacity, and sensitivity) within an overall risk index. Therefore, PCA/FA helps reduce the number of dimensions without much loss of information. In this context, a combination of PCA and Factor Analysis (FA) is used for dimension reduction and for weighing the selected variables of hazard, exposure, sensitivity, and adaptive capacity separately, which signal the contribution of each indicator to the index value.

In order to identify whether variables are suitable for factor analysis, The Kaiser-Meyer-Olkin (KMO) criteria is employed. The Kaiser-Meyer-Olkin measure of sampling adequacy is a statistic for determining whether variables can be explained by factors (Kaiser, 1974). A KMO value should be greater than or equal to 0.50 to proceed with factor analysis (Kaiser, 1974; Hair et al., 2006; Field, 2009). Moreover, Bartlett's test of sphericity is conducted to understand if the variables are correlated. If they are not correlated, it should not be proceeded with factor analysis.

The decision of how many factors to retain is an important procedure in PCA/Factor Analysis. Selecting factors with eigenvalues greater than 1 (Kaiser, 1960) is the most common strategy when deciding the number of factors extracted. According to the Kaiser criterion, each eigenvalue greater than 1 is interpreted as representing a factor, which may cause identifying too many factors (Cliff, 1988; Fabrigar et al., 1999); thus, it is poor in accuracy (Velicer et al., 2000). Another approach is to create a scree plot when determining the number of factors retained (Cattell, 1966). It is a graphical method where the factors are plotted in decreasing order of their eigenvalues. However, in case of an absence of a clear break or of multiple breaks, a subjective judgment is required since it is hard to detect the abrupt transition from the point where the curve starts to level off (Velicer et al., 2000, Ruscio and Roche, 2012). Another factor extraction strategy is parallel analysis, which was developed by Horn (1965) and recommended by Franklin et al. (1995) and Peres-Neto et al. (2005). In the context of parallel analysis, the average eigenvalues for randomly generated data sets are computed. The factor is retained if the associated eigenvalue exceeds the eigenvalue of the random data. Parallel analysis is accepted to have higher accuracy when compared to other methods in terms of deciding the number of factors extracted (Fabrigar et al., 1999; Velicer et al., 2000).

Since the Kaiser criterion tends to overextract factors, and scree test may suffer from subjectivity when deciding the actual cut-off point (Ruscio and Roche, 2012), parallel analysis was used for determining the number of components to retain from PCA using the Monte Carlo Simulation Technique through a SPSS syntax written by O'Connor (2000). Instead of using means of simulated eigenvalues, upper percentiles is used in order to avoid Type I error. Therefore, factors are retained as long as the eigenvalue of the observed data is greater than the 95th of the distribution of eigenvalues derived from the random data.

After determining the appropriate number of factors extracted in the analysis, it is necessary to interpret the results. According to Thompson (1984) unrotated factors actually give a misleading account of the true nature of the factors, which can be resolved by using factor rotation. In order to enhance the interpretability of the factors retained, factor rotation is employed. Factor rotation is a technique to rotate the coordinate system in its origin, which small factor loadings would be minimized, and large factor loadings would be maximized (Field, 2013) by redistributing the variance throughout the factors. The rationale behind the rotation is to have variables loaded especially on one of the extracted factors, thus, to get a "simpler structure" (OECD, 2008, p.90). Orthogonal rotation and oblique rotation are two types of factor rotation. In orthogonal rotation, angles of the retained factors are orthogonal (90-degree angle) to each other; thus, they are uncorrelated and easy to interpret. In oblique rotation, there is greater or less than the 90-degree angle between the new axes; therefore, the retained factors may still be correlated. The rotation method used in this study is decided based on the approach of Tabachnick and Fidell (2014). They suggest examining the loadings in the component correlation matrix obtained by oblique rotation. If the correlations are below 0.32, then the rotation method should be orthogonal (Tabachnick and Fidell, 2014). In this study, varimax as a type of orthogonal rotation was used in order to reduce the number of individual variables that have a high loading on the same factor (Kieffer, 1998; OECD, 2008), following the approach of Tabachnick and Fidell (2014).

During PCA/FA, the criteria below are followed. In light of these criteria, the structure of Factor Analysis is shown in Figure 40.

- If the determinant of the correlation matrix exceeds 0.00001, then there is no multicollinearity in the data (Field, 2013). When it is below 0.00001, the correlation matrix is examined to determine whether there is any pair with bivariate correlation scores above ±0.9, and one of a pair of items is removed, if any (Green et al., 1988; Dohoo et al., 1997).
- A minimum acceptable score for Kaiser-Meyer-Olkin Measure of Sampling Adequacy test is accepted as 0.5 (Kaiser, 1974; Hair et al., 2006; Field, 2009). A KMO value exceeding 0.5 and a significance level for the Bartlett's test below 0.05 indicate that there is a substantial correlation in the data.
- Minimum threshold for total variance explained is 0.30 in one-factor solutions, and 0.4 in multi-factor models (Büyüköztürk, 2007; Çokluk et al., 2016).

- When determining the number of factors retained, the Kaiser criterion is used in one-factor solutions, and parallel analysis is conducted for multi-factor solutions based on 95th percentile criteria (Glorfeld, 1995).
- Factor loadings below 0.32 are suppressed because 0.32 is identified as the minimum loading of an item (Tabachnick and Fidell, 2014). If all factor loadings of any variable are below 0.32, then the variable is removed and PCA is re-run.

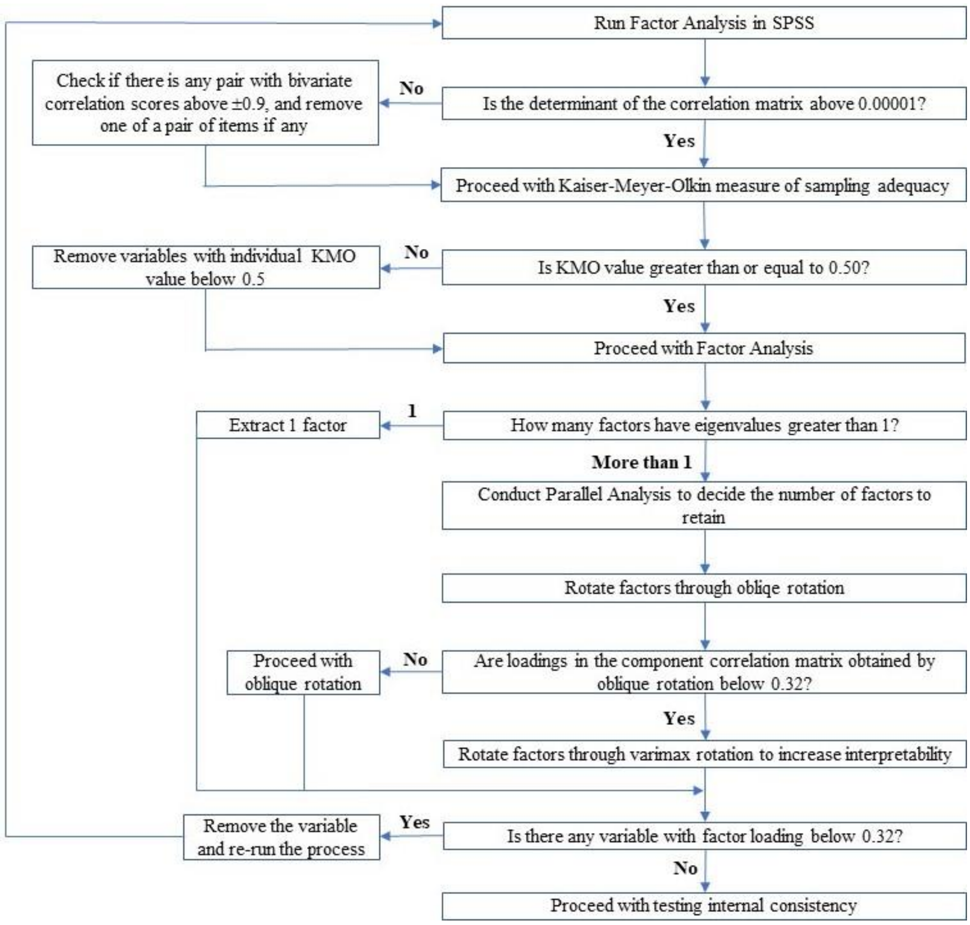

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Figure 40: The Structure of Factor Analysis

4.5. Internal Consistency Check

Before aggregating variables, internal consistency is tested through Cronbach's Alpha in order to understand if the total list of the variables measures the respective risk dimension (hazard, exposure, sensitivity, and adaptive capacity). Cronbach's alpha (Cronbach, 1951) is widely used measure when testing the internal consistency of items in a model (Boscarino et al., 2004; Nardo et al., 2005; Chmielewski & Watson, 2009). Internal consistency can vary between zero and one, in which the closer the Cronbach alpha value to one, the more variables measure the same latent phenomenon.

For Cronbach's alpha coefficient, 0.6 is determined as an acceptable threshold for reliability (Robinson et al., 1991; Bagozzi and Yi, 1988; Wim et al., 2008; Van Griethuijsen et al., 2015; Ursachi et al., 2015), meaning that consistency of the indicator variables is at a satisfactory level. Raubenheimer (2004) suggests that the minimum number of items per factor is three in usual case but could be as little as two. Therefore, if the number of items does not allow for more than one factor to be generated, Cronbach's alpha is calculated before PCA/FA. The structure of Cronbach's Alpha is shown in Figure 41.

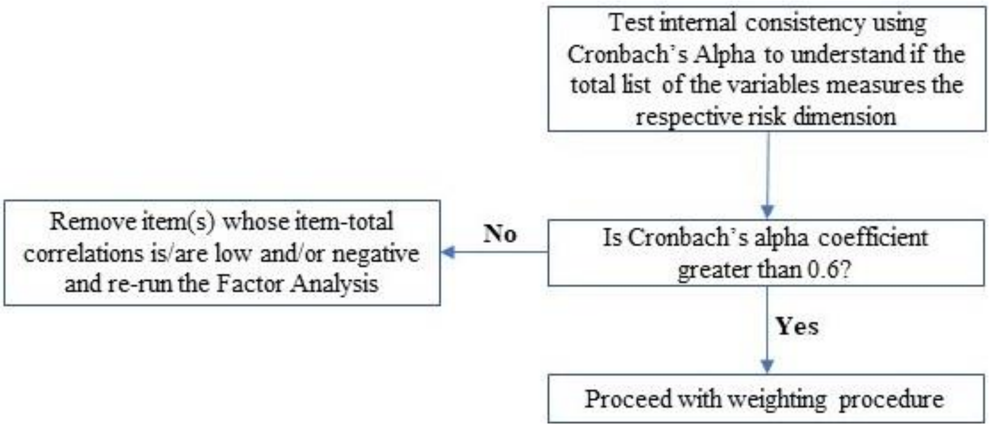

Figure 41: The Structure of Cronbach's Alpha

4.6. Weighting

In the next step, weights are assigned. Considering that some of the indicators may have a greater influence on climate change vulnerability and risk than others, and also double counting of indicators may happen, equal weighting is deemed to be inappropriate to follow.

Weights are assigned to the individual variables based on factor loadings and the variance of the variable explained by the respective factor. This weighting technique developed by Nicoletti et al. (2000) is widely used by scholars when constructing composite index (Nardo et al., 2005; Saitluanga, 2017; Seidel et al., 2019). In this technique, indicators with the highest factors loading are grouped into intermediate composite indicators. The square of rotated factor loadings (the proportion of the total unit variance of the variable explained by the corresponding factor) is calculated and scaled to the eigenvalue of the corresponding factor, which constitutes the weights of individual indicators in the factor. Moreover, the weight of the corresponding factor is calculated by dividing the eigenvalue of the corresponding factor by the sum of eigenvalues of the total number of factors retained. The final weight is obtained by geometric aggregation and then scaling the result to unity sum to preserve comparability. It is important to highlight that the weights do not represent the relative importance of the factors; however, they are used as an instrument to reduce redundant information.

4.7. Aggregation of Indicators into Risk Index

Risk index representing the degree of risk of each province in Turkey is developed based on a geometric aggregation of weighted factors obtained from PCA/FA. The reason behind arithmetic aggregation is not used is that it leads to full compensability in which low score of an indicator can be fully compensated by high scores of another indicators. Geometric aggregation, on the other hand, implies a partial compensability between the different indicators where indicators with outstanding values have a greater impact on the result (Terzi et al., 2021). A province with low scores on one indicator, therefore, necessitates a much higher score on the others to enhance its performance (Nardo et al., 2005). Moreover, loss of information is lower in geometric aggregation when compared to arithmetic aggregation (Zhou et al., 2006). Therefore, geometric aggregation is in line with the aim of the study since any of the indicators used has a crucial role in the composite index.

Before the aggregation process, z-score values need to be normalized since negative values of z-score values may lead to inaccurate result during geometric aggregation as well as when interpreting and comparing the risk index of the provinces for the final calculation. Therefore, it is necessary to normalize all the z-score values of indicators based on the equations given below to ensure that they are comparable without disrupting the structure of the variables in terms of ranking and correlation. The normalization is performed using min-max normalization within a range of 0.01 to 0.99. The reason why the range between 0 and 1 is not adopted is that the risk formula has an adaptive capacity denominator, and a fraction cannot have a denominator with 0. Moreover, geometric aggregation requires a non-zero positive value to apply (Lung et al., 2013). After normalization, indicator scores thus range between 0.01 and 0.99 as indicated in the equation below, where *Ni* is the normalized value of the z-score value of indicator *i* for the province *j*, *xi* is the z-score value of indicator *i* for province *j*; max and min are the largest and smallest observed values (Jain and Bhandare, 2013; Han et al., 2012).

$$Ni = \frac{xij - min(xij)}{max(xij) - min(xij)} * (x_{newmax} - x_{newmin)+x_{newmin}}$$

After normalization procedure, hazard, exposure, sensitivity, and adaptive capacity indexes are calculated in SPSS using the following mathematical formulas.

HI is the hazard index for province *i*, *h* is the normalized value of the j^{th} indicator at province *i*, *w* is the final weight obtained as mentioned above, and *n* is the number of indicators for the hazard dimension of risk.

$$HI_i = \prod_{j=1}^{n} h_{ij}^{w_j}$$

EI is the exposure index for province *i*, *e* is the normalized value of the j^{th} indicator at province *i*, *w* is the final weight obtained as mentioned above, and *n* is the number of indicators for the exposure dimension of risk.

$$EI_i = \prod_{j=1}^{n} e_{ij}^{w_j}$$

SI is the sensitivity index for province *i*, *s* is the normalized value of the j^th^ indicator at province *i*, *w* is the final weight obtained as mentioned above, and *n* is the number of indicators for the sensitivity dimension of risk.

$$SI_i = \prod_{j=1}^{n} s_{ij}^{w_j}$$

ACI is the adaptive capacity index for province *i*, *ac* is the normalized value of the j^th^ indicator at province *i*, *w* is the final weight obtained as mentioned above, and *n* is the number of indicators for the adaptive capacity dimension of risk.

$$ACI_i = \prod_{j=1}^{n} ac_{ij}^{w_j}$$

VI is the vulnerability index for province *i*, *v* is the normalized value of the j^th^ indicator at province *i*, *w* is the final weight obtained as mentioned above, and *n* is the number of indicators for the adaptive capacity dimension of risk.

$$VI_i = \prod_{j=1}^{n} v_{ij}^{w_j}$$

After calculating and normalizing hazard, exposure, sensitivity, adaptive capacity, and vulnerability index, they are used to obtain the risk index using the following formula (Rana and Routray, 2016; Salam et al., 2021), where R is the risk index for the province *i*, n_h is the number of hazard indicators, n_e is the number of exposure indicators, n_s is the number of sensitivity indicators, and n_{ac} is the number of adaptive capacity indicators.

$$R_i = HI_i * EJ_i * VI_i$$

$$VI_i = \frac{SI_i}{ACI_i}$$

$$R_i = \frac{\sqrt[n_h]{HI_i} * \sqrt[n_e]{EJ_i} * \sqrt[n_s]{SI_i}}{\sqrt[n_{ac}]{ACI_i}}$$

These steps are iterated for each risk determinant (heat wave, drought, forest fire, and flood). These index values are also re-scaled through min-max normalization for representation. These index results are not considered as stand-alone metrics but as tools to compare relative positions of each province and to prioritize the ones with high risk in terms of adaptation strategies and resource allocation.

4.8. Identifying Risk and Vulnerability Profiles of Provinces and Mapping

There are several techniques to classify the index results for graduated symbology. The index results of risk and its components indicate the corresponding profiles of provinces, which are represented using natural breaks classification in ArcGis 10.7 to show the results of this study. Other data classification methods are not preferred for several reasons. First, the equal interval technique divides the range of attribute values into equal-sized subclasses. This technique, for this study, resulted in the data being concentrated mostly in the first two subclasses and failed to distribute the index results to different subclasses. Also, this classification produced some subclasses with few to no values, which did not allow to make proper comparisons between provinces. The second classification technique is quantile classification, in which a sample is divided into equal-sized subclasses. This technique, for this study, led to a misleading resulting map as each subclass contains an equal number of features and provinces with widely different index values fell into the same subclass, which was totally undesired for the purpose of the study. Another classification scheme is standard deviation classification which indicate how much the data varies from the mean. Although this technique is in line with the purpose of the study, it necessitates the data to be normally distributed. Therefore, it could not be used for the spatial representation of the index results.

As mentioned above, natural breaks classification is the classification technique used in this assessment. This classification is a data-specific classification and groups similar values in the same class while maximizing the differences between subclasses. Due to being data-specific, a common standard for the classification of all components of risk index results could not be achieved, which is also the case for quintile and standard deviation classification. Since a well-classified index result of one risk component has higher priority over the common standard, this classification is preferred for the spatial representation of the index results. Table 15 shows the classification and related legend.

Table 15: The Classification of the Index Results of Risk Components

Level		Very Low	Low	Moderate	High	Very High
Heat Wave	Hazard					
	Exposure					
	Sensitivity					
	Adaptive Capacity					
	Vulnerability					
	Risk					
Drought	Hazard					
	Exposure					
	Sensitivity					
	Adaptive Capacity					
	Vulnerability					
	Risk					
Forest Fire	Hazard					
	Exposure					
	Sensitivity					
	Adaptive Capacity					
	Vulnerability					
	Risk					
Flood	Hazard					
	Exposure					
	Sensitivity					
	Adaptive Capacity					
	Vulnerability					
	Risk					

After classifying the index results of each risk type, overall climate index is obtained through which the individual risk level classification that is divided to five categories from very low to very high is given a score according to a 5-point scale, as it is indicated in Table 16. The synthesis is obtained by summing the corresponding risk scores of the provinces. When considering the four risk types, a province can have a minimum of 4 and a maximum of 20 points.

Table 16: Individual Risk Levels and Associated Scores

Risk Level	**Very Low**	**Low**	**Moderate**	**High**	**Very High**
Heat Wave	1	2	3	4	5
Drought	1	2	3	4	5
Forest Fire	1	2	3	4	5
Flood	1	2	3	4	5
Overall Climate Risk	4	8	12	16	20

Overall climate risk scores are then classified in 5 classes that include the provinces with very low, low, moderate, high, and very high overall climate risk levels based on standard deviation classification technique in ArcGis as the data is normally distributed (Figure 42), and the results are mapped.

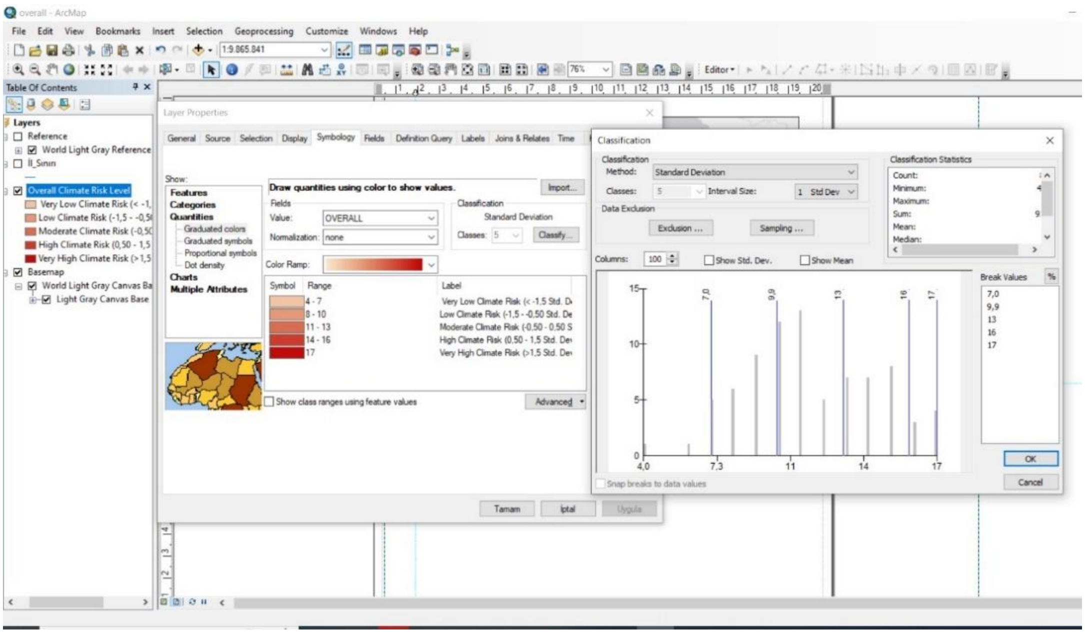

Figure 42: Data Classification and Mapping in ArcGis

CHAPTER 5

CLIMATE CHANGE RISK AND VULNERABILITY ANALYSIS

5.1. Introduction

This chapter focuses on analyzing climate-related indicators of hazard component and the climate risk and vulnerability in Turkey at the provincial level based on the research method mentioned in Chapter 4. In this vein, the first part of the chapter covers the analysis of climate-related data of hazard, which is elaborated separately from the rest of the determinants of risk (exposure, sensitivity, and adaptive capacity) because hazard indicators require further analysis of meteorological data.

The second part of this chapter focuses on analyzing heat wave risk, drought risk, forest fire risk, and flood risk separately based on the interaction between risk determinants, including hazard, exposure, sensitivity, and adaptive capacity, and vulnerability as a function of sensitivity and adaptive capacity.

5.2. Analysis Of Meteorological Parameters in The Context of Climate Change Hazard

Hazard indicators, in this thesis, cover indicators of meteorological parameters, indicators that address frequency and intensity of hazard, and indicators that exacerbate hazard (Table 17). Hazard indicators that require analyzing meteorological parameters differentiate from the rest of the components of risk in a way that they necessitate further analysis of meteorological data; therefore, it is deemed appropriate to address them separately from the rest of the components of risk. These indicators emphasized in the context of this part are increase in annual mean temperature, annual maximum temperature, the number of hot days, the number of tropical nights, as well as decrease/increase in annual total precipitation and the number of days with heavy precipitation. The rest of the hazard indicators are already emphasized in the methods chapter of the thesis.

Table 17: Hazard Indicators Used for Risk Assessment

Categorization of Hazard Indicators	Hazard Indicators	Heat Wave Hazard	Drought Hazard	Forest Fire Hazard	Flood Hazard
Meteorological parameters	Increase in annual mean temperature	✓			
	Increase in annual maximum temperature	✓	✓	✓	
	Increase in hot days	✓	✓	✓	
	Increase in tropical nights	✓			
	Decrease in annual total precipitation		✓	✓	
	Increase in annual total precipitation				✓
	Increase in days with heavy precipitation				✓
	Decrease in days with heavy precipitation		✓	✓	
Frequency and intensity	Number of forest fires			✓	
	Number of flood events				✓
	Drought conditions		✓	✓	
Exacerbating factors	Share of urban land				✓

Source: Prepared by the author

Although temperature and precipitation data for provinces were started to be recorded by the Turkish Meteorological Organization in 1929, these data for some provinces were recorded after the 1970s. In addition, there are some provinces that had abrupt breaks of data in certain years. Since this lack of data would mislead the research to present changes in temperature and precipitation, in terms of °C and mm respectively, these data is analyzed using Mann-Kendall Test and Sen's Slope Estimator to find out the overall trend of temperature and precipitation for each of the 81 provinces for the time period, 1971 to 2018. The data were processed using MAKESENS 1.0 software, an Excel macro prepared by Salmi et al. (2002). In this context, the trend is evaluated using the Z and Q_{med} values. While a positive value of Z shows an increasing trend, a negative value of Z indicates a decreasing trend. Q_{med}, on the other hand, shows the magnitude of the trend.

In this vein, increase in annual mean temperature, annual maximum temperature, the number of hot days, the number of tropical nights, as well as decrease/increase in annual total precipitation and the number of days with heavy precipitation are analyzed below.

5.2.1. Increase in Annual Mean Temperature

The increasing temperatures contributes to the increase in heatwave risk (Hübler et al. 2008; Rannow et al. 2010; WHO, 2012; Buscail et al., 2012; Lung et al., 2013; Holsten et al., 2013; Choi, 2018; Hong et al., 2018). Therefore, increase in annual mean temperature is used as one of the indicators of heat wave hazard. Annual mean temperature data for 81 provinces for the time period 1971-2018 is analyzed and the results are shown in Appendix A.

According to the results of annual mean temperature with a 90% confidence level, 77 provinces indicate statistically significant increasing trends with positive Z values; the magnitudes of the significant increasing trends vary between 0.013 °C/year in Balıkesir and 0.059 °C/year in Mersin province (Appendix A, Figure 43). On the other hand, the mean annual temperature shows increasing trends but is not statistically significant in Bitlis, Diyarbakır, and Eskişehir provinces. These four provinces have Z values thar are not significant at the 0.1 significance level; therefore it can be inferred that there is no trend. Moreover, there is no trend for Erzurum province, as its Qmed value is zero. Therefore, for these four provinces, the null hypothesis is accepted.

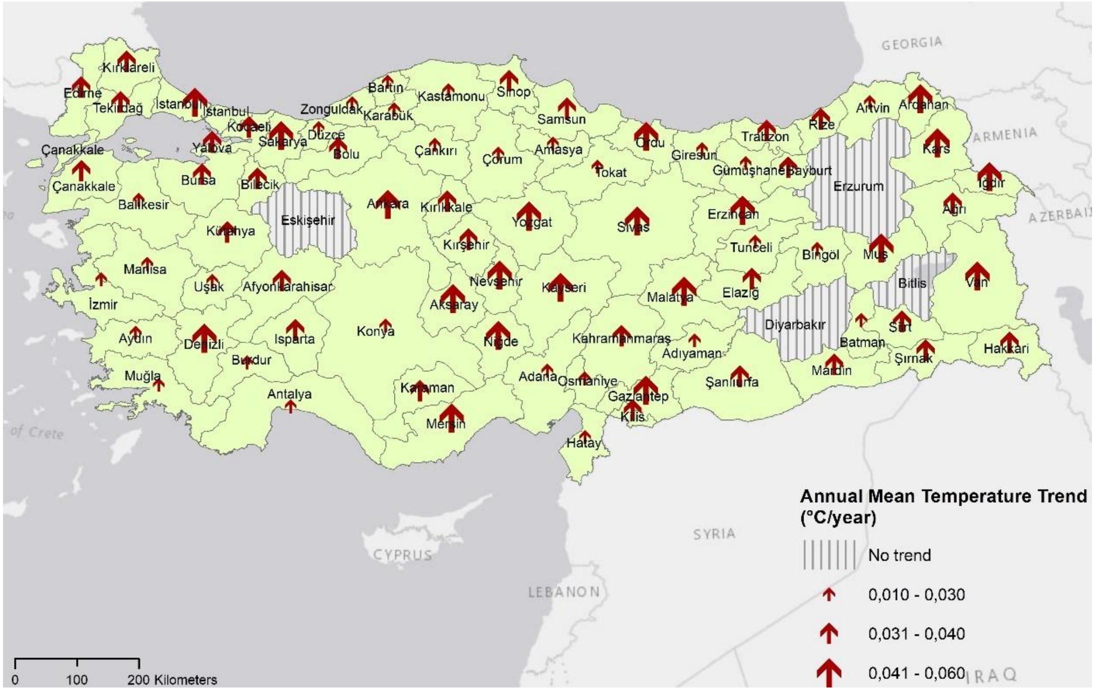

Figure 43: Mann-Kendall Test and Sen's Slope Estimator Results of Mean Annual Temperatures for 81 provinces for the time period, 1971-2018 (natural breaks data classification) (Prepared by the author)

5.2.2. Increase in Annual Maximum Temperature

Increases in temperatures can exacerbate heatwave and drought and can, in turn, increase the danger of forest fires (Westerling and Bryant, 2008; Jones et al., 2008; Girardin et al., 2009; Rannow et al., 2010; Lung et al., 2013; Holsten et al., 2013). Therefore, increase in annual maximum temperature indicator is used for heat wave, drought, and forest fire hazard. In this sense, Appendix B shows the Mann-Kendall Test and Sen's Slope estimator results of annual maximum temperatures for 81 provinces for the time period 1971-2018.

According to the results of annual maximum temperature, 55 provinces indicate statistically significant increasing trends due to positive Z values. There is no trend for Batman province as its Qmed value equals to zero. 22 provinces show increasing trends but are not statistically significant at 0.1 level. Ardahan, Bingöl, and Bitlis, on the other hand, show a non-significant decreasing trend. However, for these 26 provinces with non-significant results, the null hypothesis is accepted.

The values of Sen's slope indicate that the increase of annual maximum temperature is the lowest at 0.025 °C/year in Muş, and the highest at 0.08 °C/year in Mersin province (Appendix B, Figure 44).

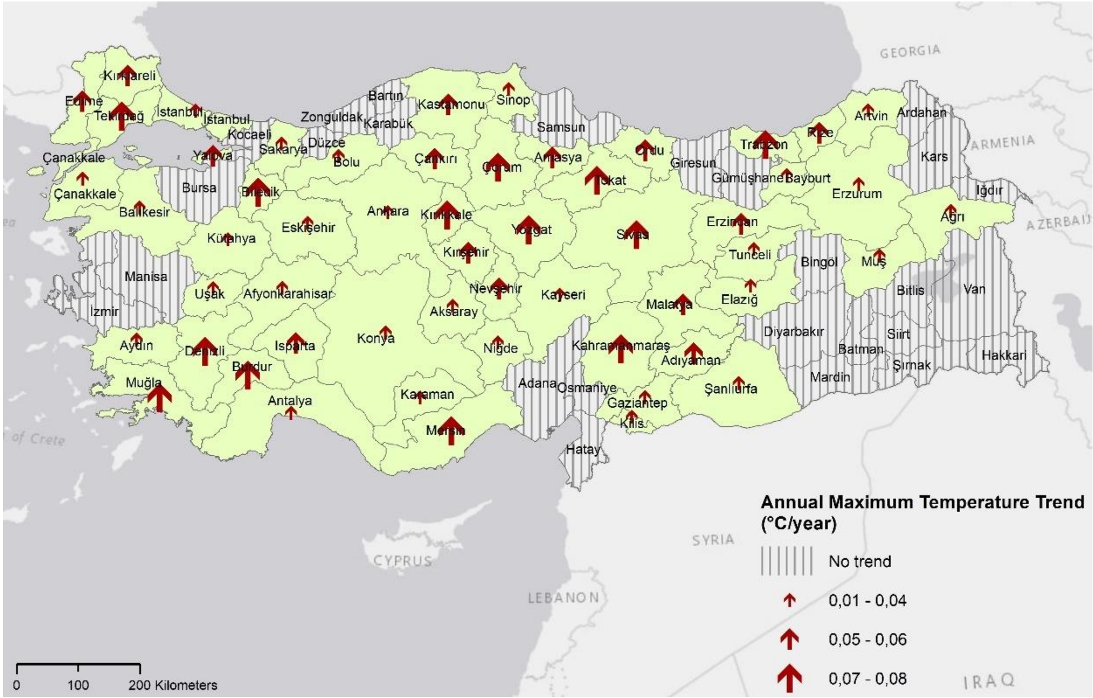

Figure 44: Mann-Kendall Test and Sen's Slope Estimator Results of Annual Maximum Temperatures for 81 provinces for the time period, 1971-2018 (natural breaks data classification) (Prepared by the author)

5.2.3. Increase in Hot Days/Year

Climate change leads to increase in the number of combined tropical nights (minimum temperature above 20 °C) and hot days (maximum temperature above 30 °C), which leads to more frequent extreme heat events (Hübler et al., 2008; Rannow et al., 2010; WHO, 2012; Lung et al., 2013; Holsten et al., 2013). The indicator of increase in number of days per year with maximum temperature greater than 30 °C is used to express heat wave, drought, and forest fire hazards.

Appendix C and Figure 45 illustrate the results of the Mann-Kendall Test and Sen's Slope estimator in terms of hot days with maximum temperature greater than 30 °C for 81 provinces for 1971-2018. The results show that 69 provinces, all of which give statistically significant results at the 0.05 level, and two provinces significant at 0.1 level indicate upward trends in terms of hot days, as the Z values are positive. Of the remaining 10 provinces which do not show statistically significant results, 8 provinces show increasing trend. However, for these 8 provinces, p value is greater than the significance level $\alpha = 0.1$; therefore null hypothesis -there is no trend- is accepted.

While the province with the lowest annual increase in the number of hot days is Sinop with 0.1 days/year, the province with the highest increase in Mersin with 1.56 days/year. Mersin stands out as the province where the most increase is seen in both annual mean, annual maximum temperature, and hot days/year with maximum temperature greater than 30 °C indicators.

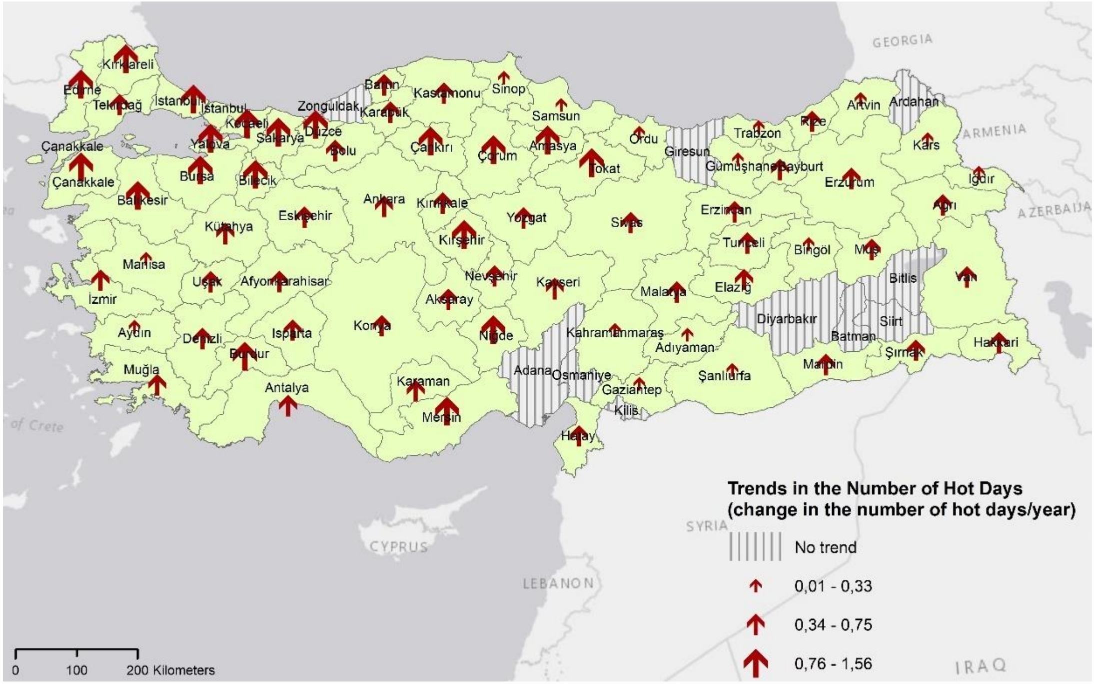

Figure 45: Mann-Kendall Test and Sen's Slope Estimator Results of the Number of Hot Days per year above 30 °C for 81 provinces for the time period, 1971-2018 (natural breaks data classification) (Prepared by the author)

5.2.4. Increase in Number of Tropical Nights

Tropical night is used to describe days when the minimum temperature does not go below 20 °C during the nighttime. Warmer nights are becoming more common as the Earth's climate warms, which leads to more frequent and intensive heat waves (Hübler et al., 2008; Rannow et al., 2010; WHO, 2012; Lung et al., 2013; Holsten et al., 2013). In particular for older or sick people, it is more challenging for the human body to cool down during these warmer nights. As a result, an increase in tropical nights may result in an increase in mortality. In this context, the indicator of increase in number of tropical days where minimum temperature is greater than 20 °C is used for heat wave hazard.

Appendix D and Figure 46 indicate the results of the Mann-Kendall Test and Sen's Slope estimator in terms of tropical nights where minimum temperature is greater than 20 °C for 81 provinces for 1971-2018 period. According to the results, there are 58 provinces which show upward trends in terms of tropical nights results that is statistically significant at the 0.1 level. Four provinces show increasing trends and two provinces have decreasing trends, but not statistically significant at 0.1 level. Moreover, the remaining 17 provinces shows no trend with their Q values equal to zero; thus, null hypothesis of no trend is accepted for 23 provinces in total.

While the province with the lowest annual increase in the number of tropical nights is Çankırı with 0.022 days/year, the province with the highest increase is Denizli with 1.39 days/year.

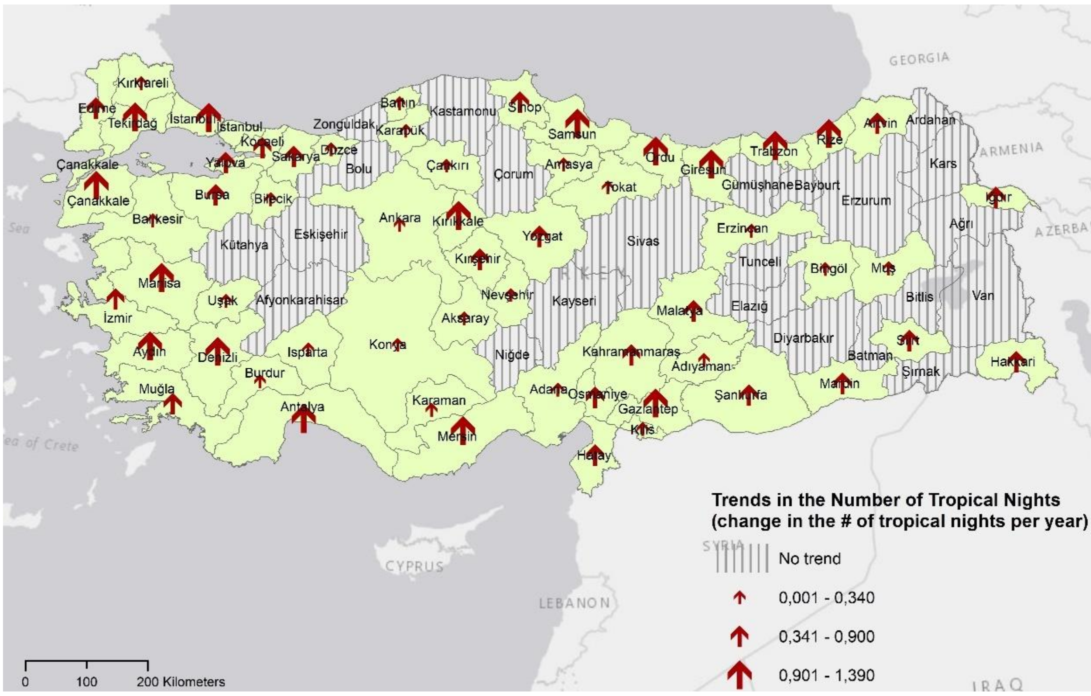

Figure 46: Mann-Kendall Test and Sen’s Slope Estimator Results of the Number of Tropical Nights per year (Tmin>20 °C) for 81 provinces for the time period 1971-2018 (natural breaks data classification) (Prepared by the author)

5.2.5. Decrease/Increase in Annual Total Precipitation

Climate change can affect the intensity and frequency of precipitation. Changes in precipitation patterns lead to substantial irregular precipitation pattern, which increases drought risk (Blanka et al., 2013). This also result in increase in the danger of forest fires (Westerling and Bryant, 2008; Girardin et al., 2009; Rannow et al., 2010; Lung et al., 2013; Holsten et al., 2013). According to many studies, decline in summer precipitation contributes to drought and wildfires (Holden et al., 2007; Littell et al., 2009; Abatzoglou and Kolden., 2013; Jolly et al., 2015; Holden et al., 2018). In this context, decrease in summer precipitation is aimed to be used for drought and forest fire hazard. However, trends for 79 provinces are not significant at the 0.05 level; thus, decrease in rainy days in summer season is intended to be selected as an indicator. Like the indicator of decrease in summer precipitation, the indicator of decrease in rainy days in summer season indicates non-significant results for the majority of the provinces. Consequently, the indicator of decrease in annual total precipitation is used to indicate drought and forest fire hazard. For flood hazard, on the other hand, increase in precipitation plays a significant role (Rannow et al., 2010; Lung et al., 2013; Holsten et al., 2013, Davenport et al., 2021). Increase in total precipitation is used as an indicator of flood hazard. In this vein, Qmed values in the table refer to increase in total precipitation to be used for flood hazard; therefore, they are multiplied by -1 to obtain decrease in total precipitation to be used for drought and forest fire hazard.

Appendix E and Figure 47 show the results of the Mann-Kendall Test and Sen's Slope estimator for 81 provinces for the time period 1971-2018. According to the results with a 90% confidence level, 10 provinces that show statistically significant results have an upward trend, as the Z values are positive in terms of total annual precipitation. Malatya, on the other hand, has a statistically significant decreasing trend in terms of annual total precipitation. The magnitude of the significant trends of annual total precipitation varies between -1.39 and 4.83 mm/year in Malatya and Rize, respectively. Of the remaining 70 provinces which do not show statistically significant results, 70% have an upward trend. However, for these 70 provinces, Z values are non-significant at 0.1 level; therefore null hypothesis is accepted. This is not a surprising result since there are similar results in studies that conduct trend analysis of precipitation for different regions of Turkey (Ercan and Yüce, 2017; Çeribaşı, 2018; Dalkılıç, 2019; Terzi and İlker, 2021).

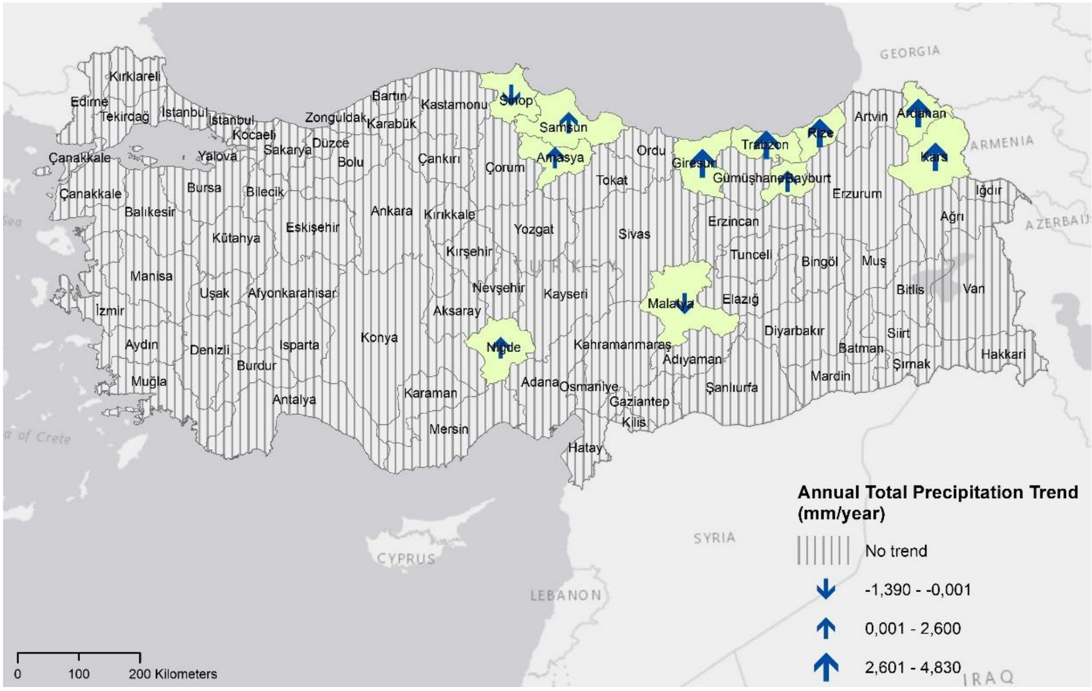

Figure 47: Mann-Kendall Test and Sen’s Slope Estimator Results of Annual Total Precipitation for 81 provinces for the time period, 1971-2018 (natural breaks data classification) (Prepared by the author)

5.2.6. Increase in Days/Year with Heavy Precipitation

Climate change increase the intensity and frequency of precipitation extremes, and extreme precipitation may increase the intensity and frequency of flooding (Schiermeier, 2011; IPCC, 2012; Zolina, 2012; Swain et al., 2020; Tabari, 2020). Therefore, the number of days per year with very heavy precipitation greater than 20 mm is aimed to be used to represent exposure to flood; however, the data is not available in Turkish Meteorological Service. In this sense, increase in days/year with heavy precipitation, where the rain rate is greater than 10 mm have to be used as the indicator for flood hazard. The number of days per year with heavy precipitation is a globally recognized and standardized climate indicator. Rain rate over 10 mm indicates heavy precipitation days according to the European Union's Earth observation programme Copernicus (Copernicus, n.d.).

Trend for extreme precipitation where rain range is greater than 10 mm was analyzed using Mann-Kendall Test and Sen’s Slope estimator, as it is shown in Appendix F and Figure 48. According to the results, 17 provinces show statistically significant increasing trend with positive Z values at the 0.1 significance level. Mardin, on the other hand, indicates a statistically significant decreasing trend. The magnitudes of the significant increasing trends vary between -0.12 days/year in Mardin and 0.21 days/year in Trabzon province.

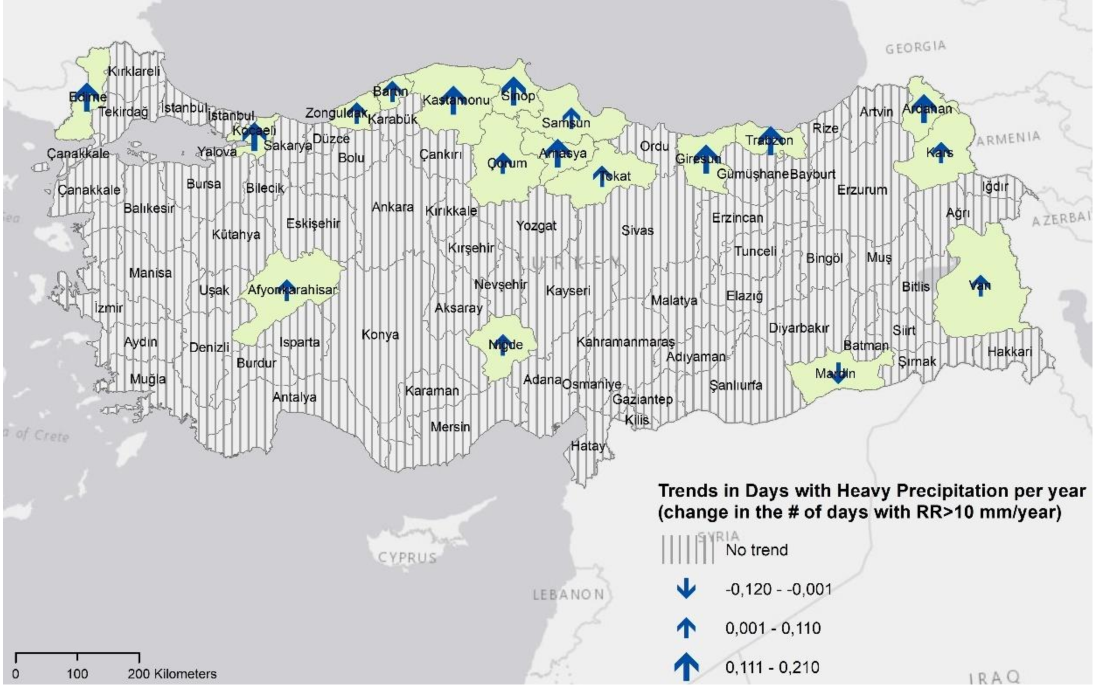

Figure 48: Mann-Kendall Test and Sen’s Slope Estimator Results of Heavy Precipitation (RR>50 mm) for 81 provinces for the time period, 1971-2018 (natural breaks data classification) (Prepared by the author)

The results for the remaining 63 provinces indicate no trend not only because p values are greater than the significance level of 0.1, but also because the majority of them have Q values equal to zero. In this sense, the null hypothesis -there is no trend- is accepted for these 63 provinces.

5.3. Risk and Vulnerability Analysis

This part includes the climate risk and vulnerability analysis in Turkey at the provincial level based on the research method mentioned in Chapter 4. Adopting the IPCC 2014 framework, the analysis is conducted separately for heat wave risk, drought risk, forest fire risk and flood risk by considering the interaction between risk determinants, including hazard, exposure, sensitivity, adaptive capacity, and vulnerability as a function of sensitivity and adaptive capacity.

The steps for the climate risk and vulnerability covers calculating item-total statistics, the KMO and Bartlett's test score, correlation matrix, total variance explained, parallel analysis (in case of multiple possible factors), (rotated) component matrix, internal reliability, factor loadings of indicators based on principal components, weights for the indicators, which is followed choropleth mapping the index of the individual risk determinant using ArcGis software through natural break classification. The index for the corresponding risk type is calculated using the risk formula explained in Chapter 4 and reflected in a choropleth map using the natural break classification. These steps are repeated for each risk type and its related risk determinants. As the final step, overall climate risk is assessed.

5.3.1. Heat Wave Risk

Heat wave risk is one of the climate-related risks addressed in this study. Heat wave risk is considered as the product of the impacts from heat wave hazard and the probability that it occurs. The impact of a heat wave is affected by vulnerability and exposure to flood. In this study, (1) the heat wave hazard is considered as a latent damaging physical event for human population and critical infrastructure; (2)

exposure refers to the presence of human population and critical infrastructure in places and settings that could be adversely affected by heat wave; (3) heat wave vulnerability is the function of sensitivity and adaptive capacity of population and critical infrastructure to the heat wave. To compute heat wave risk, there are 21 indicators in total used under the four components of risk (Figure 49).

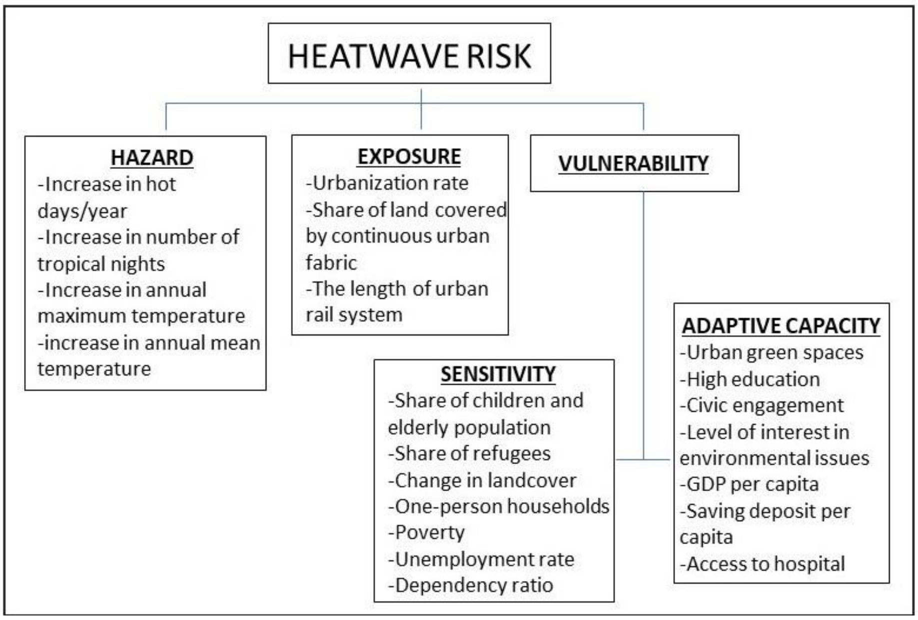

Figure 49: Indicators Scheme for Heat Wave Risk

Heat wave risk index is prepared according to the research method mentioned in the previous chapter. In this vein, heat wave hazard, heat wave exposure, heat wave sensitivity, and heat wave adaptive capacity sub-indices are generated and aggregated to obtain heat wave risk index.

5.3.1.1. Heat Wave Hazard

Four indicators are selected to represent hazard dimension of heat wave risk: increase in annual maximum temperature (TEMPER_MAX), increase in the number of hot days where Tmax>30°C in a year (HOTDAYS), increase in the number of tropical nights where TN>20°C (TROPICAL_NIGHTS), and increase in annual mean temperature (TEMPER_MEAN). First, as it is indicated in Table 18, Cronbach's alpha is calculated for these four variables before the PCA/FA since the number of items does not allow more than one factor to be generated (Raubenheimer, 2004).

Table 18: The Internal Reliability

Reliability Statistics

Cronbach's Alpha	N of Items
0,548	4

Since 0.55 is lower than 0.6 which is an acceptable threshold for reliability (Robinson et al., 1991; Bagozzi and Yi, 1988; Wim et al., 2008; Van Griethuijsen et al., 2015; Ursachi et al., 2015), item-total statistics are examined (Table 19). TROPICAL_NIGHTS is removed from the indicator list because Cronbach's alpha would increase to 0.62 if this item was deleted.

Table 19: Item-Total Statistics

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
HOTDAYS	0,0000000	4,189	0,391	0,426
TEMPER MAX	0,0000000	4,039	0,436	0,386
TEMPER MEAN	0,0000000	4,272	0,368	0,447
TROPICAL NIGHTS	0,0000000	5,083	0,157	0,615

Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) measures how strongly the variables being tested correlate. Raw data becomes suitable for conducting a factor analysis if the KMO is greater than or equals to 0.50 (Kaiser, 1974; Hair et al., 2006; Field, 2009). As indicated in Table 20, KMO value for these three variables is 0.58, which is miserable but still valid to proceed with PCA/FA (Kaiser, 1974; Hair et al., 2006).

Table 20: The KMO and Bartlett's Test Score

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,579
Bartlett's Test of Sphericity	Approx. Chi-Square	34,282
	df	3
	Sig.	0,000

According to Table 21, there is a weak positive correlation between in annual mean temperature. The number of hot days, on the other hand, have a moderate uphill relation with annual maximum temperatures. Multicollinearity exists when the variables are highly correlated. Since the determinant is greater than 0.0001 (Field, 2000), then there is no multicollinearity and variables can be used in PCA/FA.

Table 21: Correlation Matrix

Correlation Matrix[a]

		HOTDAYS	TEMPER_MAX	TEMPER_MEAN
Correlation	HOTDAYS	1,000	0,547	0,253
	TEMPER_MAX	0,547	1,000	0,241
	TEMPER_MEAN	0,253	0,241	1,000

a. Determinant = 0,645

According to the Kaiser criterion, one factor needs to be extracted. This factor explains 57.25% of the total variance (Table 22), which exceed the minimum threshold of 30% in one factor solutions (Büyüköztürk, 2007; Çokluk et al., 2016). Therefore, selected indicators represent hazard factor.

Table 22: Total Variance Explained

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1,718	57,253	57,253	1,718	57,253	57,253
2	0,830	27,667	84,920			
3	0,452	15,080	100,000			

Extraction Method: Principal Component Analysis.

Table 23 indicates the variable loadings on exposure factor extracted. When the absolute value of the loading is high, the factor contributes more to the variable. The results indicate that all the indicators make statistically significant contributions to the hazard factor, with loads higher than 0.32 (Tabachnick and Fidell, 2014).

Table 23: The Components and Their Respective Items

Component Matrix[a]	Component 1
HOTDAYS	0,836
TEMPER_MAX	0,831
TEMPER_MEAN	0,574

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Weights are assigned according to the approach used by Nicoletti et al. (2000). In this context, Table 24 shows the factor loadings, and squared factor loadings scaled to unity sum, which are used to compute weights.

Table 24: Factor Loadings of Hazard Indicators

Factor Loading		Squared Factor Loading (scaled to unity sum)
	Factor 1	Factor 1
HOTDAYS	0,836	**0,407**
TEMPER_MAX	0,831	**0,402**
TEMPER_MEAN	0,574	**0,192**
Explained Variance	1,718	
Explained Variance/ Total Variance	**1,000**	

Table 25 indicates weights for the hazard indicators based on principal components method for the extraction of the common factors.

Table 25: Weights for the Hazard Indicators

Indicators	**Weight**
HOTDAYS	0,407
TEMPER_MAX	0,402
TEMPER_MEAN	0,192

Heat wave hazard index is calculated in SPSS by multiplying the normalized variables by their weights in accordance with the methods chapter of the thesis. Heat wave hazard map is prepared based on the heat wave hazard index score using natural breaks classification by defining five classes that represent very low, low, moderate, high, and very high heat wave hazard, respectively.

The heat wave hazard index represents the aggregate of hazard from three indicators: increase in annual maximum temperature (TEMPER_MAX), increase in the number of hot days where Tmax>30°C in a year (HOTDAYS), and increase in annual mean temperature (TEMPER_MEAN). According to the results, one-third of the provinces have very low heat wave hazard level in Turkey. High or very high heat wave hazard level is observed in 40% of the total number of provinces (Table 26).

Table 26. Number of Provinces in terms of Heat Wave Hazard Levels

Heat Wave Hazard Level	**Number of Provinces**	**Share (%)**
Very Low Heat Wave Hazard	27	33,3
Low Heat Wave Hazard	3	3,7
Moderate Heat Wave Hazard	19	23,5
High Heat Wave Hazard	17	21,0
Very High Heat Wave Hazard	15	18,5
Total	81	100

Very high-hazard provinces concentrate in the northwestern parts (Kırklareli,Tekirdağ Yalova, Sakarya and Bilecik), southwestern part (Denizli and Burdur), inner part (Nevşehir, Kırşehir, Kırıkkale, Çorum, Amasya, Tokat, and Malatya) and Mersin in the southern part of Turkey (Figure 50).

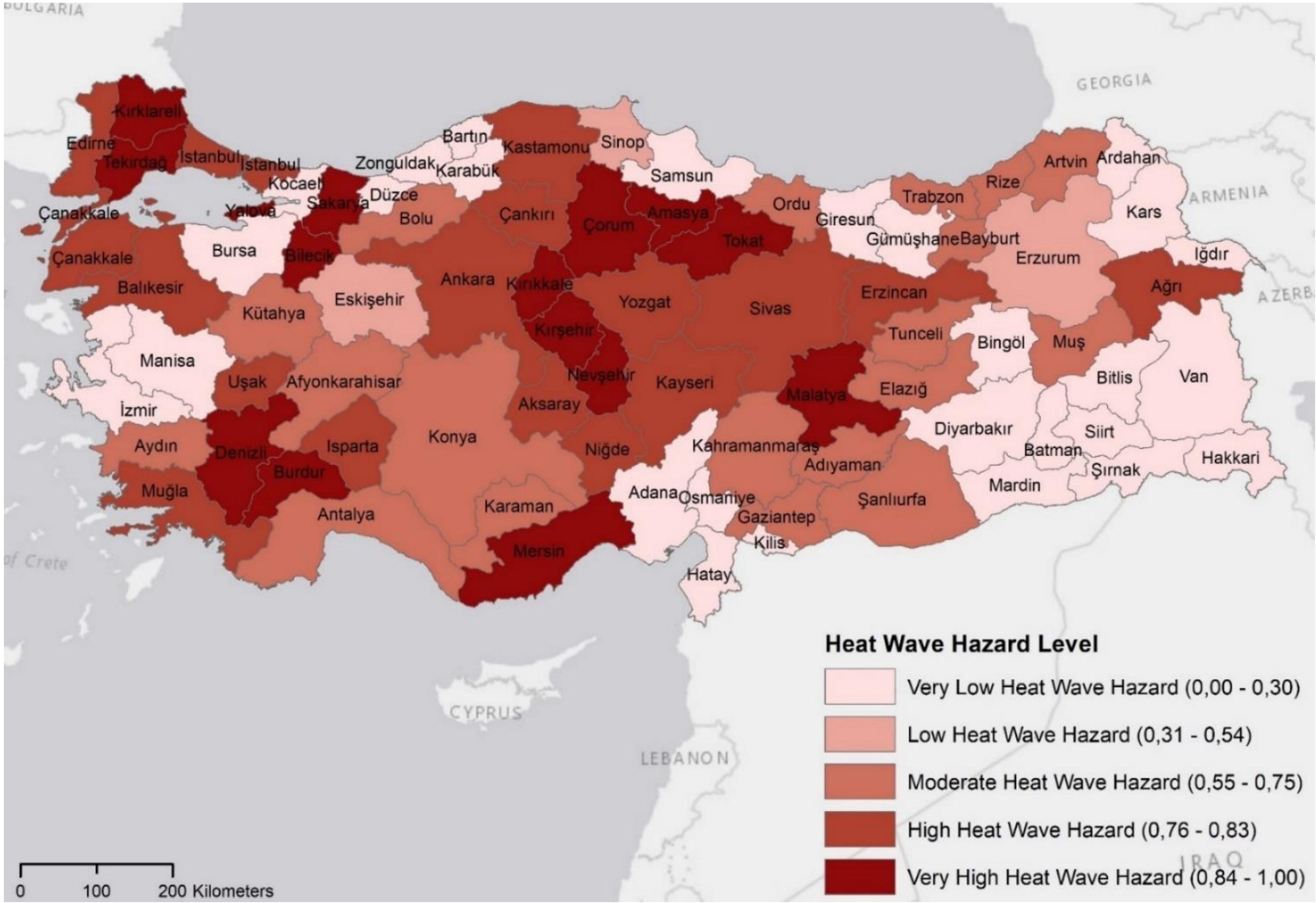

Figure 50: Heat Wave Hazard Level of the Provinces in Turkey

5.3.1.2. Heat Wave Exposure

Three indicators are selected to represent the exposure dimension of heat wave risk: share of land covered by continuous urban fabric (URBAN_LAND), urbanization rate (URBANIZATION), and the length of the urban rail system (URBAN_RAIL). First, as it is shown in Table 27, Cronbach's alpha is calculated for these three variables before the PCA/FA since the number of items does not allow more than one factor to exist (Raubenheimer, 2004). 0.73 is greater than 0.6 threshold for reliability (Robinson et al., 1991; Bagozzi and Yi, 1988; Wim et al., 2008; Van Griethuijsen et al., 2015; Ursachi et al., 2015).

Table 27: Reliability Statistics

Reliability Statistics

Cronbach's Alpha	N of Items
0,734	3

KMO and Bartlett's Test Score is calculated (Table 28). Kaiser (1974), Hair et al. (2006), and Field (2009) suggest that minimum acceptable score for KMO is 0.5. KMO value for these three variables is 0.57, which is miserable but still valid to proceed with PCA/FA (Kaiser, 1974; Hair et al., 2006).

Table 28: The KMO and Bartlett's Test Score

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,568
Bartlett's Test of Sphericity	Approx. Chi-Square	87,528
	df	3
	Sig.	0,000

According to Table 29, the area of continuous urban land is positively correlated with the length of the urban rail system (r=0.79). Since the determinant is greater than 0.0001 (Field 2000), then there is no multicollinearity and variables can be used in PCA/FA.

Table 29: Correlation Matrix

Correlation Matrix[a]		URBAN LAND	URBAN RAIL	URBANIZATION
Correlation	URBAN LAND	1,000	0,792	0,291
	URBAN RAIL	0,792	1,000	0,353
	URBANIZATION	0,291	0,353	1,000

a. Determinant = 0,326

According to the Kaiser criterion, one factor needs to be extracted. This factor explains 66.66% of the total variance (Table 30), which exceed the minimum threshold of 30% in one-factor solutions (Büyüköztürk, 2007; Çokluk et al., 2016). Therefore, selected indicators represent exposure factor.

Table 30: Total Variance Explained

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2,000	66,658	66,658	2,000	66,658	66,658
2	0,795	26,499	93,157			
3	0,205	6,843	100,000			

Extraction Method: Principal Component Analysis.

Table 31 shows the loadings of the variables on the exposure factor extracted. The results indicate that all the indicators make statistically significant contributions to the exposure factor, with loads higher than 0.32 (Tabachnick and Fidell, 2014).

Table 31: The Components and Their Respective Items

Component Matrix[a]

	Component 1
URBAN RAIL	0,920
URBAN LAND	0,900
URBANIZATION	0,587

Extraction Method: Principal Component Analysis.
a. 1 component extracted.

Weights are assigned according to the approach used by Nicoletti et al. (2000). In this context, Table 32 shows the factor loadings, and squared factor loadings scaled to unity sum, which are used to compute weights.

Table 32: Factor Loadings of Exposure Indicators

Factor Loading		Squared Factor Loading (scaled to unity sum)
	Factor 1	Factor 1
URBAN_RAIL	0,920	**0,423**
URBAN_LAND	0,900	**0,405**
URBANIZATION	0,587	**0,172**
Explained Variance	2,000	
Explained Variance/Total Variance	**1**	

Table 33 indicates weights for the exposure indicators based on principal components method for the extraction of the common factors.

Table 33: Weights for the Exposure Indicators

Indicators	**Weight**
URBAN_RAIL	0,423
URBAN_LAND	0,405
URBANIZATION	0,172

Heat wave exposure index is calculated in SPSS by multiplying the normalized variables raised to the power of their weights in accordance with the methods chapter of the thesis. Heat wave exposure map is generated based on the heat wave exposure index score using natural breaks classification by defining five classes that represent very low, low, moderate, high, and very high exposure to heat wave, respectively.

The heat wave exposure index represents the aggregate of exposure from three indicators: share of land covered by continuous urban fabric (URBAN_LAND), urbanization rate (URBANIZATION), and the length of the urban rail system (URBAN_RAIL). The results show that 65% of the provinces are exposed to heat wave at low or very low levels (Table 34). 14% of provinces are found to have high/very high levels of exposure to heat wave.

Table 34: Number of Provinces in terms of Heat Wave Exposure Levels

Heat Wave Exposure Level	**Number of Provinces**	**Share (%)**
Very Low Heat Wave Exposure	13	16,0
Low Heat Wave Exposure	40	49,4
Moderate Heat Wave Exposure	17	21,0
High Heat Wave Exposure	9	11,1
Very High Heat Wave Exposure	2	2,5
Total	81	100

Istanbul and İzmir stand out as the most exposed provinces to heat wave. It is followed by the provinces that are highly exposed to heat wave which are particularly evident in the Marmara region (Kocaeli, Yalova, and Bursa), the inner part of Turkey (Eskişehir, Ankara, Kayseri), in the southern part (Antalya, Adana, and Gaziantep) because these provinces are highly urbanized with a significant proportion of land covered by continuous urban fabric (Figure 51).

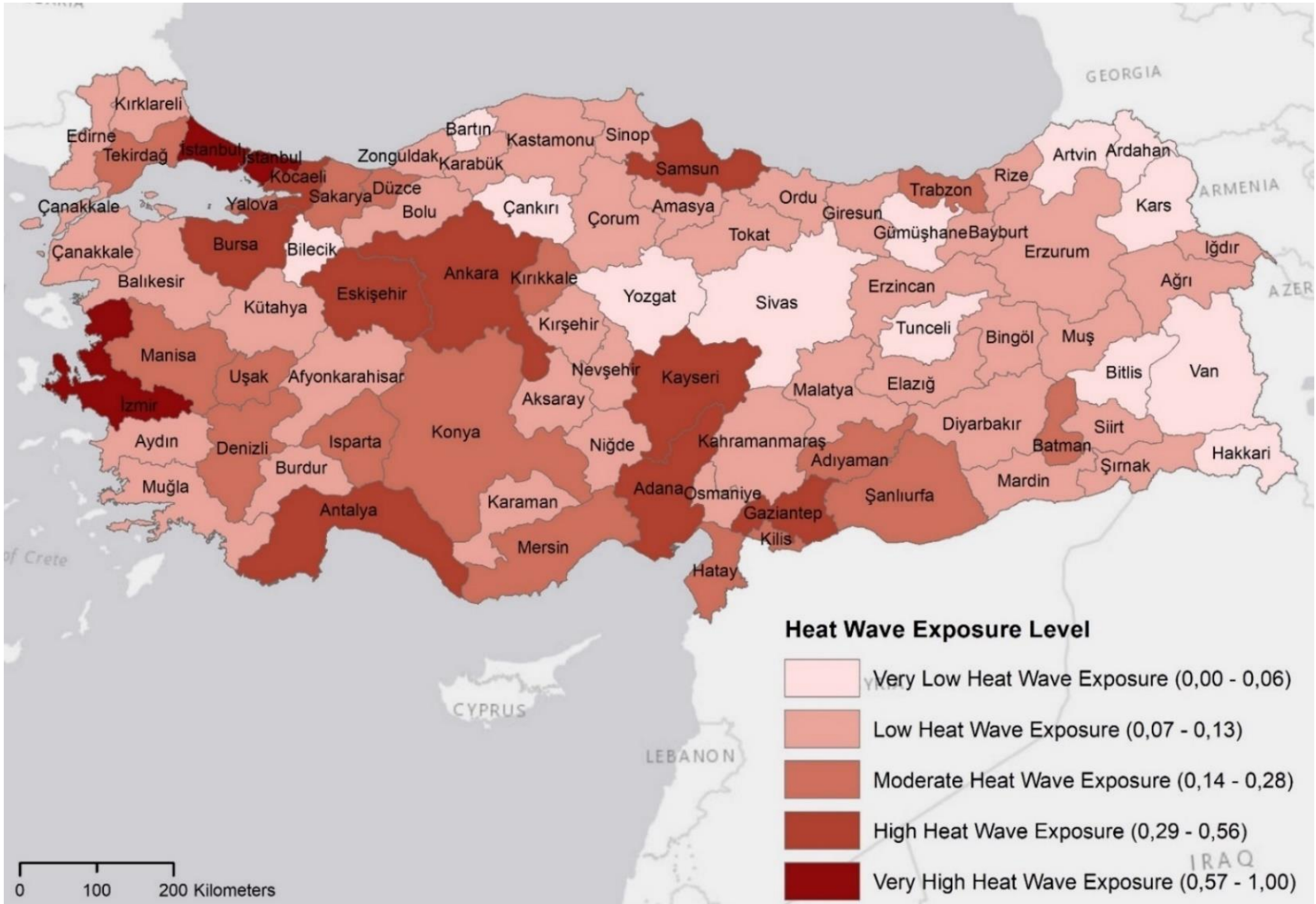

Figure 51: Heat Wave Exposure Level of the Provinces in Turkey

5.3.1.3. Heat Wave Sensitivity

Seven indicators are selected to represent sensitivity dimension of heat wave risk: share of children and elderly population (CHILD_ELDER), share of refugees (REFUGEES), change in landcover (LANDCOVER), one-person households (ONE_P_HH), poverty (PVRTY), unemployment (UNEMP), and dependency ratio (DEPND).

KMO and Bartlett’s Test Score are calculated. KMO value being equal to 0.59 and a significance level for the Bartlett’s test below 0.05 indicate there is substantial correlation in the data (Table 35).

Table 35: The KMO and Bartlett’s Test Score

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,592
Bartlett's Test of Sphericity	Approx. Chi-Square	269,496
	df	21
	Sig.	0,000

According to Table 36, the strongest correlation is between dependency rate and poverty rate ($r=0.75$, $p<0.05$).

Table 36: Correlation Matrix

Correlation Matrix		CHILD_ ELDER	REFUGEES	LAND COVER	ONE_ P_HH	PVRTY	UNEMP	DEPND
Correlation	CHILD_ ELDER	1,000	-0,073	-0,253	0,666	-0,262	-0,386	-0,098
	REFUGEES	-0,073	1,000	0,327	-0,195	0,209	0,144	0,287
	LAND COVER	-0,253	0,327	1,000	-0,269	0,080	0,269	0,156
	ONE_P_HH	0,666	-0,195	-0,269	1,000	-0,587	-0,544	-0,679
	PVRTY	-0,262	0,209	0,080	-0,587	1,000	0,501	0,748
	UNEMP	-0,386	0,144	0,269	-0,544	0,501	1,000	0,534
	DEPND	-0,098	0,287	0,156	-0,679	0,748	0,534	1,000

The total variance explained (Table 37) for measuring this construct is 78.5% which is acceptable as it exceeds the minimum of 40 (Büyüköztürk, 2007; Çokluk et al., 2016). Therefore, selected indicators represent sensitivity factor.

Table 37: Total Variance Explained

Total Variance Explained

Component	Initial Eigenvalues Total	Initial Eigenvalues % of Variance	Initial Eigenvalues Cumulative %	Extraction Sums of Squared Loadings Total	Extraction Sums of Squared Loadings % of Variance	Extraction Sums of Squared Loadings Cumulative %	Rotation Sums of Squared Loadings Total	Rotation Sums of Squared Loadings % of Variance	Rotation Sums of Squared Loadings Cumulative %
1	3,246	46,369	46,369	3,246	46,369	46,369	2,496	35,653	35,653
2	1,163	16,612	62,981	1,163	16,612	62,981	1,664	23,777	59,430
3	1,087	15,532	78,512	1,087	15,532	78,512	1,336	19,083	78,512
4	0,643	9,186	87,699						
5	0,474	6,776	94,474						
6	0,309	4,420	98,894						
7	0,077	1,106	100,000						

Extraction Method: Principal Component Analysis.

A parallel analysis is conducted to decide the number of factors to retain. Parallel analysis indicated that the eigenvalues of the first factor obtained from PCA are greater than the one obtained from PA (Table 38). Therefore, one factor is decided to be retained as the eigenvalue of the second factor's simulated data is higher than that of the actual data.

Table 38: Eigenvalues Retrieved from PCA and PA

Factor	Eigenvalues obtained from PCA	Eigenvalues obtained from PA
1	**3,246**	**1,615**
2	1,163	1,348
3	1,087	1,202
4	0,643	1,051
5	0,474	0,946
6	0,309	0,833
7	0,077	0,712

Scree plot covering the factors and respective eigenvalues also shows that there is one factor above the interpolation line of Parallel Analysis (Figure 52). Therefore, one factor is decided to be retained.

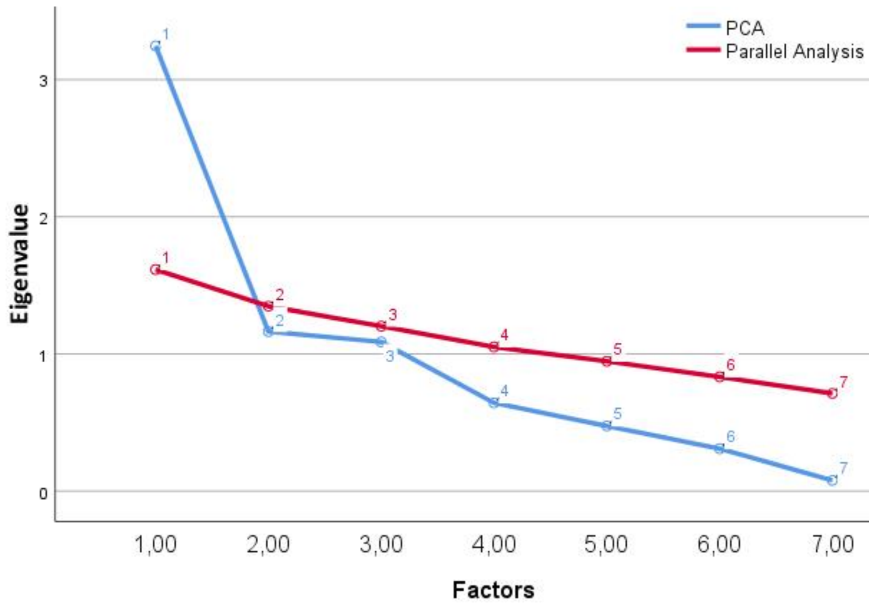

Figure 52: Scree Plot of Parallel Analysis

Cronbach’s alpha is calculated for these seven variables loaded on factor 1 (Table 39). 0.65 is greater than 0.6 threshold for reliability (Robinson et al., 1991; Bagozzi and Yi, 1988; Wim et al., 2008; Van Griethuijsen et al., 2015; Ursachi et al., 2015).

Table 39: The Internal Reliability

Reliability Statistics

Cronbach's Alpha[a]	N of Items
0,164	7

a. The value is negative due to a negative average covariance among items.

Since Cronbach’s alpha is low, item-total statistics is examined (Table 40). ONE_P_HH and CHILD_ELDER are removed from the indicator list because Cronbach’s alpha would increase to 0.711 if these items are deleted.

Table 40: Item-Total Statistics

Item-Total Statistics	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
REFUGEES	0,0000000	5,749	0,292	-0,052[a]
LANDCOVER	0,0000000	6,529	0,121	0,097
PVRTY	0,0000000	5,773	0,286	-0,047[a]
UNEMP	0,0000000	6,112	0,209	0,022
DEPND	0,0000000	5,254	0,413	-0,170[a]
CHILD_ELDER	0,0000000	7,961	-0,144	0,296
ONE_P_HH	0,0000000	10,363	-0,499	0,505

a. The value is negative due to a negative average covariance among items. This violates reliability model assumptions. You may want to check item codings.

After these two variables are removed, Cronbach's alpha is calculated again. As it is indicated in Table 41, 0.71 is greater than 0.6 threshold for reliability (Robinson et al., 1991; Bagozzi and Yi, 1988; Wim et al., 2008; Van Griethuijsen et al., 2015; Ursachi et al., 2015).

Table 41: The Internal Reliability

Reliability Statistics	
Cronbach's Alpha	N of Items
0,707	5

KMO and Bartlett's Test Score are calculated. KMO value being equal to 0.66 and a significance level for the Bartlett's test below 0.05 indicate there is substantial correlation in the data (Table 42).

Table 42: The KMO and Bartlett's Test Score

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,665
Bartlett's Test of Sphericity	Approx. Chi-Square	113,168
	df	10
	Sig.	0,000

According to Table 43, indicators are correlated with each other. The strongest correlation is between dependency rate and poverty rate ($r=0.75$, $p<0.05$).

Table 43: Correlation Matrix

Correlation Matrix[a]

		REFUGEES	LANDCOVER	PVRTY	UNEMP	DEPND
Correlation	REFUGEES	1,000	0,327	0,209	0,144	0,287
	LANDCOVER	0,327	1,000	0,080	0,269	0,156
	PVRTY	0,209	0,080	1,000	0,501	0,748
	UNEMP	0,144	0,269	0,501	1,000	0,534
	DEPND	0,287	0,156	0,748	0,534	1,000

a. Determinant = 0,232

The total variance explained (Table 44) for measuring this construct is 48% which exceeds the minimum threshold of 30% in one-factor solutions (Büyüköztürk, 2007; Çokluk et al., 2016). Therefore, selected indicators represent sensitivity factor.

Table 44: Total Variance Explained

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2,400	48,005	48,005	2,400	48,005	48,005
2	1,139	22,779	70,784			
3	0,760	15,198	85,982			
4	0,456	9,111	95,093			
5	0,245	4,907	100,000			

Extraction Method: Principal Component Analysis.

Table 45 displays the loadings of the five variables on sensitivity factor extracted. The results indicate that all the indicators make statistically significant contributions to the sensitivity factor, with loads higher than 0.32 (Tabachnick and Fidell, 2014).

Table 45: The Components and Their Respective Items

Component Matrix[a]

	Component 1
DEPND	0,872
PVRTY	0,829
UNEMP	0,754
REFUGEES	0,473
LANDCOVER	0,400

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Weights are assigned according to the approach used by Nicoletti et al. (2000). In this context, Table 46 shows the factor loadings, and squared factor loadings scaled to unity sum, which are used to compute weights.

Table 46: Factor Loadings of Sensitivity Indicators

Factor Loading		**Squared Factor Loading (scaled to unity sum)**
	Factor 1	Factor 1
DEPND	0,872	**0,317**
PVRTY	0,829	**0,286**
UNEMP	0,754	**0,237**
REFUGEES	0,473	**0,093**
LANDCOVER	0,400	**0,067**
Explained Variance	2,4	
Explained Variance/Total Variance	**1**	

Table 47 indicates weights for the sensitivity indicators based on principal components method for the extraction of the common factors.

Table 47: Weights for the Sensitivity Indicators

Indicators	**Weight**
DEPND	0,317
PVRTY	0,286
UNEMP	0,237
REFUGEES	0,093
LANDCOVER	0,067

Heat wave sensitivity index is calculated in SPSS by multiplying the normalized variables raised to the power of their weights in accordance with the methods chapter of the thesis. Heat wave sensitivity map is generated based on the heat wave sensitivity index score using natural breaks classification by defining five classes that represent very low, low, moderate, high, and very high sensitivity to heat wave, respectively.

The heat wave sensitivity index represents the aggregate of sensitivity from five indicators: share of refugees (REFUGEES), change in landcover (LANDCOVER), poverty (PVRTY), unemployment (UNEMP), and dependency ratio (DEPND). Results indicate that approximately one-fourth of the provinces have high or very high levels of sensitivity to heat wave (Table 48).

Table 48: Number of Provinces in terms of Heat Wave Sensitivity Levels

Heat Wave Sensitivity Level	**Number of Provinces**	**Share (%)**
Very Low Sensitivity to Heat Wave	6	7,4
Low Sensitivity to Heat Wave	28	34,6
Moderate Sensitivity to Heat Wave	28	34,6
High Sensitivity to Heat Wave	14	17,3
Very High Sensitivity to Heat Wave	5	6,2
Total	81	100

Provinces with high sensitivity are mostly concentrated in the south-eastern part of Turkey in which Şanlıurfa, Diyarbakır, Mardin, Batman and Şırnak are the provinces that are found to have very high sensitivity to heat wave (Figure 53). Since dependency, poverty, and unemployment rates are found to weigh more on heat wave sensitivity (Table 47), the eastern and south-eastern parts of Turkey, which is known to be the least developed regions of Turkey, become highly sensitive to heat wave.

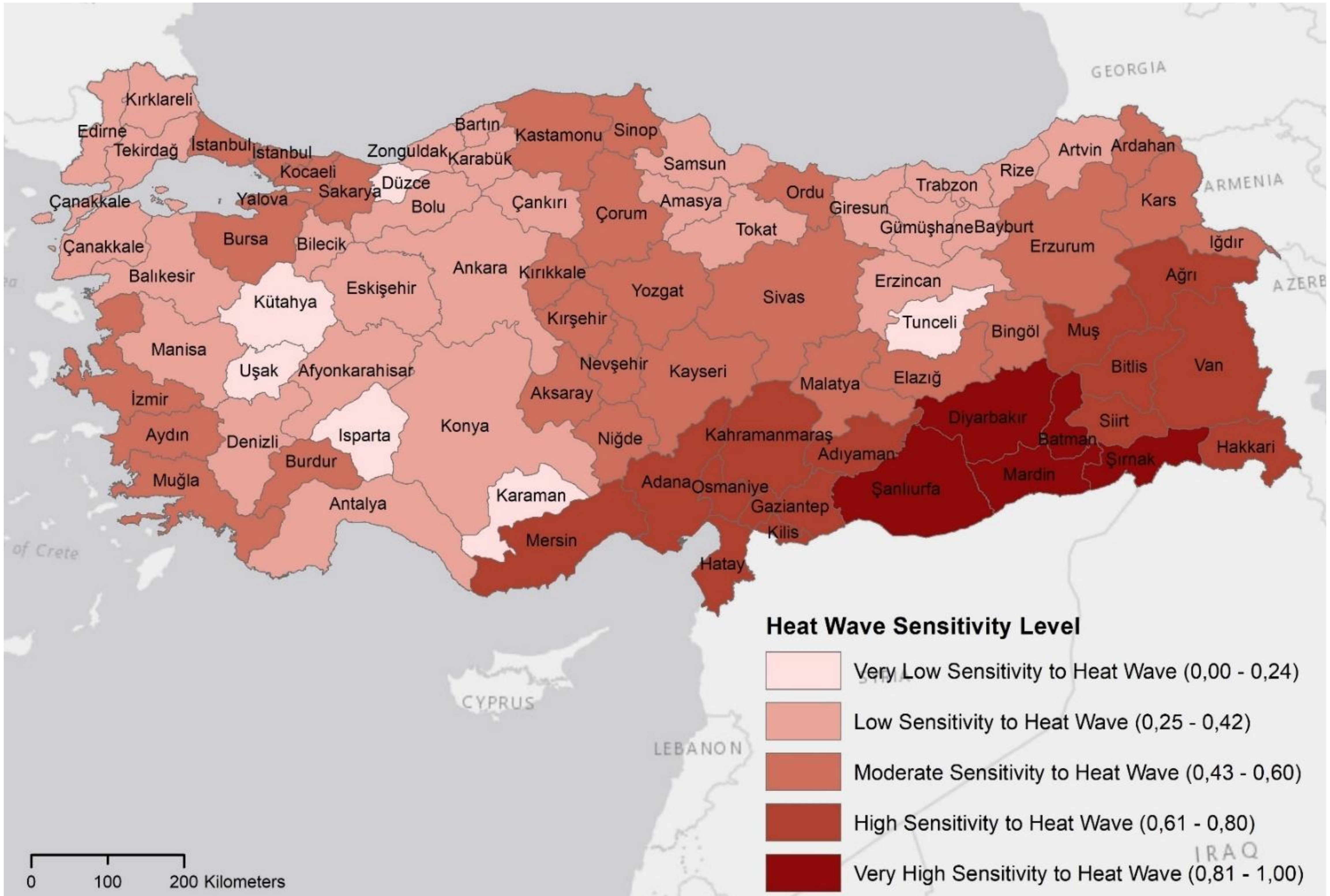

Figure 53: Heat Wave Sensitivity Level of the Provinces in Turkey

5.3.1.4. Heat Wave Adaptive Capacity

Seven indicators are selected to represent adaptive capacity dimension of heat wave risk: Urban green spaces (GREEN), high education (HIGH_EDU), civic engagement (CIVIC_ENG), level of interest in environmental issues (ENV_INT), GDP per capita (GDPPERC), saving deposit per capita (SAV_DEP), and access to hospitals (HOSPIT).

KMO and Bartlett’s Test Score are calculated. KMO value being equal to 0.60 and a significance level for the Bartlett’s test below 0.05 indicate there is substantial correlation in the data (Table 49).

Table 49: The KMO and Bartlett’s Test Score

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,601
Bartlett's Test of Sphericity	Approx. Chi-Square	283,376
	df	21
	Sig.	0,000

According to Table 50, indicators are correlated with each other. The strongest correlation is between high education and saving deposits per capita ($r=0.762$, $p<0.05$).

Table 50: Correlation Matrix

Correlation Matrix[a]

		HIGH EDU	CIVIC_ ENG	ENV_ INT	GDP PERC	SAV_ DEP	GREEN	HOSPIT
Correlation	HIGH_EDU	1,000	0,200	0,197	0,758	0,762	0,370	0,353
	CIVIC_ENG	0,200	1,000	0,529	0,279	0,138	0,101	0,118
	ENV_INT	0,197	0,529	1,000	0,037	0,053	-0,091	0,069
	GDPPERC	0,758	0,279	0,037	1,000	0,759	0,458	0,521
	SAV_DEP	0,762	0,138	0,053	0,759	1,000	0,331	0,607
	GREEN	0,370	0,101	-0,091	0,458	0,331	1,000	0,566
	HOSPIT	0,353	0,118	0,069	0,521	0,607	0,566	1,000

a. Determinant = 0,025

According to the total variance explained table (Table 51), two factors have eigenvalues above 1 and they explain 68.69% of the total variance.

Table 51: Total Variance Explained

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3,312	47,317	47,317	3,312	47,317	47,317	3,211	45,868	45,868
2	1,496	21,376	68,693	1,496	21,376	68,693	1,598	22,825	68,693
3	0,868	12,396	81,089						
4	0,561	8,018	89,107						
5	0,450	6,430	95,537						
6	0,193	2,760	98,297						
7	0,119	1,703	100,000						

Extraction Method: Principal Component Analysis.

A parallel analysis is conducted to decide the number of factors to retain. Parallel analysis indicates that eigenvalues of the first two factors obtained from PCA are greater than those obtained from PA (Table 52). Therefore, two factors are decided to be retained since the eigenvalue of the third factor's simulated data is higher than that of the actual data.

Table 52: Eigenvalues Retrieved from PCA and PA

Factor	Eigenvalues obtained from PCA	Eigenvalues obtained from PA
1	**3,312**	**1,615**
2	**1,496**	**1,348**
3	0,868	1,202
4	0,561	1,051
5	0,450	0,946
6	0,193	0,833
7	0,119	0,712

Scree plot covering the factors and respective eigenvalues also shows that there are two factors above the interpolation line of Parallel Analysis (Figure 54). Therefore, two factors are decided to be retained.

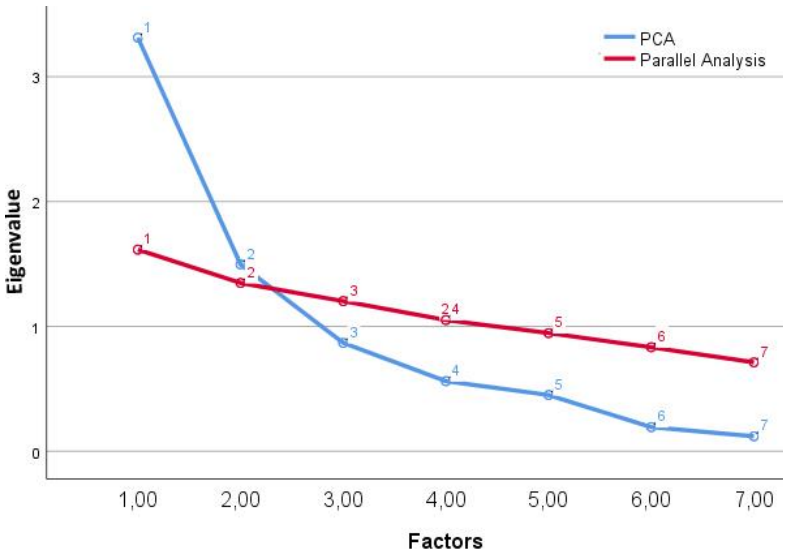

Figure 54: Scree Plot of Parallel Analysis

Since the number of factors is not different from what PCA extracted, total variance explained remains unchanged, as it is indicated in Table 51. As the next step, Table 53 shows the loadings of the seven variables on the factors extracted. The higher the absolute value of the loading, the more the factor contributes to the variable. The results indicate that all the indicators make statistically significant contributions to the adaptive capacity factor.

Table 53: Rotated Component Matrix

Rotated Component Matrix[a]

	Component	
	1	2
GDPPERC	0,877	
SAV_DEP	0,873	
HIGH_EDU	0,798	
HOSPIT	0,754	
GREEN	0,673	
ENV_INT		0,883
CIVIC_ENG		0,838

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.

Cronbach's alpha is calculated for the two factors retained (Table 54). The alpha values are 0.86 and 0.69 for factor 1 and factor 2, respectively. These values are greater than 0.6 threshold for reliability (Robinson et al., 1991; Bagozzi and Yi, 1988; Wim et al., 2008; Van Griethuijsen et al., 2015; Ursachi et al., 2015).

Table 54: The Internal Reliability

	Cronbach's Alpha	N of Items
Factor 1	0,859	5
Factor 2	0,692	2

Weights are assigned according to the approach used by Nicoletti et al. (2000). In this context, Table 55 shows the rotated factor loadings, and squared factor loadings scaled to unity sum, which are used to compute weights.

Table 55: Factor Loadings of Adaptive Capacity Indicators

Factor Loading			Squared Factor Loading (scaled to unity sum)	
	Factor 1	Factor 2	Factor 1	Factor 2
GDPPERC	0,877	0,159	**0,240**	0,016
SAV_DEP	0,873	0,097	**0,238**	0,006
HIGH_EDU	0,798	0,249	**0,198**	0,039
HOSPIT	0,754	-0,007	**0,177**	0,000
GREEN	0,673	-0,139	**0,141**	0,012
ENV_INT	-0,030	0,883	0,000	**0,488**
CIVIC_ENG	0,143	0,838	0,006	**0,439**
Explained Variance	3,211	1,598		
Explained Variance/ Total Variance	**0,668**	**0,332**		

Table 56 indicates weights for the adaptive capacity indicators based on principal components method for the extraction of the common factors.

Table 56: Weights for the Adaptive Capacity Indicators

Indicators	**Weight**
GDPPERC	0,165
SAV_DEP	0,163
HIGH_EDU	0,136
HOSPIT	0,122
GREEN	0,097
ENV_INT	0,167
CIVIC_ENG	0,150

For the fourth dimension of heat wave risk, heat wave adaptive capacity index is calculated in SPSS by multiplying the normalized variables raised to the power of their weights in accordance with the methods chapter of the thesis. Heat wave adaptive capacity map is prepared based on the heat wave adaptive capacity index score using natural breaks classification by defining five classes that represent the very low, low, moderate, high, and very high adaptive capacity to heat wave, respectively.

The heat wave adaptive capacity index represents the aggregate of adaptive capacity from seven indicators: urban green spaces (GREEN), high education (HIGH_EDU), civic engagement (CIVIC_ENG), level of interest in environmental issues (ENV_INT), GDP per capita (GDPPERC), saving deposit per capita (SAV_DEP), and access to hospitals (HOSPIT). According to the results, approximately 45% of the provinces have low/very low levels of adaptive capacity to heat wave (Table 57).

Table 57: Number of Provinces in terms of Heat Wave Adaptive Capacity Levels

Heat Wave Adaptive Capacity Level	**Number of Provinces**	**Share (%)**
Very Low Adaptive Capacity to Heat Wave	8	9,9
Low Adaptive Capacity to Heat Wave	28	34,6
Moderate Adaptive Capacity to Heat Wave	19	23,5
High Adaptive Capacity to Heat Wave	19	23,5
Very High Adaptive Capacity to Heat Wave	7	8,6
Total	81	100

Provinces with lowest adaptive capacity are particularly evident in the eastern and southeastern part of Turkey due to low level of educational, economic and social capacity as well as the western part (Afyonkarahisar) due to low level of civic engagement, environmental interest, and urban green space (Figure 55).

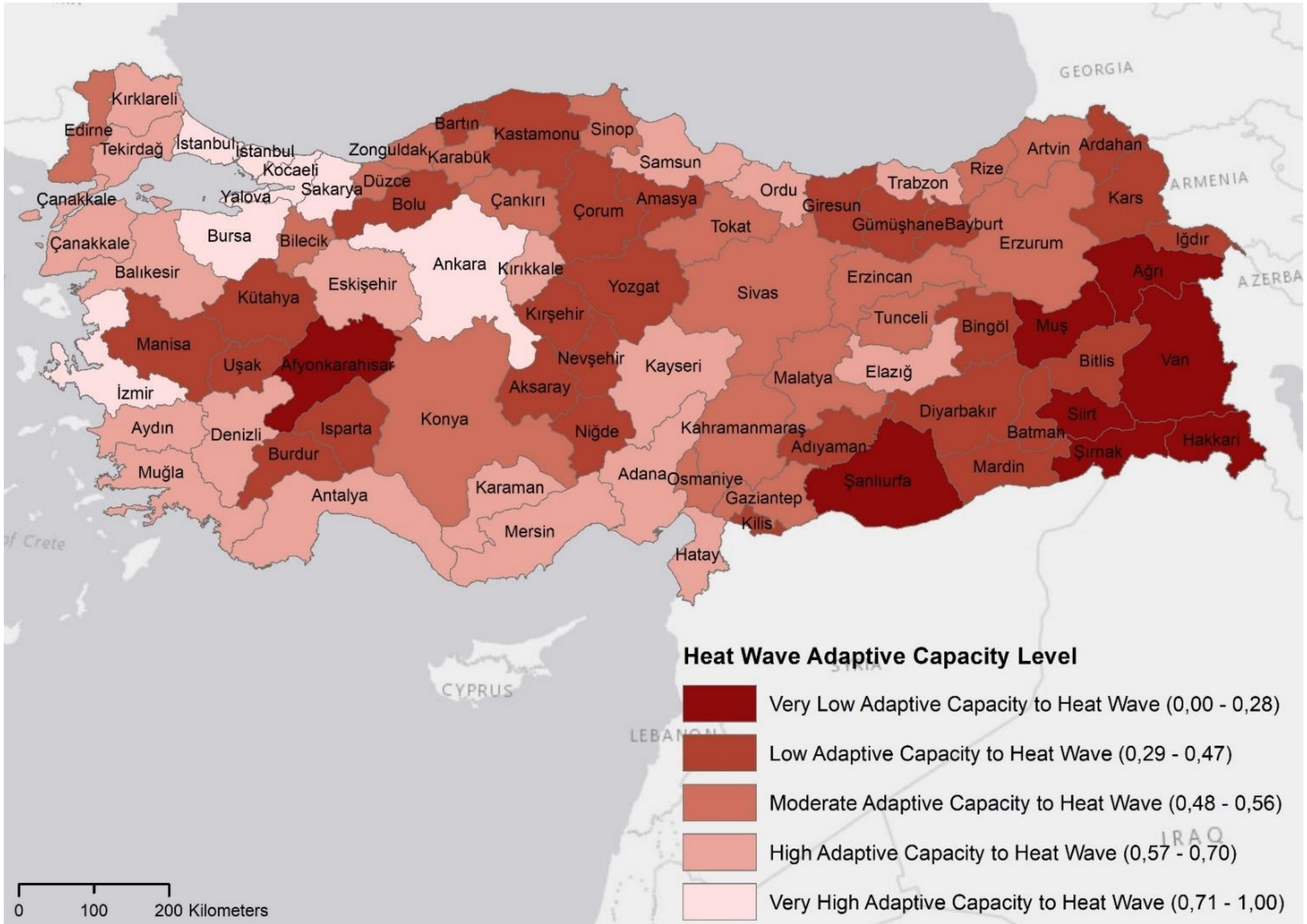

Figure 55: Heat wave Adaptive Capacity Level of the Provinces in Turkey

5.3.1.5. Heat Wave Vulnerability and Risk Profiles of Provinces

As it was mentioned in the Chapter 2, vulnerability is a function of sensitivity and adaptive capacity. It has a positive functional relationship with sensitivity, and a negative functional relationship with adaptive capacity, which leads to vulnerability increases as sensitivity increases and adaptive capacity decreases, or vice versa.

The heat wave vulnerability index therefore is calculated using heat wave sensitivity index and heat wave adaptive capacity index which are elaborated in previous parts. Results show that 28% of the provinces are of high or very high levels of vulnerability to heat wave (Table 58).

Table 58: Number of Provinces in terms of Heat Wave Vulnerability Levels

Heat Wave Vulnerability Level	**Number of Provinces**	**Share (%)**
Very Low Vulnerability to Heat Wave	9	11,1
Low Vulnerability to Heat Wave	28	34,6
Moderate Vulnerability to Heat Wave	21	25,9
High Vulnerability to Heat Wave	14	17,3
Very High Vulnerability to Heat Wave	9	11,1
Total	81	100

According to Figure 55, the southeastern part of Turkey is particularly vulnerable to heat wave due to high levels of sensitivity and low levels of adaptive capacity. The low adaptive capacity of western provinces is found to be compensated by low sensitivity to heat wave (Figure 56).

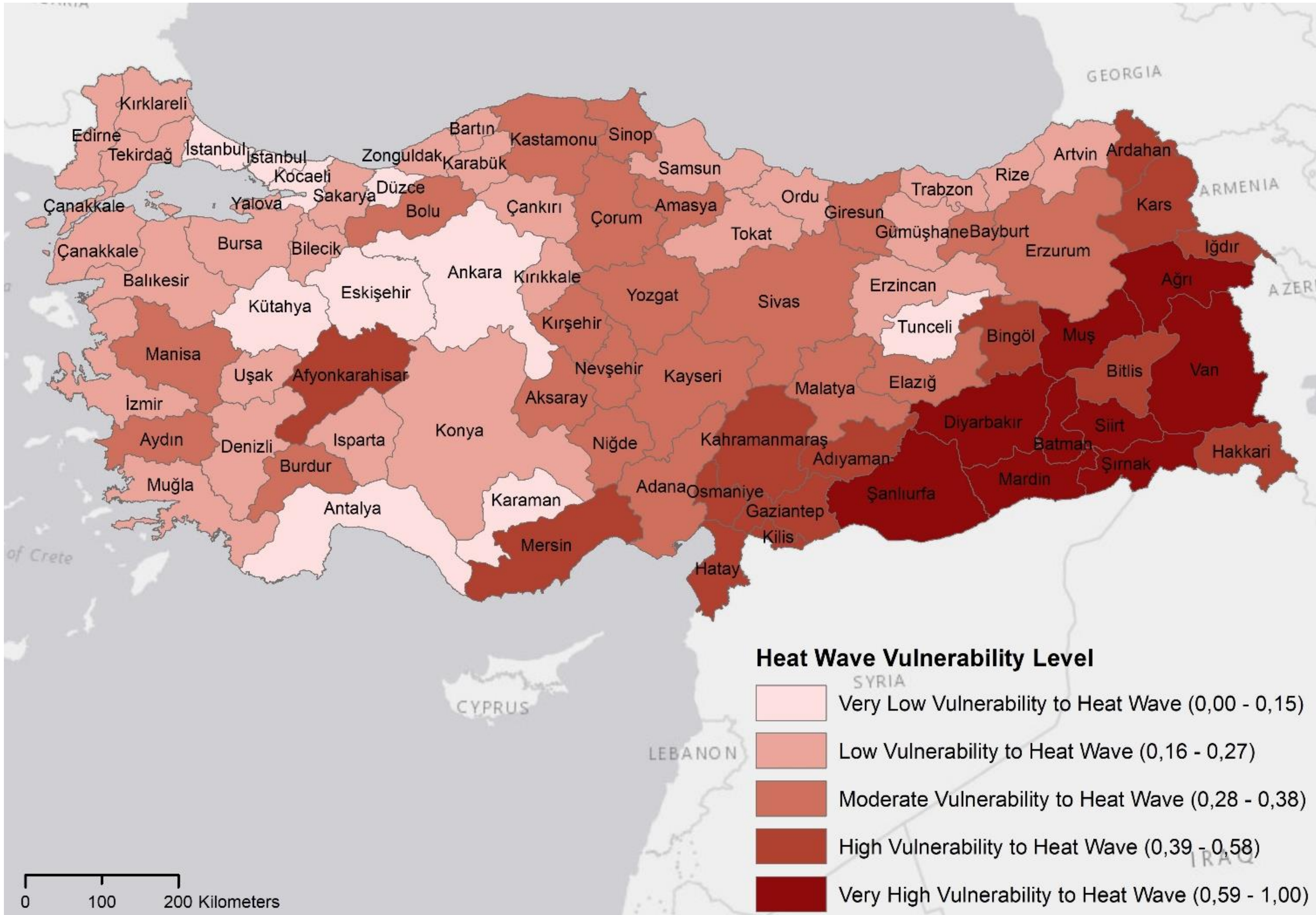

Figure 56: Heat wave Vulnerability Level of the Provinces in Turkey

Heat wave risk index is calculated in SPSS by multiplying the sub-indices of hazard, exposure, sensitivity, and dividing the result by adaptive capacity in accordance with the methods chapter of the thesis. The results of heat wave risk index indicate the risk levels of provinces, which were represented using the natural breaks technique in SPSS to show the results of this study. In this context, the aggregated risk value is categorized into five classes to explain the relative position of each province that represent the very low, low, moderate, high, and very high risk of heat wave, respectively. The results show that 20% of the provinces have moderate and higher levels of heat wave risk (Table 59).

Table 59: Number of Provinces in terms of Heat Wave Risk Levels

Heat Wave Risk Level	**Number of Provinces**	**Share (%)**
Very Low Risk of Heat Wave	16	19,8
Low Risk of Heat Wave	20	24,7
Moderate Risk of Heat Wave	34	42,0
High Risk of Heat Wave	7	8,6
Very High Risk of Heat Wave	4	4,9
Total	81	100

After categorizing provinces in terms of their risk values, risk levels are mapped using ArcGis 10.7 as it is indicated in Figure 56. Heat wave risk is particularly evident in Istanbul where 18.49% of the population in Turkey is concentrated (TurkStat, 2020), in Ankara, which is the second populated province, Kayseri in the inner part, and Gaziantep in the southern part (Figure 57).

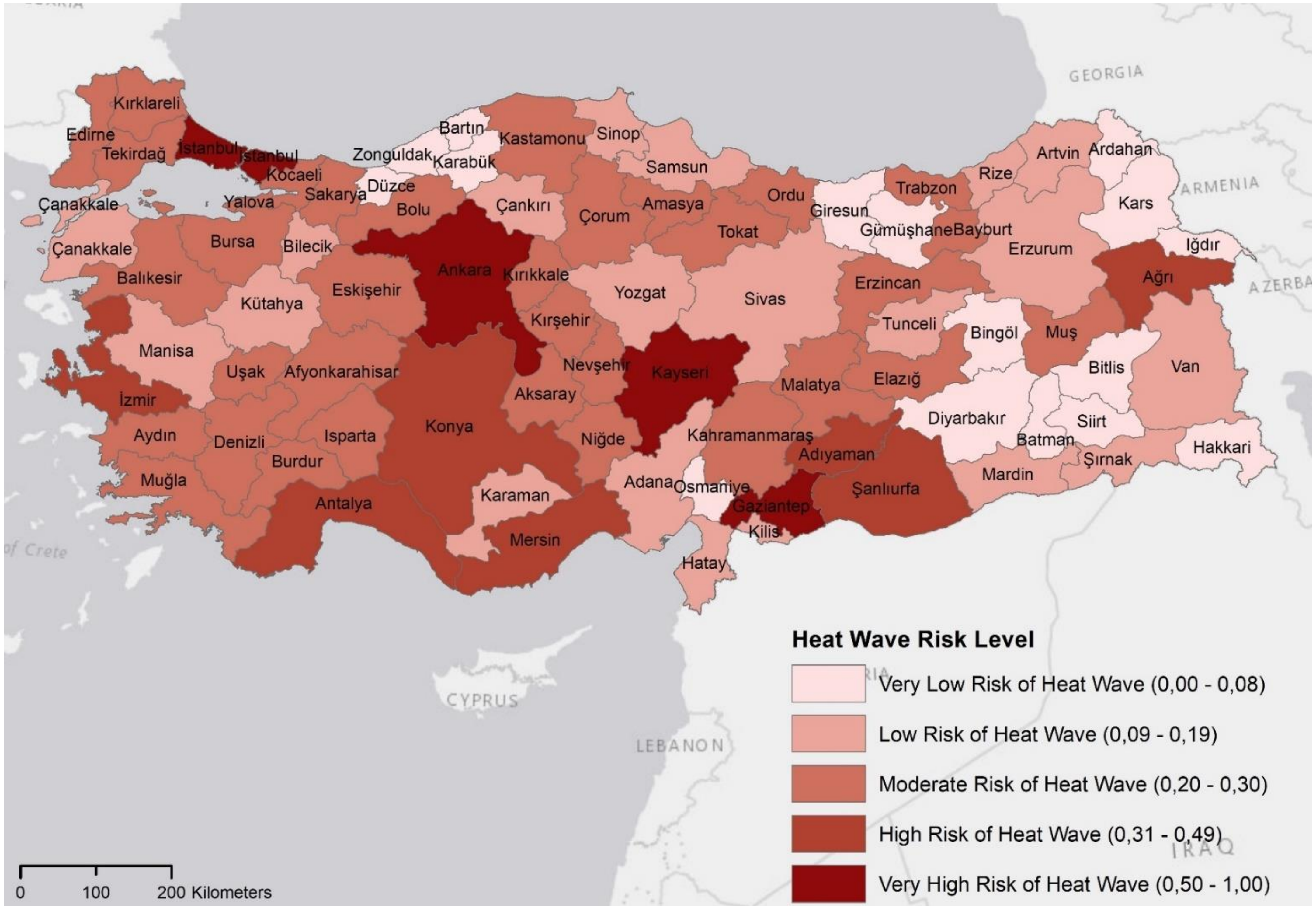

Figure 57: Heat wave Risk Profiles of Provinces in Turkey

5.3.2. Drought Risk

Drought risk is one of the climate-related risks addressed in this study. Drought risk is considered the product of the impacts from drought hazard and the probability that it occurs. The impact of a drought is affected by vulnerability and exposure to drought. In this study, (1) the drought hazard is considered as a latent damaging physical event for the rural population, agricultural livelihood, biodiversity, and water resources; (2) exposure refers to the presence of rural population, agricultural livelihood, biodiversity, and water resources in places and settings that could be adversely affected by drought; (3) drought vulnerability is the function of sensitivity and adaptive capacity of rural population, agricultural livelihood, biodiversity, and water resources to drought. To compute drought risk, there are 22 indicators in total used under the four components of risk (Figure 58).

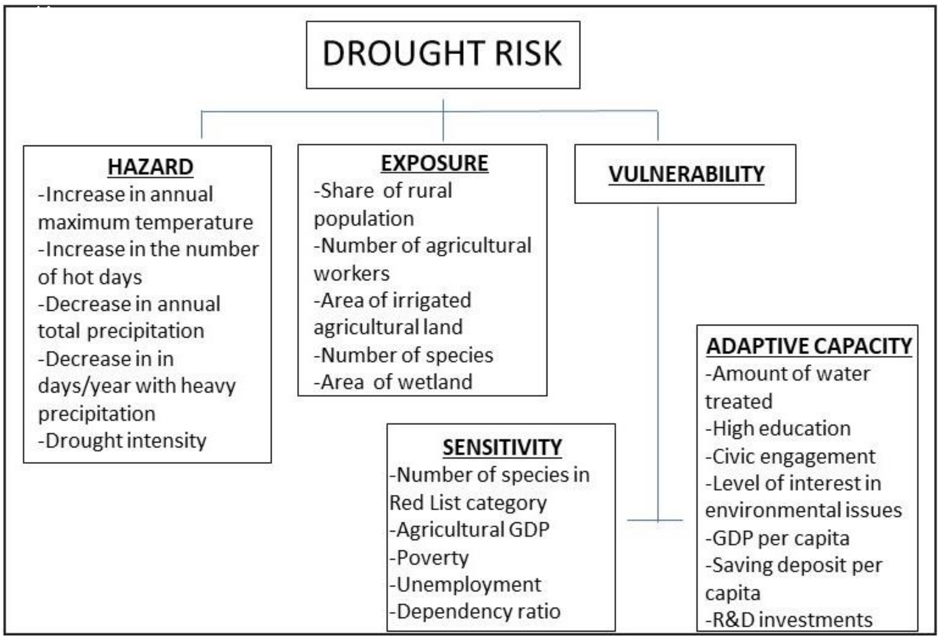

Figure 58: Indicators Scheme for Drought Risk

Drought risk index is prepared according to the methods mentioned in the previous chapter. In this vein, drought hazard, drought exposure, drought sensitivity, and drought adaptive capacity sub-indices are generated and aggregated to obtain drought risk index.

5.3.2.1. Drought Hazard

Five indicators are selected to represent hazard dimension of drought risk: increase in annual maximum temperature (TEMPER_MAX), increase in the number of hot days where Tmax>30°C in a year (HOTDAYS), decrease in annual total precipitation (PRECIP), and decrease in in days/year with heavy precipitation (HEAVY_PRECIP), and drought conditions (DROUGHT).

Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) measures how strongly the variables being tested correlate. Raw data becomes suitable for conducting a factor analysis if the KMO is greater than or equals to 0.50 (Kaiser, 1974; Hair et al., 2006; Field, 2009). Since KMO value is 0.6 and significance level for the Bartlett's test is below 0.05, there is substantial correlation in the data (Table 60). Therefore, the results meet the assumptions to proceed with PCA/FA.

Table 60: The KMO and Bartlett's Test Score

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,595
Bartlett's Test of Sphericity	Approx. Chi-Square	118,881
	df	10
	Sig.	0,000

According to Table 61, there is positive correlation among drought conditions, decrease in heavy precipitation, and decrease in annual precipitation. The number of hot days, on the other hand, is positively correlated with the increase in annual maximum temperature. Drought conditions have no significant relationship with the number of hot days and increase in annual maximum temperature, which indicates that drought conditions are characterized more by decrease in precipitation than increase in temperature.

Table 61: Correlation Matrix

		Correlation Matrix[a]				
		PRECIP	HOTDAYS	TEMPER MAX	HEAVY PRECIP	DROUGHT
Correlation	PRECIP	1,000	0,317	0,146	0,691	0,411
	HOTDAYS	0,317	1,000	0,547	0,109	-0,109
	TEMPER_MAX	0,146	0,547	1,000	0,027	-0,032
	HEAVY_PRECIP	0,691	0,109	0,027	1,000	0,529
	DROUGHT	0,411	-0,109	-0,032	0,529	1,000

a. Determinant = 0,216

The total variance explained for measuring this construct is 74.6% (Table 62), which is acceptable as it exceeds the minimum 40% (Büyüköztürk, 2007; Çokluk et al., 2016). Therefore, selected indicators represent hazard factor.

Table 62: Total Variance Explained

Total Variance Explained									
	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2,170	43,392	43,392	2,170	43,392	43,392	2,089	41,784	41,784
2	1,561	31,220	74,612	1,561	31,220	74,612	1,641	32,828	74,612
3	0,620	12,397	87,009						
4	0,377	7,542	94,551						
5	0,272	5,449	100,000						

Extraction Method: Principal Component Analysis.

A parallel analysis is conducted to decide the number of factors to retain. Parallel analysis indicates that eigenvalues of the first two factors obtained from PCA is greater than those obtained from PA (Table 63). Therefore, two factors are decided to be retained because the eigenvalue of the third factor's simulated data is higher than that of the actual data.

Table 63: Eigenvalues Retrieved from PCA and PA

Factor	Eigenvalues obtained from PCA	Eigenvalues obtained from PA
1	**2,170**	**1,473**
2	**1,561**	**1,225**
3	0,620	1,077
4	0,377	0,956
5	0,273	0,823

Scree plot covering the factors and respective eigenvalues also shows that there are two factors above the interpolation line of Parallel Analysis (Figure 59). Therefore, two factors are decided to be retained, and PCA is rerun so as to extract two factors.

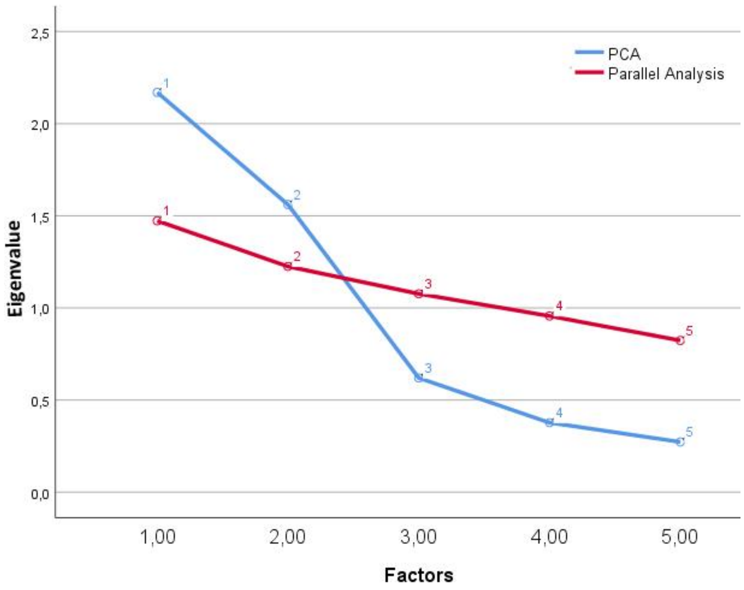

Figure 59: Scree Plot of Parallel Analysis

Since the number of factors is not different from what PCA extracted, total variance explained remains unchanged as it is indicated in Table 62. As the next step, Table 64 demonstrates the loadings of the five variables on the factors extracted. The results indicate that all the indicators make statistically significant contributions to the hazard factor.

Table 64: Rotated Component Matrix

Rotated Component Matrix[a]

	Component 1	Component 2
HEAVY PRECIP	0,895	
PRECIP	0,824	0,303
DROUGHT	0,776	
HOTDAYS		0,890
TEMPER MAX		0,845

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.

Cronbach's alpha is calculated for the two factors retained (Table 65). The alpha values are 0.78 and 0.71 for factor 1 and factor 2, respectively. These values are greater than 0.6 threshold for reliability (Robinson et al., 1991; Bagozzi and Yi, 1988; Wim et al., 2008; Van Griethuijsen et al., 2015; Ursachi et al., 2015).

Table 65: The Internal Reliability

	Cronbach's Alpha	N of Items
Factor 1	0,781	3
Factor 2	0,708	2

Weights are assigned according to the approach used by Nicoletti et al. (2000). In this context, Table 66 shows the factor loadings, and squared factor loadings scaled to unity sum, which are used to compute weights.

Table 66: Factor Loadings of Hazard Indicators

Factor Loading			Squared Factor Loading (scaled to unity sum)	
	Factor 1	Factor 2	Factor 1	Factor 2
HEAVY_PRECIP	0,895	0,059	**0,384**	0,002
PRECIP	0,824	0,303	**0,325**	0,056
DROUGHT	0,776	-0,201	**0,288**	0,025
HOTDAYS	0,077	0,890	0,003	**0,483**
TEMPER_MAX	-0,011	0,845	0,000	**0,435**
Explained Variance	2,089	1,641		
Explained Variance/ Total Variance	**0,560**	**0,440**		

Table 67 indicates weights for the hazard indicators based on principal components method for the extraction of the common factors.

Table 67: Weights for the Hazard Indicators

Indicators	**Weight**
HEAVY_PRECIP	0,223
PRECIP	0,189
DROUGHT	0,168
HOTDAYS	0,221
TEMPER_MAX	0,199

Drought hazard index is calculated in SPSS by multiplying the normalized variables raised to the power of their weights as it is indicated in the methods chapter of the thesis. Drought hazard map is generated based on the hazard index score using natural breaks classification by defining five classes that represent very low, low, moderate, high, and very high drought hazard, respectively.

The drought hazard index represents the aggregate of hazard from five indicators: increase in annual maximum temperature (TEMPER_MAX), increase in the number of hot days where Tmax>30°C in a year (HOTDAYS), decrease in annual total precipitation (PRECIP), and decrease in in days/year with heavy precipitation

(HEAVY_PRECIP), and drought conditions (DROUGHT). According to the results, high or very high drought hazard level prevails approximately half of the total number of provinces (Table 68).

Table 68: Number of Provinces in terms of Drought Hazard Levels

Drought Hazard Level	**Number of Provinces**	**Share (%)**
Very Low Drought Hazard	14	17,3
Low Drought Hazard	17	21,0
Moderate Drought Hazard	11	13,6
High Drought Hazard	27	33,3
Very High Drought Hazard	12	14,8
Total	81	100

High-hazard provinces concentrate in the western parts (Balıkesir and Bilecik), southwestern part (Denizli, Burdur, and Muğla), inner part (Kırıkkale, Kırşehir, Nevşehir, Tokat, Malatya, and Erzincan) and Mersin in the southern part of Turkey (Figure 60).

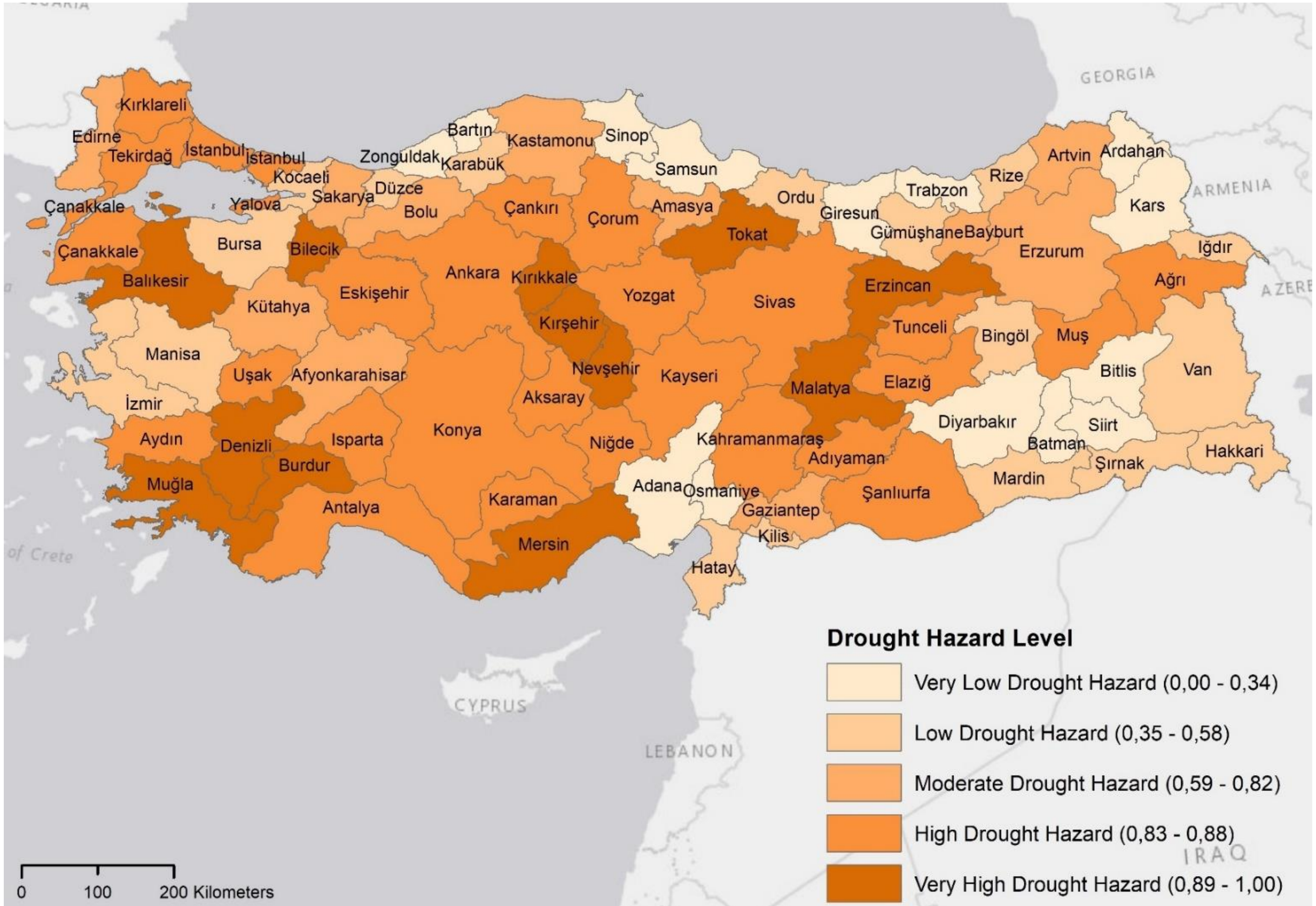

Figure 60: Drought Hazard Level of the Provinces in Turkey

5.3.2.2. Drought Exposure

Five indicators are selected to represent exposure dimension of drought risk: share of rural population (RUR_POP), the number of agricultural workers (AGR_WORKERS), the area of irrigated agricultural land (IRRIGATED), the number of species (SPECIES), and the area of wetland (WETLAND). First, Cronbach's alpha is calculated for these five variables (Table 69).

Table 69: Reliability Statistics

Cronbach's Alpha	N of Items
0,371	5

Since 0.37 is well below 0.6, which is an acceptable threshold for reliability (Robinson et al., 1991; Bagozzi and Yi, 1988; Wim et al., 2008; Van Griethuijsen et al., 2015; Ursachi et al., 2015), item-total statistics is examined (Table 70). RUR_POP is removed from the indicator list because Cronbach's alpha would increase to 0.73 if this item is deleted.

Table 70: Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
RUR_POP	0,0000000	8,803	-0,454	0,727
IRRIGATED	0,0000000	4,318	0,431	0,098
AGR_WORKERS	0,0000000	4,248	0,451	0,078
SPECIES	0,0000000	4,552	0,365	0,162
WETLAND	0,0000000	4,406	0,406	0,123

After removing RUR_POP from the items, KMO and Bartlett's Test Score is calculated. KMO value being equal to 0.635 and a significance level for the Bartlett's test below 0.05 indicate there is substantial correlation in the data (Table 71).

Table 71: The KMO and Bartlett's Test Score

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,635
Bartlett's Test of Sphericity	Approx. Chi-Square	82,314
	df	6
	Sig.	0,000

According to Table 72, the area of irrigated agricultural land is positively correlated with the number of agricultural workers (r=0.67). All the variables are correlated with each other at various degrees.

Table 72: Correlation Matrix

Correlation Matrix[a]		IRRIGATED	AGR_ WORKERS	SPECIES	WETLAND
Correlation	IRRIGATED	1,000	0,669	0,282	0,363
	AGR_WORKERS	0,669	1,000	0,495	0,330
	SPECIES	0,282	0,495	1,000	0,262
	WETLAND	0,363	0,330	0,262	1,000

a. Determinant = 0,347

According to the Kaiser criterion, one factor needs to be extracted. This factor explains 55.77% of the total variance (Table 73), which exceeds the minimum threshold of 30% in one factor solutions (Büyüköztürk, 2007; Çokluk et al., 2016). Therefore, selected indicators represent exposure factor.

Table 73: Total Variance Explained

Total Variance Explained	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2,231	55,774	55,774	2,231	55,774	55,774
2	0,771	19,282	75,056			
3	0,716	17,894	92,950			
4	0,282	7,050	100,000			

Extraction Method: Principal Component Analysis.

Table 74 indicates the loadings of the variables on exposure factor extracted. The results indicate that all the indicators make statistically significant contributions to the exposure factor, with loads higher than 0.32 (Tabachnick and Fidell, 2014).

Table 74: The Components and Their Respective Items

Component Matrix[a]

	Component 1
AGR_WORKERS	0,871
IRRIGATED	0,807
SPECIES	0,666
WETLAND	0,613

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Weights are assigned according to the approach used by Nicoletti et al. (2000). In this context, Table 75 shows the factor loadings, and squared factor loadings scaled to unity sum, which are used to compute weights.

Table 75: Factor Loadings of Exposure Indicators

Factor Loading		**Squared Factor Loading (scaled to unity sum)**
	Factor 1	Factor 1
AGR_WORKERS	0,871	**0,340**
IRRIGATED	0,807	**0,292**
SPECIES	0,666	**0,199**
WETLAND	0,613	**0,168**
Explained Variance	2,231	
Explained Variance/Total Variance	**1**	

Table 76 indicates the weights for the exposure indicators based on principal components method for the extraction of the common factors.

Table 76: Weights for the Exposure Indicators

Indicators	**Weight**
AGR_WORKERS	0,340
IRRIGATED	0,292
SPECIES	0,199
WETLAND	0,168

Drought exposure index is calculated in SPSS by multiplying the normalized variables raised to the power of their weights as it is indicated in the methods chapter of the thesis. Drought exposure map is generated based on exposure index score using natural breaks classification by defining five classes that represent very low, low, moderate, high, and very high exposure to drought, respectively.

The drought exposure index represents the aggregate of exposure from four indicators: the number of agricultural workers (AGR_WORKERS), the area of irrigated agricultural land (IRRIGATED), the number of species (SPECIES), and the area of wetland (WETLAND). Results indicate that 38% of the provinces have high or very high levels of exposure to drought (Table 77).

Table 77: Number of Provinces in terms of Drought Exposure Levels

Drought Exposure Level	**Number of Provinces**	**Share (%)**
Very Low Exposure to Drought	16	19,8
Low Exposure to Drought	17	21,0
Moderate Exposure to Drought	17	21,0
High Exposure to Drought	16	19,8
Very High Exposure to Drought	15	18,5
Total	81	100

Provinces that are very highly exposed to drought are particularly evident in the majority of western, southwestern and inner parts of Turkey. Samsun stands out as the only province that is highly exposed to drought in the northern part, which receives the most precipitation in Turkey (Figure 61).

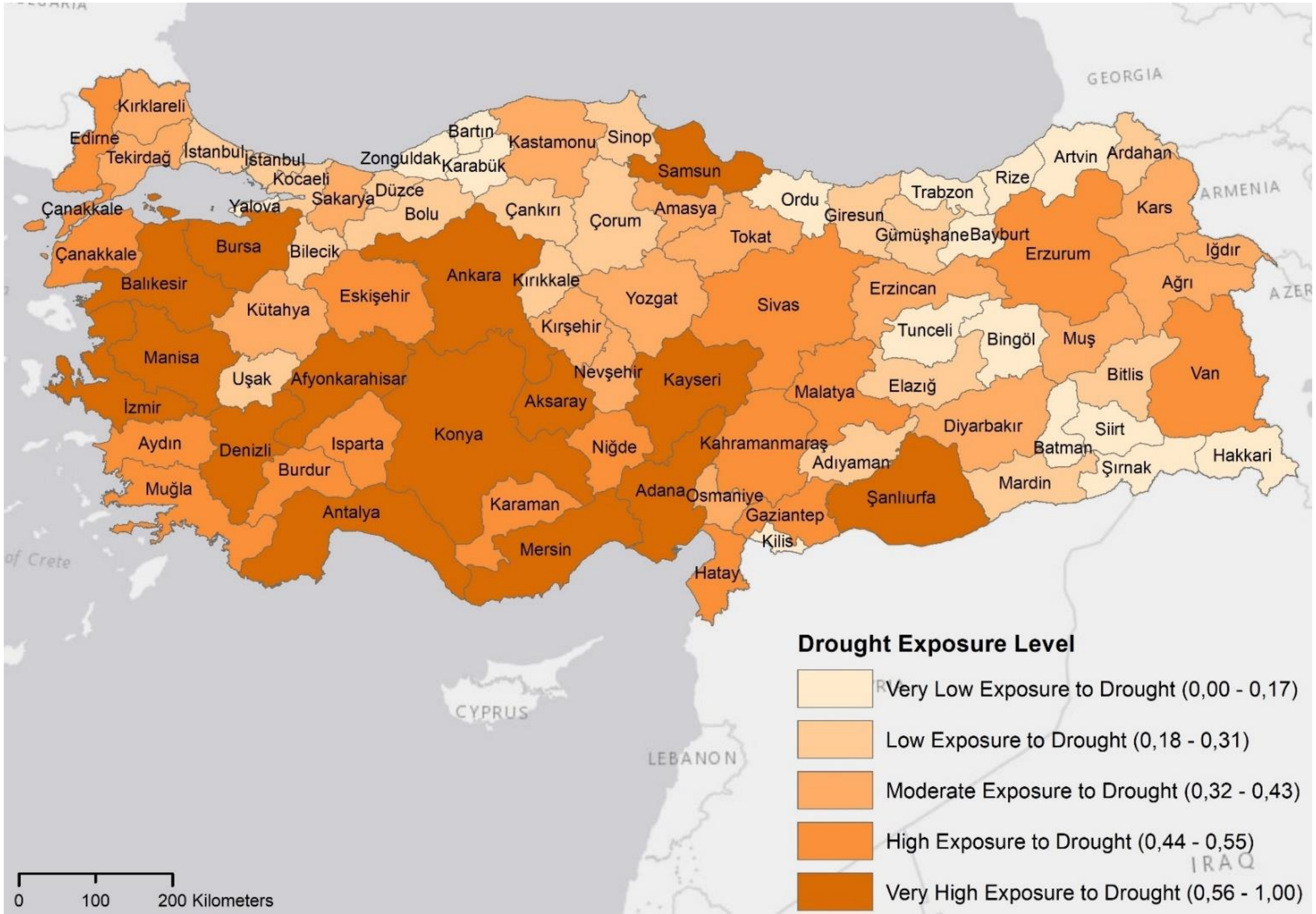

Figure 61: Drought Exposure Level of the Provinces in Turkey

5.3.2.3. Drought Sensitivity

Five indicators are selected to represent sensitivity dimension of drought risk: the number of species in Red List category (SPECIES_RED), agricultural GDP (AGR_GDP), poverty (PVRTY), unemployment (UNEMP), and dependency ratio (DEPND).

KMO and Bartlett's Test Score is calculated. KMO value being equal to 0.76 and a significance level for the Bartlett's test below 0.05 indicate there is substantial correlation in the data (Table 87).

Table 78: The KMO and Bartlett's Test Score

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,763
Bartlett's Test of Sphericity	Approx. Chi-Square	159,657
	df	10
	Sig.	0,000

According to Table 79, indicators are correlated with each other. The strongest correlation is between dependency rate and poverty rate (r=0.748, p<0.05).

Table 79: Correlation Matrix

Correlation Matrix[a]

		SPECIES_RED	AGR_GDP	PVRTY	UNEMP	DEPND
Correlation	SPECIES_RED	1,000	0,420	0,355	0,609	0,421
	AGR_GDP	0,420	1,000	0,495	0,387	0,469
	PVRTY	0,355	0,495	1,000	0,501	0,748
	UNEMP	0,609	0,387	0,501	1,000	0,534
	DEPND	0,421	0,469	0,748	0,534	1,000

a. Determinant = 0,127

The total variance explained (Table 80) for measuring this construct is 59.73% which exceeds the minimum threshold of 30% in one-factor solutions (Büyüköztürk, 2007; Çokluk et al., 2016). Therefore, selected indicators represent sensitivity factor.

Table 80: Total Variance Explained

Total Variance Explained

Component	Initial Eigenvalues Total	Initial Eigenvalues % of Variance	Initial Eigenvalues Cumulative %	Extraction Sums of Squared Loadings Total	Extraction Sums of Squared Loadings % of Variance	Extraction Sums of Squared Loadings Cumulative %
1	2,987	59,734	59,734	2,987	59,734	59,734
2	0,796	15,927	75,661			
3	0,618	12,359	88,020			
4	0,354	7,084	95,104			
5	0,245	4,896	100,000			

Extraction Method: Principal Component Analysis.

Table 81 shows the loadings of the five variables on sensitivity factor extracted. The results indicate that all the indicators make statistically significant contributions to the sensitivity factor, with loads higher than 0.32 (Tabachnick and Fidell, 2014).

Table 81: The Components and Their Respective Items,

Component Matrix[a]

	Component 1
DEPND	0,836
PVRTY	0,816
UNEMP	0,786
SPECIES_RED	0,713
AGR_GDP	0,704

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Cronbach’s alpha is calculated for these five variables loaded on factor 1 (Table 82). 0.830 is greater than 0.6 threshold for reliability (Robinson et al., 1991; Bagozzi and Yi, 1988; Wim et al., 2008; Van Griethuijsen et al., 2015; Ursachi et al., 2015).

Table 82: The Internal Reliability

Reliability Statistics

Cronbach's Alpha	N of Items
0,830	5

Weights are assigned according to the approach used by Nicoletti et al. (2000). In this context, Table 83 shows the factor loadings, and squared factor loadings scaled to unity sum, which are used to compute weights.

Table 83: Factor Loadings of Sensitivity Indicators

Factor Loading		**Squared Factor Loading (scaled to unity sum)**
	Factor 1	Factor 1
DEPND	0,836	**0,234**
PVRTY	0,816	**0,223**
UNEMP	0,786	**0,207**
SPECIES_RED	0,713	**0,170**
AGR_GDP	0,704	**0,166**
Explained Variance	2,987	
Explained Variance/Total Variance	1	

Table 84 indicates weights for the sensitivity indicators based on principal components method for the extraction of the common factors.

Table 84: Weights for the Sensitivity Indicators

Indicators	**Weight**
DEPND	0,234
PVRTY	0,223
UNEMP	0,207
SPECIES_RED	0,170
AGR_GDP	0,166

Drought sensitivity index is calculated in SPSS by multiplying the normalized variables raised to the power of their weights as it is indicated in the methods chapter of the thesis. Drought hazard map is generated based on sensitivity index score using natural breaks classification by defining five classes that represent very low, low, moderate, high, and very high sensitivity to drought, respectively.

The drought sensitivity index represents the aggregate of sensitivity from five indicators: the number of species in Red List category (SPECIES_RED), agricultural GDP (AGR_GDP), poverty (PVRTY), unemployment (UNEMP), and dependency ratio (DEPND). According to Table 85, high/very high levels of drought sensitivity are observed in more than 20% of the total number of provinces.

Table 85: Number of Provinces in terms of Drought Sensitivity Levels

Drought Sensitivity Level	**Number of Provinces**	**Share (%)**
Very Low Sensitivity to Drought	6	7,4
Low Sensitivity to Drought	33	40,7
Moderate Sensitivity to Drought	24	29,6
High Sensitivity to Drought	12	14,8
Very High Sensitivity to Drought	6	7,4
Total	81	100

Provinces with high sensitivity are mostly concentrated in the south-eastern and eastern parts of Turkey, as it is also the case for heat wave sensitivity (Figure 62). Kilis, Diyarbakır, Batman, Şırnak, Siirt, and Mardin take the lead as the provinces most sensitive to drought.

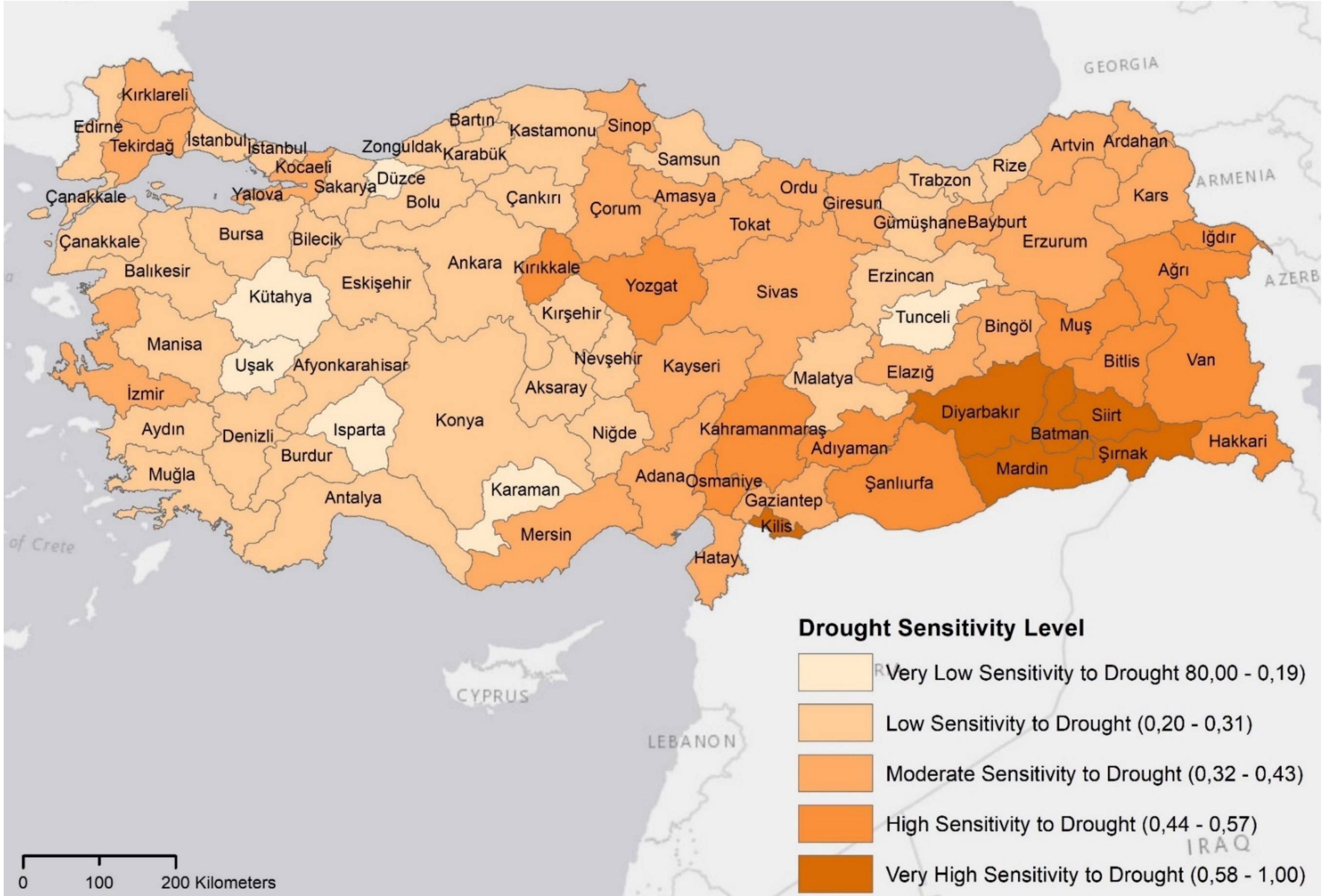

Figure 62: Drought Sensitivity Level of the Provinces in Turkey

5.3.2.4. Drought Adaptive Capacity

Six indicators were selected to represent adaptive capacity dimension of drought risk: Amount of water treated (WATER_TRE), high education (HIGH_EDU), civic engagement (CIVIC_ENG), level of interest in environmental issues (ENV_INT), GDP per capita (GDPPERC), saving deposit per capita (SAV_DEP), and R&D investments (R&D_INV).

KMO and Bartlett's Test Score is calculated. KMO value being equal to 0.69 and a significance level for the Bartlett's test below 0.05 indicate there is substantial correlation in the data (Table 86).

Table 86: The KMO and Bartlett's Test Score

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,689
Bartlett's Test of Sphericity	Approx. Chi-Square	474,599
	df	21
	Sig.	0,000

According to Table 87, indicators are correlated with each other. The strongest correlation is between the amount of water treated and R&D investments ($r=0.98$, $p<0.05$). However, the determinant of the correlation matrix exceeds 0.00001, then there is no multicollinearity in the data (Field, 2013).

Table 87: Correlation Matrix

Correlation Matrix[a]

		HIGH EDU	CIVIC_ ENG	GDP PERC	SAV_ DEP	WATER TRE	R&D_ INV	ENV_ INT
Correlation	HIGH_EDU	1,000	0,200	0,758	0,762	0,489	0,491	0,197
	CIVIC_ENG	0,200	1,000	0,279	0,138	0,121	0,097	0,529
	GDPPERC	0,758	0,279	1,000	0,759	0,548	0,543	0,037
	SAV_DEP	0,762	0,138	0,759	1,000	0,664	0,665	0,053
	WATER_TRE	0,489	0,121	0,548	0,664	1,000	0,975	0,018
	R&D_INV	0,491	0,097	0,543	0,665	0,975	1,000	0,051
	ENV_INT	0,197	0,529	0,037	0,053	0,018	0,051	1,000

a. Determinant = 0,002

According to total variance explained table (Table 88), two factors have eigenvalues above 1 and they explain 74.86% of the total variance.

Table 88: Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3,735	53,361	53,361	3,735	53,361	53,361	3,654	52,198	52,198
2	1,505	21,499	74,860	1,505	21,499	74,860	1,586	22,662	74,860
3	0,833	11,894	86,754						
4	0,516	7,365	94,119						
5	0,203	2,894	97,012						
6	0,186	2,662	99,674						
7	0,023	0,326	100,000						

Extraction Method: Principal Component Analysis.

A parallel analysis is conducted to decide the number of factors to retain. Parallel analysis indicates that eigenvalues of the first two factors obtained from PCA are greater than those obtained from PA (Table 89). Therefore, two factors are decided to be retained as the eigenvalue of the third factor's simulated data is higher than that of the actual data.

Table 89: Eigenvalues Retrieved from PCA and PA

Factor	Eigenvalues obtained from PCA	Eigenvalues obtained from PA
1	**3,735**	**1,615**
2	**1,505**	**1,348**
3	0,833	1,202
4	0,516	1,051
5	0,203	0,946
6	0,186	0,833
7	0,023	0,712

Scree plot covering the factors and respective eigenvalues also shows that there are two factors above the interpolation line of Parallel Analysis (Figure 63). Therefore, two factors are decided to be retained.

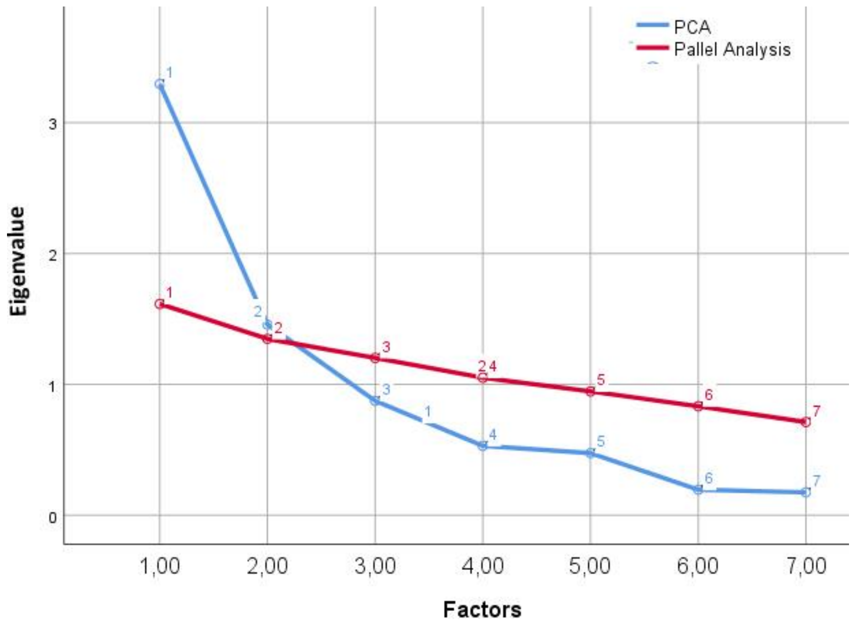

Figure 63: Scree Plot of Parallel Analysis

Since the number of factors is not different from what PCA extracted, total variance explained remains unchanged, as it is indicated in Table 88. As the next step, Table 90 displays the loadings of the seven variables on the factors extracted. The results indicate that all the indicators make statistically significant contributions to the adaptive capacity factor.

Table 90: Rotated Component Matrix

Rotated Component Matrix[a]

	Component	
	1	2
SAV_DEP	0,896	
WATER_TRE	0,876	
R&D_INV	0,874	
GDPPERC	0,826	
HIGH_EDU	0,787	
ENV_INT		0,867
CIVIC_ENG		0,855

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.

Cronbach's alpha is calculated for the two factors retained (Table 91). The alpha values are 0.85 and 0.69 for factor 1 and factor 2, respectively. These values are greater than 0.6 threshold for reliability (Robinson et al., 1991; Bagozzi and Yi, 1988; Wim et al., 2008; Van Griethuijsen et al., 2015; Ursachi et al., 2015).

Table 91: The Internal Reliability

	Cronbach's Alpha	N of Items
Factor 1	0,847	5
Factor 2	0,692	2

Weights are assigned according to the approach used by Nicoletti et al. (2000). In this context, Table 92 shows the rotated factor loadings, and squared factor loadings scaled to unity sum, which are used to compute weights.

Table 92: Factor Loadings of Adaptive Capacity Indicators

Factor Loading			**Squared Factor Loading (scaled to unity sum)**	
	Factor 1	Factor 2	Factor 1	Factor 2
SAV_DEP	0,896	0,068	**0,220**	0,003
WATER_TRE	0,876	-0,058	**0,210**	0,002
R&D_INV	0,874	-0,052	**0,209**	0,002
GDP_PERC	0,826	0,178	**0,187**	0,020
HIGH_EDU	0,787	0,249	**0,169**	0,039
ENV_INT	0,000	0,867	0,000	**0,473**
CIVIC_ENG	0,130	0,855	0,005	**0,461**
Explained Variance	3,654	1,586		
Explained Variance/ Total Variance	**0,697**	**0,303**		

Table 93 indicates weights for the adaptive capacity indicators based on principal components method for the extraction of the common factors.

Table 93: Weights for the Adaptive Capacity Indicators

Indicators	**Weight**
SAV_DEP	0,157
WATER_TRE	0,150
R&D_INV	0,149
GDP_PERC	0,133
HIGH_EDU	0,121
ENV_INT	0,147
CIVIC_ENG	0,143

Drought adaptive capacity index is calculated in SPSS by multiplying the normalized variables raised to the power of their weights as it is indicated in the methods chapter of the thesis. Drought adaptive capacity map is generated based on adaptive capacity index score using natural breaks classification by defining five classes that represent very low, low, moderate, high, and very high adaptive capacity to drought, respectively.

The drought adaptive capacity index represents the aggregate of adaptive capacity from seven indicators: the amount of water treated (WATER_TRE), high education (HIGH_EDU), civic engagement (CIVIC_ENG), level of interest in environmental issues (ENV_INT), GDP per capita (GDPPERC), saving deposit per capita (SAV_DEP), and R&D investments (R&D_INV). Results indicate that 54% of the provinces have low/very low levels of capacity to adapt to drought, while there are only four provinces with very high adaptive capacity (Table 94).

Table 94: Number of Provinces in terms of Drought Adaptive Capacity Levels

Drought Adaptive Capacity Level	**Number of Provinces**	**Share (%)**
Very Low Adaptive Capacity to Drought	12	14,8
Low Adaptive Capacity to Drought	32	39,5
Moderate Adaptive Capacity to Drought	22	27,2
High Adaptive Capacity to Drought	11	13,6
Very High Adaptive Capacity to Drought	4	4,9
Total	81	100

As mentioned above, more than half of the provinces in Turkey have low capacity against drought. Provinces with the lowest adaptive capacity are particularly evident in the eastern and southeastern parts, Afyonkarahisar in the western part, and Osmaniye in the south (Figure 64).

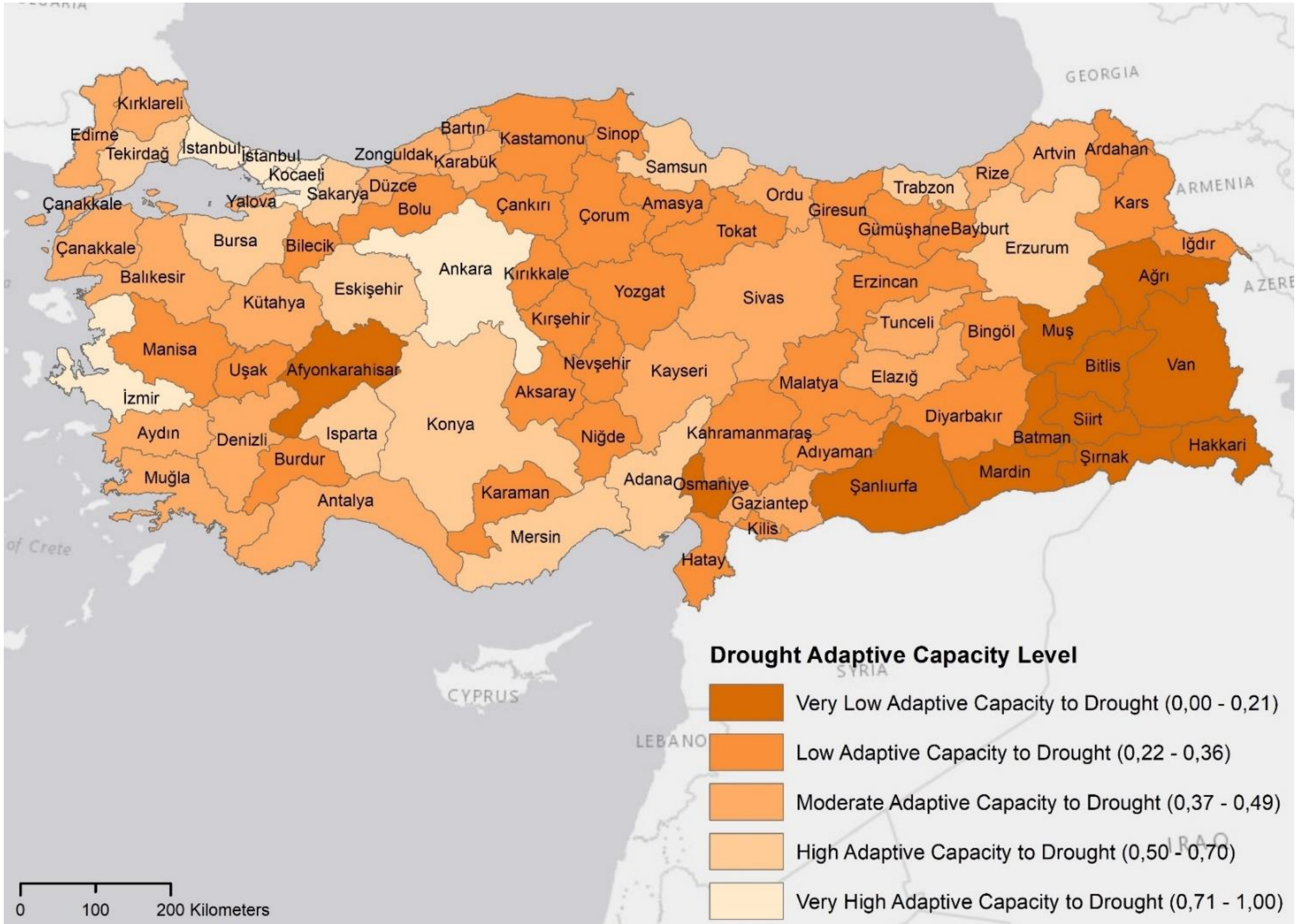

Figure 64: Drought Adaptive Capacity Level of the Provinces in Turkey

5.3.2.5. Drought Vulnerability and Risk Profiles of Provinces

As it is previously discussed in Chapter 2, vulnerability as a function of sensitivity and adaptive capacity, has a positive functional relationship with sensitivity, and a negative functional relationship with adaptive capacity, which leads to vulnerability increases as sensitivity increases and adaptive capacity decreases, or vice versa.

The drought vulnerability index is thus calculated using drought sensitivity index and drought adaptive capacity index, which are elaborated in previous parts. Results demonstrate that 16% of the provinces are high/very high levels of drought vulnerability. 63% of them are vulnerable to drought at low or very low levels (Table 95).

Table 95: Number of Provinces in terms of Drought Vulnerability Level

Drought Vulnerability Level	**Number of Provinces**	**Share (%)**
Very Low Vulnerability to Drought	14	17,3
Low Vulnerability to Drought	37	45,7
Moderate Vulnerability to Drought	17	21,0
High Vulnerability to Drought	9	11,1
Very High Vulnerability to Drought	4	4,9
Total	81	100

According to the results, the southeastern part of Turkey is particularly vulnerable to drought due to high levels of sensitivity and low levels of adaptive capacity, as it is also the case for heat wave vulnerability (Figure 65). Siirt, Şırnak, Batman, and Mardin are found to be the most vulnerable provinces to drought.

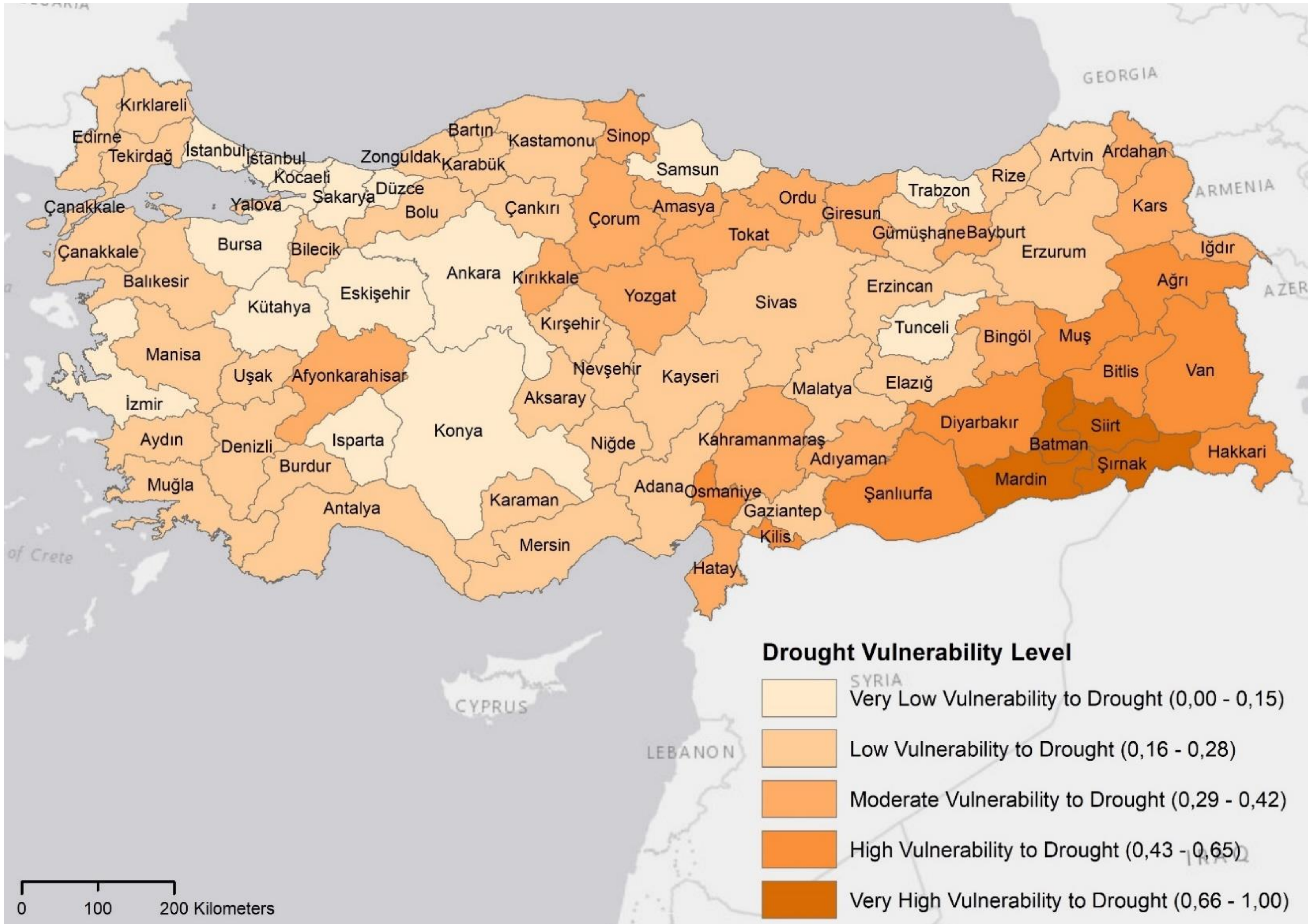

Figure 65: Drought Vulnerability Level of the Provinces in Turkey

Drought risk index is calculated in SPSS by multiplying the sub-indices of hazard, exposure, sensitivity, and dividing the result by adaptive capacity in accordance with the methods chapter of the thesis. The results of drought risk index indicate the risk levels of provinces, which are represented using natural breaks classification technique in SPSS to show the results of this study. In this context, the drought risk value is categorized into five classes to explain the relative position of each province that represent the very low, low, moderate, high, and very high risk of drought, respectively. The results show that 37% of the provinces indicate high/very high levels of drought risk (Table 96).

Table 96: Number of Provinces in terms of Drought Risk Level

Drought Risk Level	**Number of Provinces**	**Share (%)**
Very Low Risk of Drought	11	13,6
Low Risk of Drought	15	18,5
Moderate Risk of Drought	25	30,9
High Risk of Drought	20	24,7
Very High Risk of Drought	10	12,3
Total	81	100

After categorizing provinces in terms of their risk values, risk levels are mapped using ArcGis 10.7 as it is shown in Figure 66. Drought risk is particularly evident in the inner, southern, and eastern parts of Turkey. There is a medium to very high drought risk in all provinces of Turkey except for the provinces on the northern line and a few provinces in the south-eastern region.

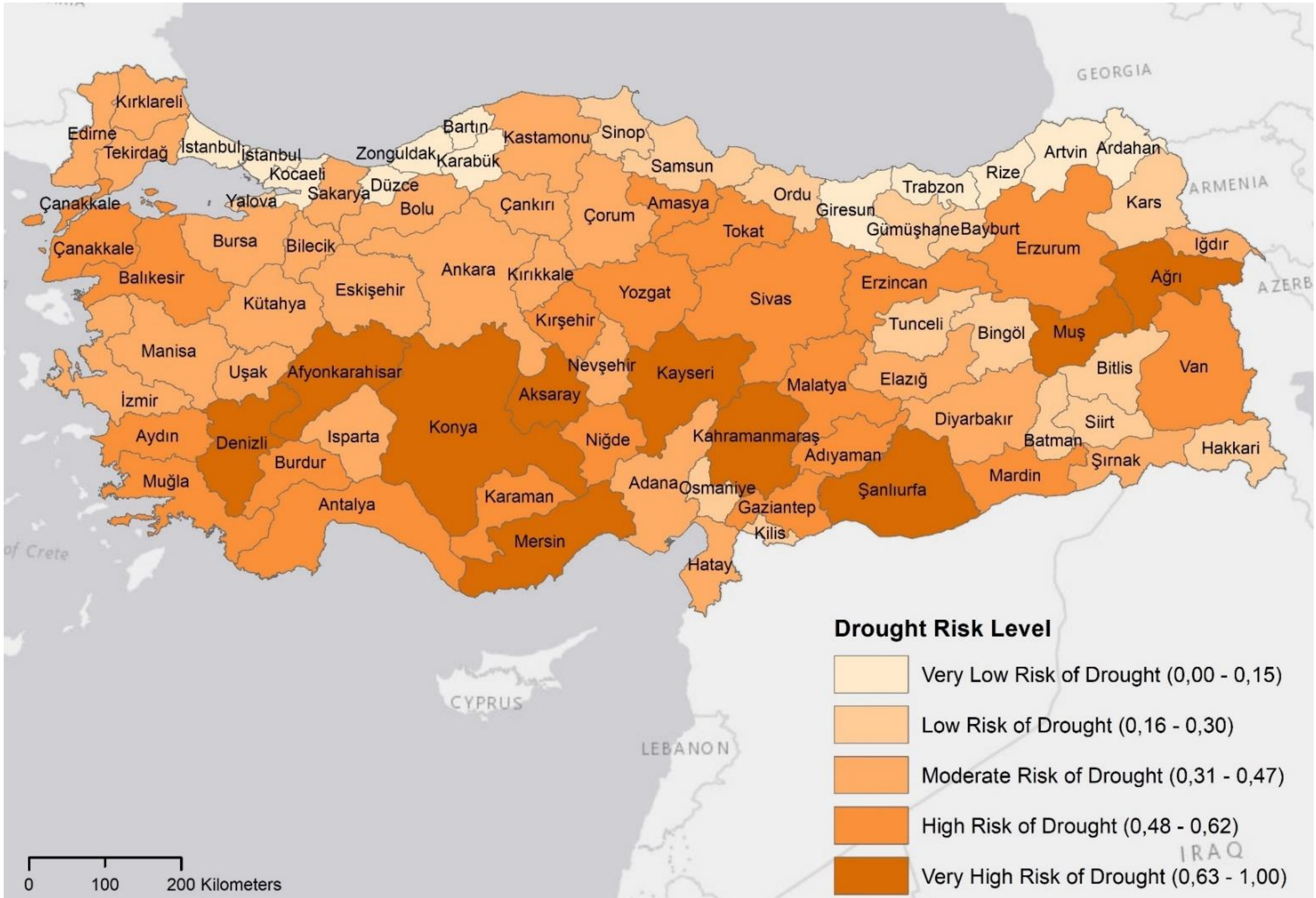

Figure 66: Drought Risk Level

5.3.3. Forest Fire Risk

Forest fire risk is another climate-related risk analyzed in this study. Forest fire risk is considered as the product of the impacts from forest fire hazard and the probability that it occurs. The impact of a forest fire is affected by vulnerability and exposure to forest fire. In this study, (1) the forest fire hazard is considered as a latent damaging physical event for forest areas as natural resources, forest-based livelihood and biodiversity; (2) exposure refers to the presence of forest areas, forest-based livelihood and biodiversity in places and settings that could be adversely affected by forest fire; (3) forest fire vulnerability is the function of sensitivity and adaptive capacity of forests, forest-based livelihood and biodiversity to forest fire. To compute forest fire risk, there are 21 indicators in total used under the four components of risk (Figure 67).

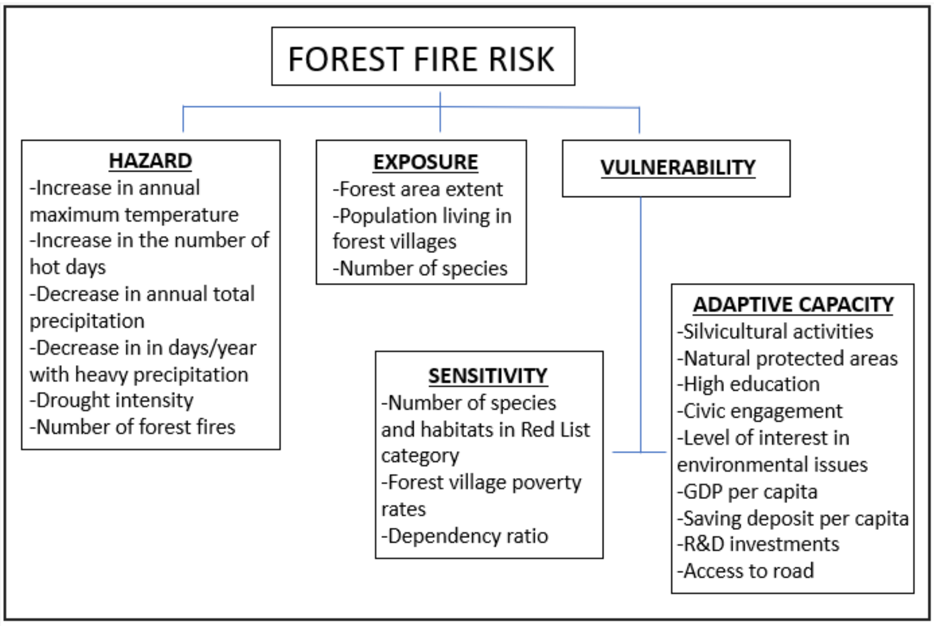

Figure 67: Indicators Scheme for Forest Fire Risk

Forest fire risk index is prepared according to the methods mentioned in the previous chapter. In this vein, forest fire hazard, forest fire exposure, forest fire sensitivity, and forest fire adaptive capacity sub-indices are generated and aggregated to obtain forest fire risk index.

5.3.3.1. Forest Fire Hazard

Six indicators are selected to represent hazard dimension of forest fire risk: increase in annual maximum temperature (TEMPER_MAX), increase in the number of hot days where Tmax>30°C in a year (HOTDAYS), decrease in annual total precipitation (PRECIP), and decrease in in days/year with heavy precipitation (HEAVY_PRECIP), drought conditions (DROUGHT), and the number of forest fire (FFIRES). Drought and forest fires are highly connected, in which drought increases the risk of forest fires as dry trees and shrubs serve as fuel for fires (IPCC, 2012). Considering the drought and heat exacerbate forest fires, the indicators in drought hazard used in this dimension as well.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) measures how strongly the variables being tested correlate. Raw data becomes suitable for conducting a factor analysis if the KMO is greater than or equals to 0.50 (Kaiser, 1974; Hair et al., 2006; Field, 2009). Since KMO value is 0.6 and significance level for the Bartlett's test is below 0.05, there is substantial correlation in the data (Table 97). Therefore, the results meet the assumptions to proceed with PCA/FA.

Table 97: The KMO and Bartlett's Test Score

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,596
Bartlett's Test of Sphericity	Approx. Chi-Square	123,509
	df	15
	Sig.	0,000

According to Table 98, there is a weak positive correlation between the number of forest fires and the other variables, which may stem from the data of the number of forest fires in provinces cover the years between 2013 and 2018, unlike the rest of the variables. Multicollinearity exists when the variables are highly correlated. Since the determinant is greater than 0.0001 (Field 2000), then there is no multicollinearity and variables can be used in PCA/FA.

Table 98: Correlation Matrix

Correlation Matrix[a]							
		TEMPER_MAX	HOTDAYS	DROUGHT	PRECIP	FFIRES	HEAVY_PRECIP
Correlation	TEMPER_MAX	1,000	0,547	-0,032	0,146	0,037	0,027
	HOTDAYS	0,547	1,000	-0,109	0,317	0,101	0,109
	DROUGHT	-0,032	-0,109	1,000	0,411	0,218	0,529
	PRECIP	0,146	0,317	0,411	1,000	0,124	0,691
	FFIRES	0,037	0,101	0,218	0,124	1,000	0,138
	HEAVY_PRECIP	0,027	0,109	0,529	0,691	0,138	1,000

a. Determinant = 0,202

The two-factor model accounted for 63.3% of the total variance (Table 99), which is acceptable as it exceeds the minimum 40% (Büyüköztürk, 2007; Çokluk et al., 2016). Therefore, selected indicators represent hazard factor.

Table 99: Total Variance Explained

Total Variance Explained									
	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2,236	37,263	37,263	2,236	37,263	37,263	2,164	36,068	36,068
2	1,562	26,031	63,294	1,562	26,031	63,294	1,634	27,227	63,294
3	0,957	15,957	79,252						
4	0,608	10,131	89,383						
5	0,365	6,083	95,466						
6	0,272	4,534	100,000						

Extraction Method: Principal Component Analysis.

A parallel analysis is conducted to decide the number of factors to retain. Parallel analysis indicates that eigenvalues of the first two factors obtained from PCA is greater than those obtained from PA (Table 100). Therefore, two factors are decided to be retained as the eigenvalue of the third factor's simulated data is higher than that of the actual data.

Table 100: Eigenvalues Retrieved from PCA and PA

Factor	Eigenvalues obtained from PCA	Eigenvalues obtained from PA
1	**2,236**	**1,519**
2	**1,562**	**1,292**
3	0,957	1,113
4	0,608	0,997
5	0,365	0,900
6	0,272	0,748

Scree plot covering the factors and respective eigenvalues also shows that there are two factors above the interpolation line of Parallel Analysis (Figure 68). Therefore, two factors are decided to be retained, and PCA is rerun so as to extract two factors.

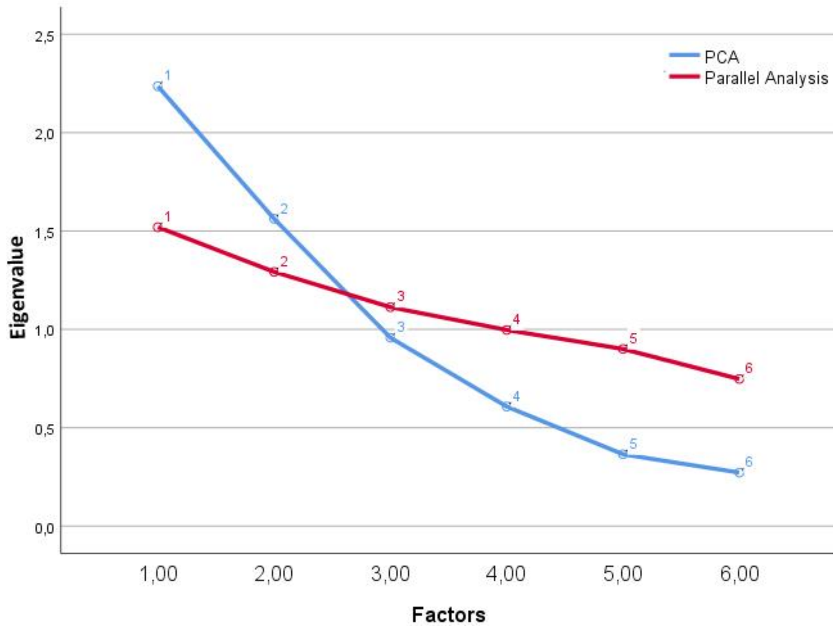

Figure 68: Scree Plot of Parallel Analysis

Since the number of factors is not different from what PCA extracted, total variance explained remains unchanged, as it is indicated in Table 99. As the next step, Table 101 indicates the loadings of the six variables on the factors extracted. The results indicate that all the indicators make statistically significant contributions to the hazard factor.

Table 101: Rotated Component Matrix

Rotated Component Matrix[a]

	Component 1	Component 2
HEAVY_PRECIP	0,880	
PRECIP	0,813	
DROUGHT	0,778	
FFIRES	0,334	
HOTDAYS		0,888
TEMPER_MAX		0,844

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.

Cronbach's alpha is calculated for the two factors retained (Table 102). The alpha values are 0.69 and 0.71 for factor 1 and factor 2, respectively. These values are greater than 0.66 threshold for reliability (Robinson et al., 1991; Bagozzi and Yi, 1988; Wim et al., 2008; Van Griethuijsen et al., 2015; Ursachi et al., 2015).

Table 102: The Internal Reliability

	Cronbach's Alpha	N of Items
Factor 1	0,685	4
Factor 2	0,708	2

Weights are assigned according to the approach used by Nicoletti et al. (2000). In this context, Table 103 shows the factor loadings, and squared factor loadings scaled to unity sum, which are used to compute weights.

Table 103: Factor Loadings of Hazard Indicators

Factor Loading			Squared Factor Loading (scaled to unity sum)	
	Factor 1	Factor 2	Factor 1	Factor 2
HEAVY_PRECIP	0,880	0,032	**0,358**	0,001
PRECIP	0,813	0,277	**0,305**	0,047
DROUGHT	0,778	-0,221	**0,280**	0,030
FFIRES	0,334	0,068	**0,052**	0,003
HOTDAYS	0,106	0,888	0,005	**0,483**
TEMPER_MAX	0,011	0,844	0,000	**0,436**
Explained Variance	2,164	1,634		
Explained Variance/ Total Variance	**0,570**	**0,430**		

Table 104 indicates weights for the hazard indicators based on principal components method for the extraction of the common factors.

Table 104: Weights for the Hazard Indicators

Indicators	**Weight**
HEAVY_PRECIP	0,212
PRECIP	0,181
DROUGHT	0,166
FFIRES	0,031
HOTDAYS	0,216
TEMPER_MAX	0,195

Forest fire hazard index is calculated in SPSS by multiplying the normalized variables raised to the power of their weights as it is indicated in the methods chapter of the thesis. Forest fire hazard map is prepared based on the hazard index score using natural breaks classification by defining five classes that represent very low, low, moderate, high, and very high forest fire hazard, respectively.

The forest fire hazard index represents the aggregate of hazard from six indicators: increase in annual maximum temperature (TEMPER_MAX), increase in the number of hot days where Tmax>30°C in a year (HOTDAYS), decrease in annual total precipitation (PRECIP), and decrease in in days/year with heavy precipitation (HEAVY_PRECIP), drought conditions (DROUGHT), and the number of forest fire (FFIRES). According to the results, high or very high forest fire hazard level is observed in 47% of the total number of provinces. When the provinces with moderate hazard level, this rate increases to 62% (Table 105).

Table 105: Number of Provinces in terms of Forest Fire Hazard Levels

Forest Fire Hazard Level	**Number of Provinces**	**Share (%)**
Very Low Forest Fire Hazard	14	17,3
Low Forest Fire Hazard	17	21,0
Moderate Forest Fire Hazard	12	14,8
High Forest Fire Hazard	27	33,3
Very High Forest Fire Hazard	11	13,6
Total	81	100

As it is indicated above, moderate and higher levels of forest fire hazard prevail the majority of provinces in Turkey. Provinces with very high forest fire hazard concentrate in the northwestern parts (Balıkesir and Bilecik), southwestern part (Denizli, Burdur, and Muğla), inner part (Kırıkkale, Kırşehir, Tokat, Malatya, and Kahramanmaraş) and Mersin in the southern part of Turkey (Figure 69).

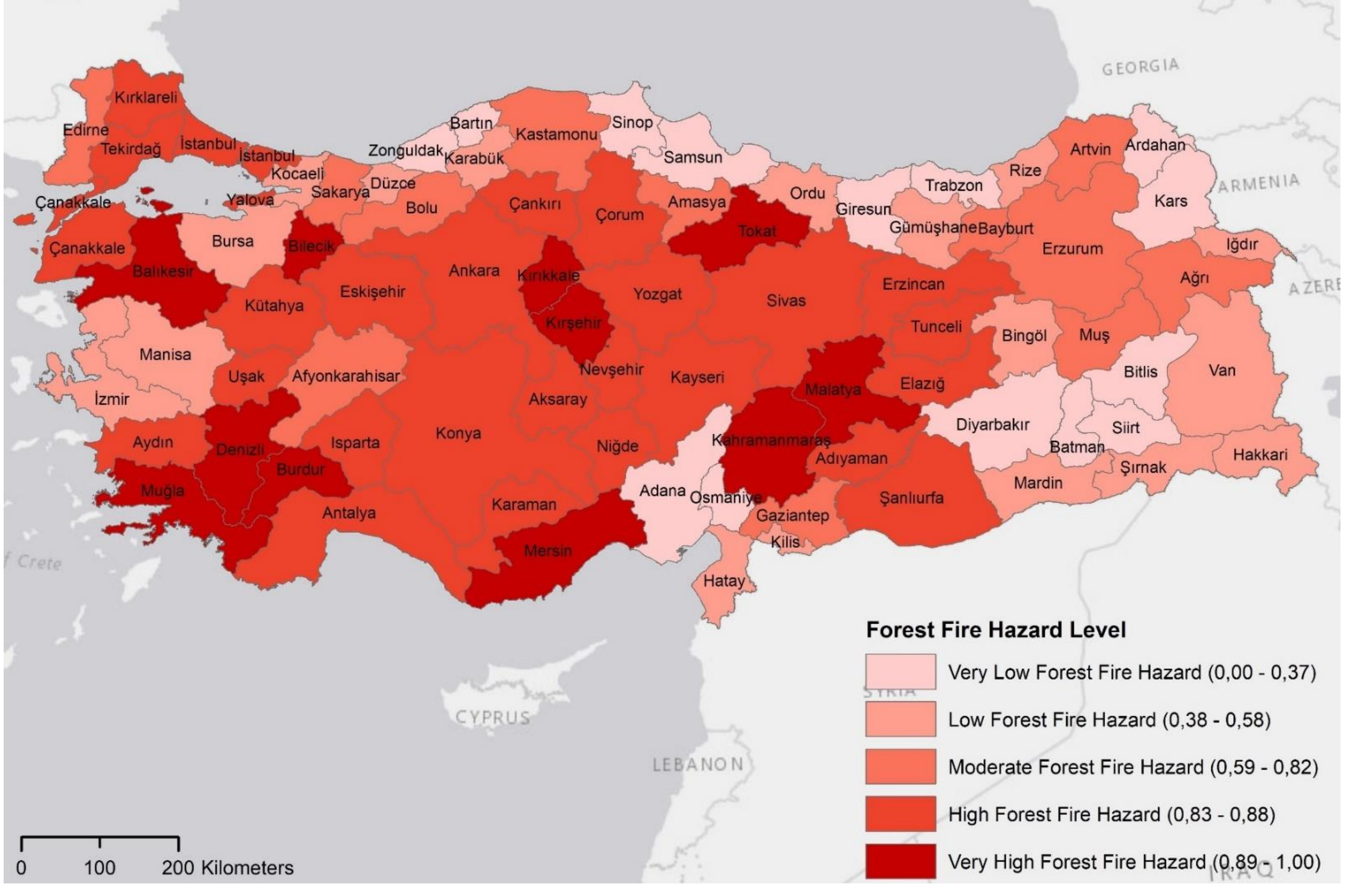

Figure 69: Forest Fire Hazard Level of the Provinces in Turkey

5.3.3.2. Forest Fire Exposure

Three indicators are selected to represent exposure dimension of forest fire risk: forest area extent (FOREST), population living in forest villages (POP_FOR_VIL), and the number of species (SPECIES). First, as it is indicated in Table 106, Cronbach's alpha is calculated for these three variables before the PCA/FA since the number of items does not allow more than one factor to exist (Raubenheimer, 2004). 0.77 is greater than 0.6 threshold for reliability (Robinson et al., 1991; Bagozzi and Yi, 1988; Wim et al., 2008; Van Griethuijsen et al., 2015; Ursachi et al., 2015), thus, consistency of the variables is at a satisfactory level.

Table 106: Reliability Statistics

Reliability Statistics

Cronbach's Alpha	N of Items
0,770	3

KMO and Bartlett's Test Score is calculated. KMO value being equal to 0.611 and a significance level for the Bartlett's test below 0.05 indicate there is substantial correlation in the data (Table 107).

Table 107: The KMO and Bartlett's Test Score

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,611
Bartlett's Test of Sphericity	Approx. Chi-Square	78,271
	df	3
	Sig.	0,000

According to Table 108, the area of irrigated agricultural land is positively correlated with the number of agricultural workers (r=0.67). Since the determinant is greater than 0.0001 (Field 2000), then there is no multicollinearity and variables can be used in PCA/FA.

Table 108: Correlation Matrix

Correlation Matrix[a]

		SPECIES	POP_FOR_VIL	FOREST
Correlation	SPECIES	1,000	0,366	0,501
	POP_FOR_VIL	0,366	1,000	0,714
	FOREST	0,501	0,714	1,000

a. Determinant = 0,367

According to the Kaiser criterion, one factor needs to be extracted. This factor explains 68,93% of the total variance (Table 109), which exceed the minimum threshold of 30% in one-factor solutions (Büyüköztürk, 2007; Çokluk et al., 2016). Therefore, selected indicators represent exposure factor.

Table 109: Total Variance Explained

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2,068	68,927	68,927	2,068	68,927	68,927
2	0,665	22,168	91,095			
3	0,267	8,905	100,000			

Extraction Method: Principal Component Analysis.

Table 110 shows the loadings of the variables on exposure factor extracted. The results indicate that all the indicators make statistically significant contributions to the exposure factor, with loads higher than 0.32 (Tabachnick and Fidell, 2014).

Table 110: The Components and Their Respective Items

Component Matrix[a]

	Component 1
FOREST	0,908
POP_FOR_VIL	0,853
SPECIES	0,719

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Weights are assigned according to the approach used by Nicoletti et al. (2000). In this context, Table 111 shows the factor loadings, and squared factor loadings scaled to unity sum, which are used to compute weights.

Table 111: Factor Loadings of Exposure Indicators

Factor Loading		**Squared Factor Loading (scaled to unity sum)**
	Factor 1	Factor 1
FOREST	0,908	**0,398**
POP_FOR_VIL	0,853	**0,352**
SPECIES	0,719	**0,250**
Explained Variance	2,068	
Explained Variance/Total Variance	**1**	

Table 112 indicates weights for the exposure indicators based on principal components method for the extraction of the common factors.

Table 112: Weights for the Exposure Indicators

Indicators	**Weight**
FOREST	0,398
POP_FOR_VIL	0,352
SPECIES	0,250

Forest fire exposure index is calculated in SPSS by multiplying the normalized variables raised to the power of their weights as it is explained in the methods chapter of the thesis. Forest fire exposure map is prepared based on the exposure index score using natural breaks classification by defining five classes that represent very low, low, moderate, high, and very high exposure to forest fire, respectively.

The forest fire index represents the aggregate of exposure from three indicators: forest area extent (FOREST), population living in forest villages (POP_FOR_VIL), and the number of species (SPECIES). As it is indicated in Table 113, 79% of the provinces are exposed to forest fire at moderate to a very high level.

Table 113: Number of Provinces in terms of Forest Fire Exposure Levels

Forest Fire Exposure Level	**Number of Provinces**	**Share (%)**
Very Low Exposure to Forest Fire	6	7,4
Low Exposure to Forest Fire	11	13,6
Moderate Exposure to Forest Fire	26	32,1
High Exposure to Forest Fire	23	28,4
Very High Exposure to Forest Fire	15	18,5
Total	81	100

Provinces that are highly and very highly exposed to forest fire are particularly evident in the majority of western, southwestern and southern parts, in Samsun and Kastamonu in the northern part of Turkey (Figure 70). The concentration of provinces with very high exposure levels in the coastal areas is prominent.

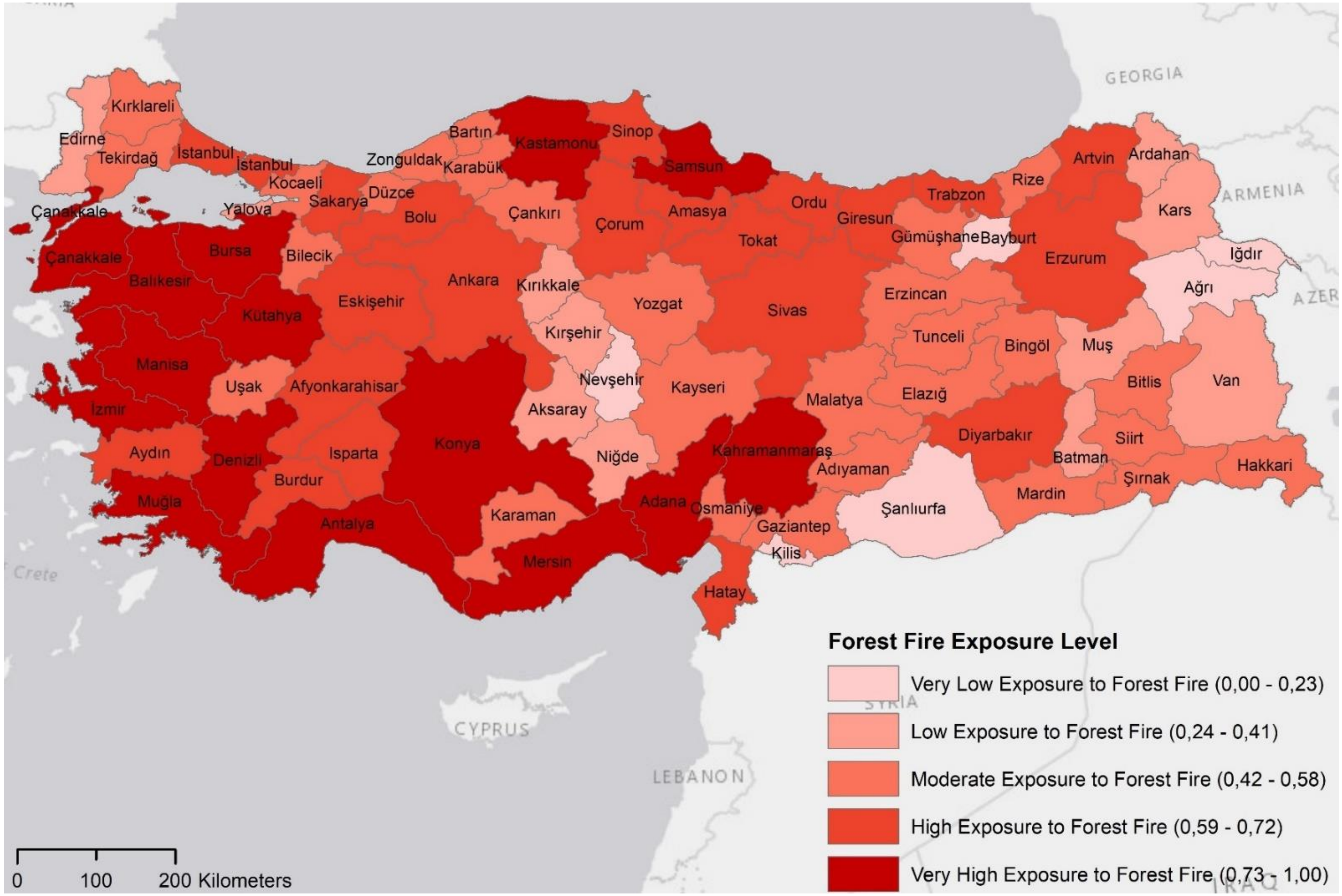

Figure 70: Forest Fire Exposure Level of the Provinces in Turkey

5.3.3.3. Forest Fire Sensitivity

Three indicators are selected to represent sensitivity dimension of forest fire risk: the number of species in Red List category (SPECIES_RED), forest village poverty rates (FOREST_POVERTY), and dependency ratio (DEPND). First, as indicated in Table 114, Cronbach's alpha is calculated for these three variables before the PCA/FA since the number of items does not allow more than one factor to exist (Raubenheimer, 2004). 0.65 is greater than 0.6 threshold for reliability (Robinson et al., 1991; Bagozzi and Yi, 1988; Wim et al., 2008; Van Griethuijsen et al., 2015; Ursachi et al., 2015), therefore, consistency of the variables is at a satisfactory level.

Table 114: The Internal Reliability

Reliability Statistics	
Cronbach's Alpha	N of Items
0,651	3

KMO and Bartlett's Test Score is calculated. KMO value being equal to 0.61 and a significance level for the Bartlett's test below 0.05 indicate there is substantial correlation in the data (Table 115).

Table 115: The KMO and Bartlett's Test Score

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,608
Bartlett's Test of Sphericity	Approx. Chi-Square	35,369
	df	3
	Sig.	0,000

According to Table 116, indicators are correlated with each other. The strongest correlation is between dependency rate and forest poverty rate ($r=0.471$, $p<0.05$).

Table 116: Correlation Matrix

Correlation Matrix[a]

		SPECIES RED	FOREST_ POVERTY	DEPND
Correlation	SPECIES_RED	1,000	0,259	0,422
	FOREST_POVERTY	0,259	1,000	0,471
	DEPND	0,422	0,471	1,000

a. Determinant = 0,636

The total variance explained (Table 117) for measuring this construct is 59.14% which exceeds the minimum threshold of 0.30 in one-factor solutions (Çokluk et al., 2016). Therefore, selected indicators represent sensitivity factor.

Table 117: Total Variance Explained

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1,774	59,143	59,143	1,774	59,143	59,143
2	0,744	24,790	83,932			
3	0,482	16,068	100,000			

Extraction Method: Principal Component Analysis.

Table 118 presents the loadings of the five variables on sensitivity factor extracted. The results indicate that all the indicators make statistically significant contributions to the sensitivity factor, with loads higher than 0.32 (Tabachnick and Fidell, 2014).

Table 118: The Components and Their Respective Items

Component Matrix[a]

	Component 1
DEPND	0,842
FOREST_POVERTY	0,750
SPECIES_RED	0,709

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Weights are assigned according to the approach used by Nicoletti et al. (2000). In this context, Table 119 shows the factor loadings, and squared factor loadings scaled to unity sum, which are used to compute weights.

Table 119: Factor Loadings of Sensitivity Indicators

Factor Loading		**Squared Factor Loading (scaled to unity sum)**
	Factor 1	Factor 1
DEPND	0,842	**0,400**
FOREST_POVERTY	0,750	**0,317**
SPECIES_RED	0,709	**0,283**
Explained Variance	1,774	
Explained Variance/Total Variance	**1**	

Table 120 indicates weights for the sensitivity indicators based on principal components method for the extraction of the common factors.

Table 120: Weights for the Sensitivity Indicators

Indicators	**Weight**
DEPND	0,400
FOREST_POVERTY	0,317
SPECIES_RED	0,283

Forest fire sensitivity index is calculated in SPSS by multiplying the normalized variables raised to the power of their weights as it is explained in the methods chapter of the thesis. Forest fire sensitivity map is prepared based on the sensitivity index score using natural breaks classification by defining five classes that represent very low, low, moderate, high, and very high sensitivity to forest fire, respectively.

The forest fire sensitivity index represents the aggregate of sensitivity from three indicators: the number of species in Red List category (SPECIES_RED), forest village poverty rates (FOREST_POVERTY), and dependency ratio (DEPND).

According to results, approximately one-third of the provinces are highly/very highly sensitive to forest fire (Table 121).

Table 121: Number of Provinces in terms of Forest Fire Sensitivity Levels

Forest Fire Sensitivity Level	**Number of Provinces**	**Share (%)**
Very Low Sensitivity to Forest Fire	9	11,1
Low Sensitivity to Forest Fire	18	22,2
Moderate Sensitivity to Forest Fire	28	34,6
High Sensitivity to Forest Fire	20	24,7
Very High Sensitivity to Forest Fire	6	7,4
Total	81	100

Provinces with very high sensitivity are mostly concentrated in the south-eastern part of Turkey. Also, highly and very highly sensitive provinces are found to be mostly located in the east half of the country (Figure 71).

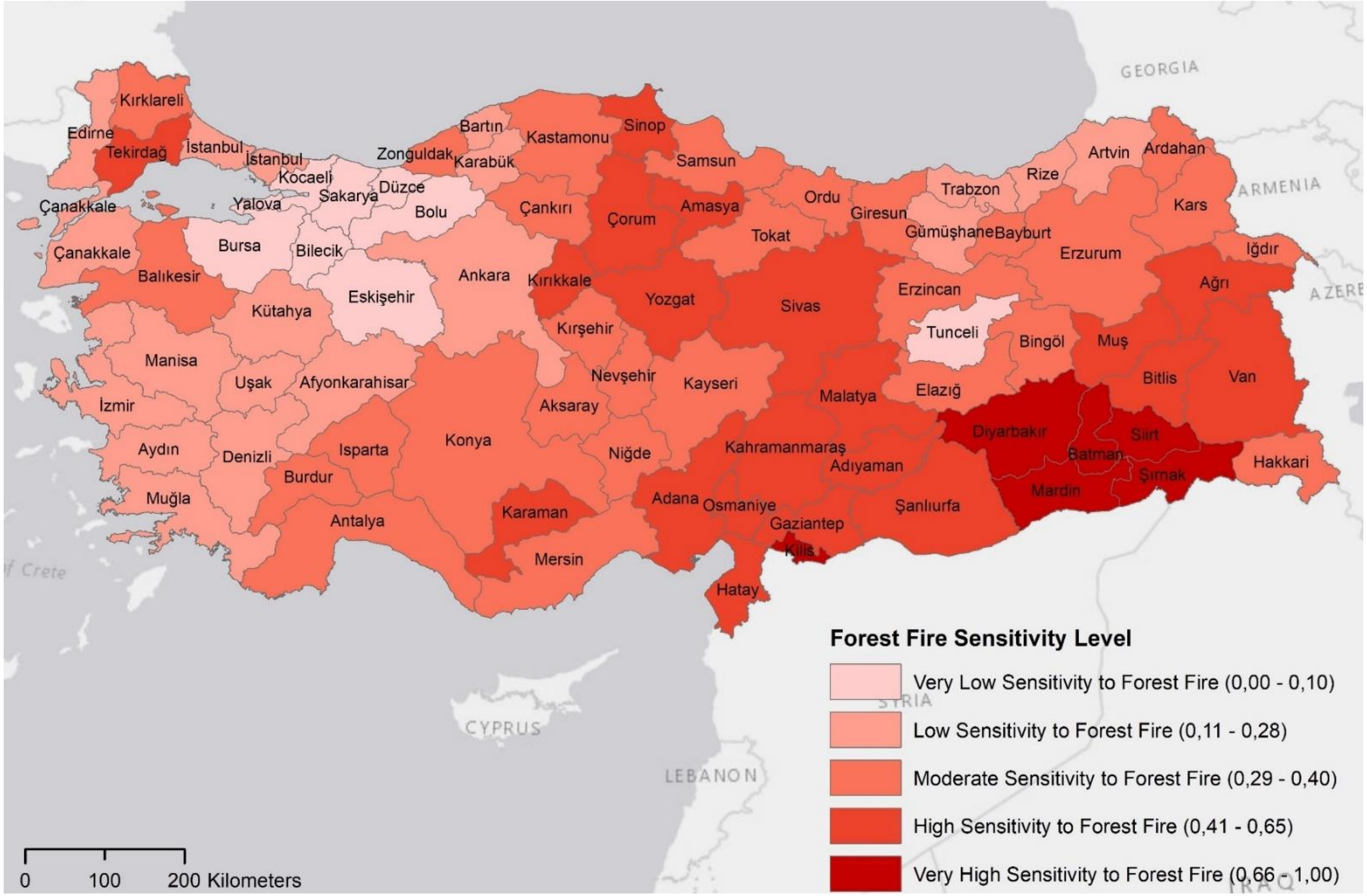

Figure 71: Forest Fire Sensitivity Level of the Provinces in Turkey

5.3.3.4. Forest Fire Adaptive Capacity

Nine indicators are selected to represent adaptive capacity dimension of forest fire risk: Silvicultural activities (SILVICULTURE), area protected by nature conservation law (PROTECT), high education (HIGH_EDU), civic engagement (CIVIC_ENG), level of interest in environmental issues (ENV_INT), GDP per capita (GDPPERC), saving deposit per capita (SAV_DEP), R&D investments (R&D_INV), and access to road network (ROAD).

KMO and Bartlett's Test Score is calculated. KMO value being equal to 0.70 and a significance level for the Bartlett's test below 0.05 indicate there is substantial correlation in the data (Table 122).

Table 122: The KMO and Bartlett's Test Score

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,697
Bartlett's Test of Sphericity	Approx. Chi-Square	372,581
	df	36
	Sig.	0,000

According to total variance explained table (Table 123), three factors have eigenvalues above 1 and they explain 73.14% of the total variance.

Table 123: Total Variance Explained

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3,981	44,233	44,233	3,981	44,233	44,233	3,680	40,891	40,891
2	1,510	16,775	61,008	1,510	16,775	61,008	1,594	17,709	58,600
3	1,092	12,129	73,137	1,092	12,129	73,137	1,308	14,536	73,137
4	0,809	8,988	82,124						
5	0,644	7,154	89,279						
6	0,423	4,703	93,981						
7	0,243	2,695	96,676						
8	0,181	2,007	98,683						
9	0,119	1,317	100,000						

Extraction Method: Principal Component Analysis.

A parallel analysis is conducted to decide the number of factors to retain. Parallel analysis indicates that eigenvalues of the first two factors obtained from PCA is greater than those obtained from PA (Table 124). Therefore, two factors are decided to be retained because the eigenvalue of the third factor's simulated data is higher than that of the actual data.

Table 124: Eigenvalues Retrieved from PCA and PA

Factor	Eigenvalues obtained from PCA	Eigenvalues obtained from PA
1	**3,981**	**1,704**
2	**1,510**	**1,459**
3	1,092	1,314
4	0,809	1,164

Scree plot covering the factors and respective eigenvalues also shows that there are two factors above the interpolation line of Parallel Analysis (Figure 72). Therefore, two factors are decided to be retained, and PCA is rerun so as to extract two factors.

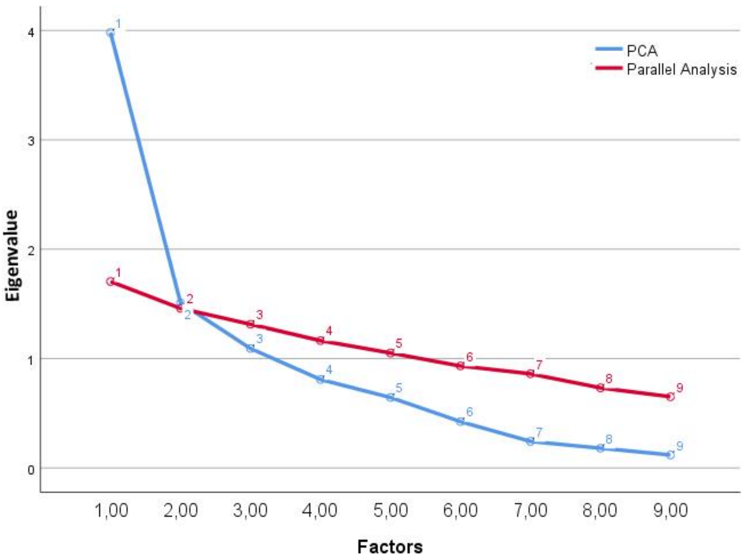

Figure 72: Scree Plot of Parallel Analysis

After determining the number of factors retained, the new table of total variance explained is generated. Two factors extracted explains 61.01% of the total variance (Table 125), which is acceptable as it exceeds the minimum 40% (Büyüköztürk, 2007; Çokluk et al., 2016). Therefore, selected indicators represent adaptive capacity factor.

Table 125: Total Variance Explained

Total Variance Explained

Component	Initial Eigenvalues Total	Initial Eigenvalues % of Variance	Initial Eigenvalues Cumulative %	Extraction Sums of Squared Loadings Total	Extraction Sums of Squared Loadings % of Variance	Extraction Sums of Squared Loadings Cumulative %	Rotation Sums of Squared Loadings Total	Rotation Sums of Squared Loadings % of Variance	Rotation Sums of Squared Loadings Cumulative %
1	3,981	44,233	44,233	3,981	44,233	44,233	3,897	43,296	43,296
2	1,510	16,775	61,008	1,510	16,775	61,008	1,594	17,712	61,008
3	1,092	12,129	73,137						
4	0,809	8,988	82,124						
5	0,644	7,154	89,279						
6	0,423	4,703	93,981						
7	0,243	2,695	96,676						
8	0,181	2,007	98,683						
9	0,119	1,317	100,000						

Extraction Method: Principal Component Analysis.

As the next step, Table 126 shows the loadings of the nine variables on the factors extracted. The results indicate that all the indicators make statistically significant contributions to the adaptive capacity factor.

Table 126: Rotated Component Matrix

Rotated Component Matrix[a]

	Component 1	Component 2
SAV_DEP	0,905	
GDPPERC	0,894	
HIGHEDU	0,765	
ROAD	0,749	
R&D_INV	0,738	
SILVICULTURE	0,678	
PROTECT	0,312	
ENV_INT		0,897
CIVIC_ENG		0,823

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.

Cronbach's alpha is calculated for the two factors retained (Table 127). The alpha values are 0.85 and 0.69 for factor 1 and factor 2, respectively. These values are greater than 0.6 threshold for reliability (Robinson et al., 1991; Bagozzi and Yi, 1988; Wim et al., 2008; Van Griethuijsen et al., 2015; Ursachi et al., 2015).

Table 127: The Internal Reliability

	Cronbach's Alpha	N of Items
Factor 1	0,852	7
Factor 2	0,692	2

Weights are assigned according to the approach used by Nicoletti et al. (2000). In this context, Table 128 shows the rotated factor loadings, and squared factor loadings scaled to unity sum, which are used to compute weights.

Table 128: Factor Loadings of Adaptive Capacity Indicators

Factor Loading			Squared Factor Loading (scaled to unity sum)	
	Factor 1	Factor 2	Factor 1	Factor 2
SAV_DEP	0,905	0,063	**0,210**	0,002
GDPPERC	0,894	0,120	**0,205**	0,009
HIGHEDU	0,765	0,243	**0,150**	0,037
ROAD	0,749	0,033	**0,144**	0,001
R&D_INV	0,738	0,035	**0,140**	0,001
SILVICULTURE	0,678	-0,146	**0,118**	0,013
PROTECT	0,312	0,111	**0,025**	0,008
ENV_INT	-0,030	0,897	0,000	**0,505**
CIVIC_ENG	0,170	0,823	0,007	**0,424**
Explained Variance	3,897	1,594		
Explained Variance/ Total Variance	**0,710**	**0,290**		

Table 129 indicates weights for the adaptive capacity indicators based on principal components method for the extraction of the common factors.

Table 129: Weights for the Adaptive Capacity Indicators

Indicators	**Weight**
SAV_DEP	0,153
GDPPERC	0,149
HIGHEDU	0,109
ROAD	0,105
R&D_INV	0,102
SILVICULTURE	0,086
PROTECT	0,018
ENV_INT	0,150
CIVIC_ENG	0,127

Forest fire adaptive capacity index is calculated in SPSS by multiplying the normalized variables raised to the power of their weights as it is mentioned in the methods chapter of the thesis. Forest fire adaptive capacity map is prepared based on the adaptive capacity index score using natural breaks classification by defining five classes that represent very low, low, moderate, high, and very high exposure to forest fire, respectively.

The forest fire adaptive capacity index represents the aggregate of adaptive capacity from nine indicators: Silvicultural activities (SILVICULTURE), area protected by nature conservation law (PROTECT), high education (HIGH_EDU), civic engagement (CIVIC_ENG), level of interest in environmental issues (ENV_INT), GDP per capita (GDPPERC), saving deposit per capita (SAV_DEP), R&D investments (R&D_INV), and access to road network (ROAD). The result show that 38% of the provinces have low or very low levels of adaptive capacity to forest fire. When provinces with moderate capacity to adapt to forest fire are taken into account, the proportion becomes 70% (Table 130).

Table 130: Number of Provinces in terms of Forest Fire Adaptive Capacity Levels

Forest Fire Adaptive Capacity Level	**Number of Provinces**	**Share (%)**
Very Low Adaptive Capacity to Forest Fire	11	13,6
Low Adaptive Capacity to Forest Fire	20	24,7
Moderate Adaptive Capacity to Forest Fire	26	32,1
High Adaptive Capacity to Forest Fire	18	22,2
Very High Adaptive Capacity to Forest Fire	6	7,4
Total	81	100

As it is discussed above, the majority of provinces have moderate to very low levels capacity to adapt to forest fire. Provinces with very low adaptive capacity particularly prevail in the majority of the southeastern and eastern parts, and Afyonkarahisar in the western part of Turkey (Figure 73).

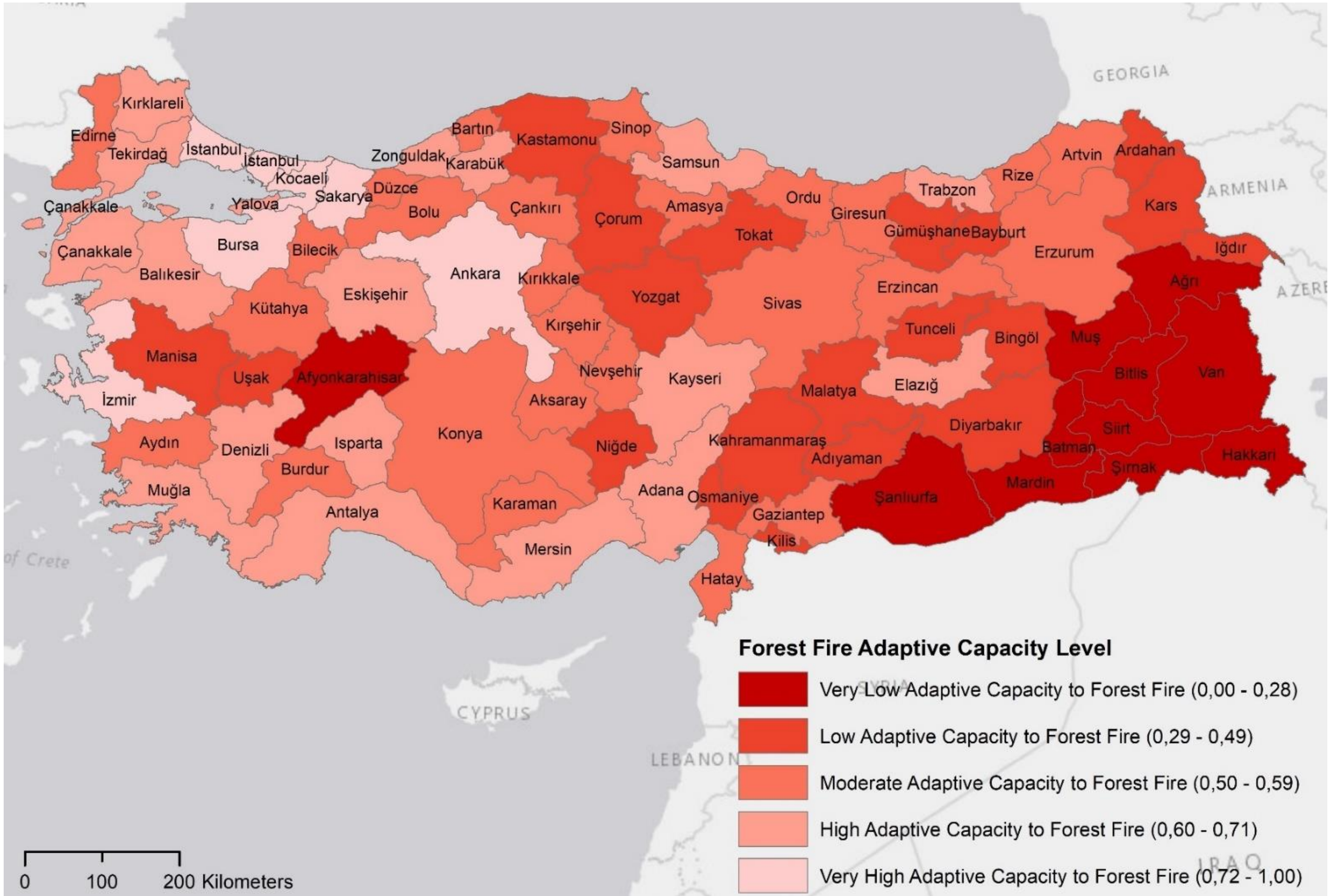

Figure 73: Forest Fire Adaptive Capacity Level of the Provinces in Turkey

5.3.3.5. Forest Fire Vulnerability and Risk Profiles of Provinces

As it is previously elaborated in Chapter 2, vulnerability as a function of sensitivity and adaptive capacity, has a positive functional relationship with sensitivity, and a negative functional relationship with adaptive capacity, which leads to vulnerability increases as sensitivity increases and adaptive capacity decreases, or vice versa.

The forest fire vulnerability index is thus calculated using forest fire sensitivity index and forest fire adaptive capacity index which are addressed in previous parts. Results indicate that approximately one-fifth of the provinces are highly/very highly vulnerable to forest fire (Table 131).

Table 131: Number of Provinces in terms of Forest Fire Vulnerability Level

Forest Fire Vulnerability Level	**Number of Provinces**	**Share (%)**
Very Low Vulnerability to Forest Fire	13	16,0
Low Vulnerability to Forest Fire	25	30,9
Moderate Vulnerability to Forest Fire	28	34,6
High Vulnerability to Forest Fire	10	12,3
Very High Vulnerability to Forest Fire	5	6,2
Total	81	100

Moreover, the very southeastern part of Turkey has higher levels of vulnerability to forest fire due to very high levels of sensitivity and very low levels of adaptive capacity, as it is also the case for heat wave and drought vulnerability. Kilis, Mardin, Batman, Siirt, and Şırnak are found to be the provinces that are the most vulnerable to forest fire, as they are also to drought except Kilis (Figure 74).

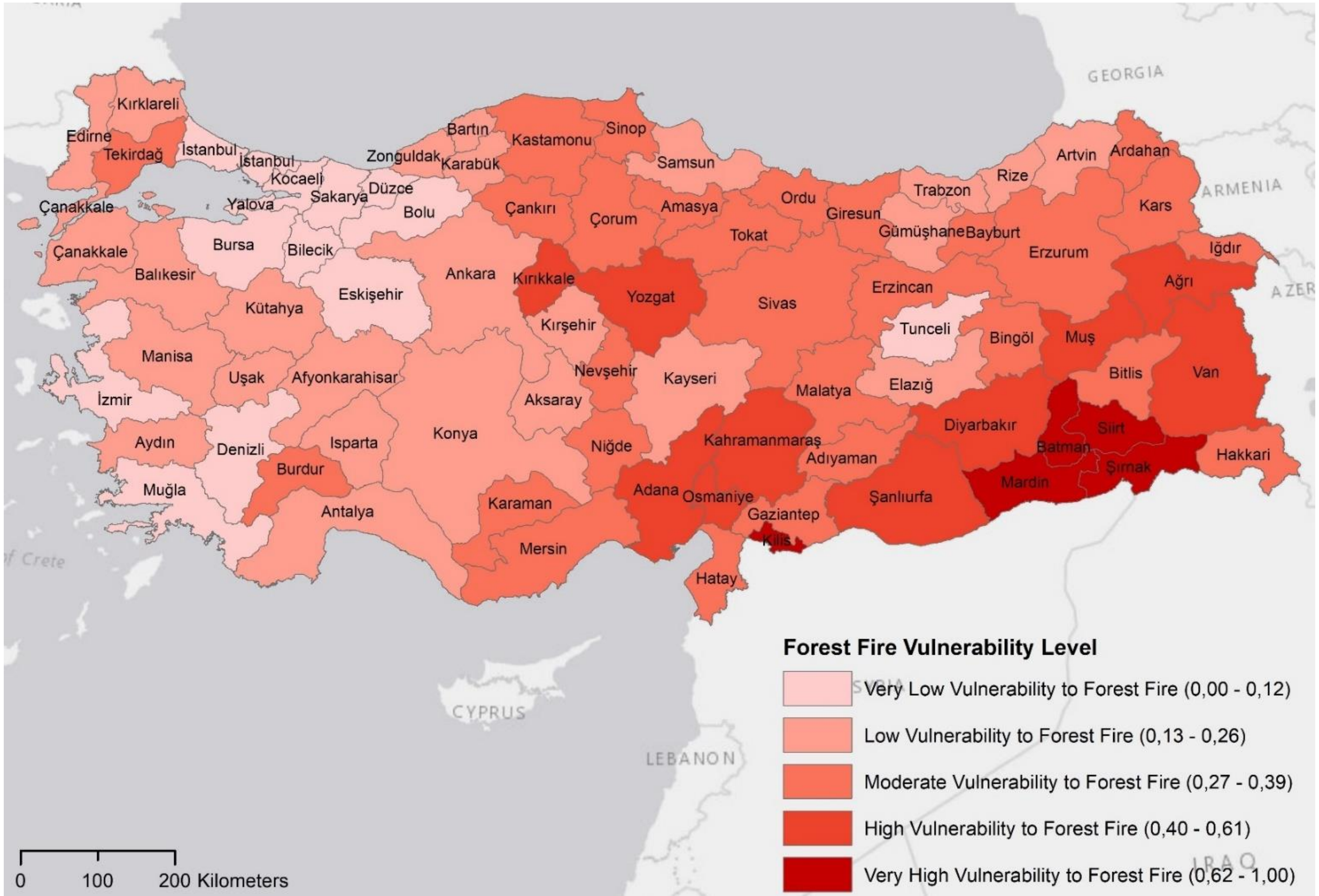

Figure 74: Forest Fire Vulnerability Level of the Provinces in Turkey

Forest fire risk index was calculated in SPSS by multiplying the sub-indices of hazard, exposure, sensitivity, and dividing the result by adaptive capacity in accordance with the methods chapter of the thesis. The results of forest fire risk index indicate the risk levels of provinces, which are represented using the natural breaks classification technique in SPSS to show the results of this study. In this context, the aggregated risk value is categorized into five classes to explain the relative position of each province that represent the very low, low, moderate, high, and very high risk of forest fire, respectively. The results show that the provinces with high or very high risk constitute one-third of the total (Table 132).

Table 132: Number of Provinces in terms of Forest Fire Risk Levels

Forest Fire Risk Level	**Number of Provinces**	**Share (%)**
Very Low Risk of Forest Fire	12	14,8
Low Risk of Forest Fire	17	21,0
Moderate Risk of Forest Fire	25	30,9
High Risk of Forest Fire	22	27,2
Very High Risk of Forest Fire	5	6,2
Total	81	100

After categorizing provinces in terms of their risk values, risk levels are mapped using ArcGis 10.7 as it is presented in Figure 76. Among the 81 provinces of Turkey, Mersin, Kahramanmaraş, Mardin, Şırnak, and Siirt have the most forest fire risk. The risk level of Mersin results from very high exposure and hazard levels as well as high vulnerability, while that of Kahramanmaraş stems from very high exposure and hazard levels and moderate vulnerability. Being moderately exposed and vulnerable at a very high level, Mardin, Şırnak, and Siirt are among the provinces with a very high forest fire risk (Figure 74).

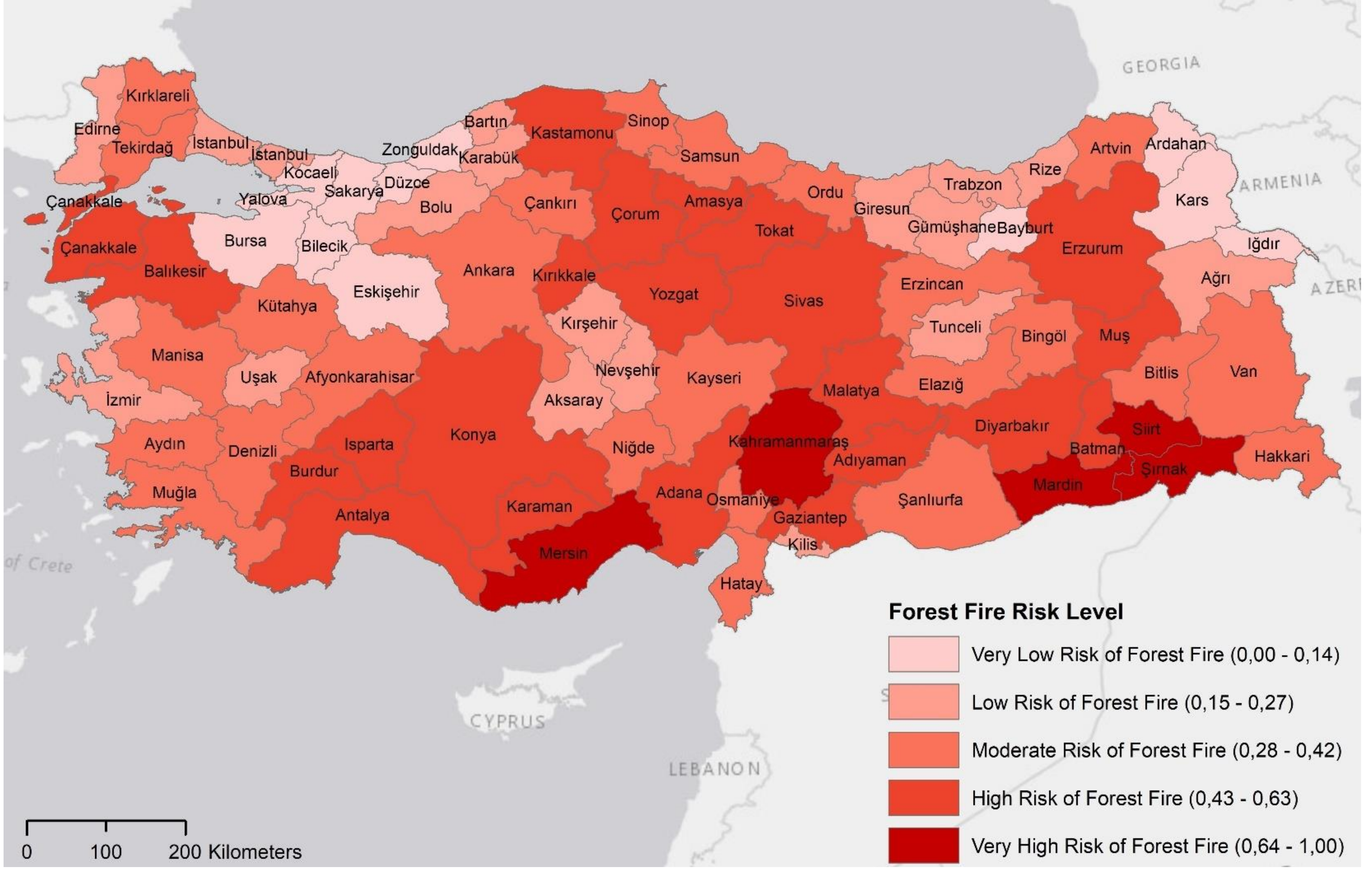

Figure 75: Forest Fire Risk Level

5.3.4. Flood Risk

Floods are the most frequent natural hazard in Turkey (Turkish State Meteorological Service, 2021) like many parts of the world. In this context, flood risk is one of the climate-related risks addressed in this study. Flood risk is considered as the product of the impacts from flood hazard and the probability that it occurs. The impact of a flood is affected by vulnerability and exposure to flood. In this study, (1) the flood hazard is considered as a latent damaging physical event for human population and critical infrastructure; (2) exposure refers to the presence of human population and critical infrastructure in places and settings that could be adversely affected by flood; (3) flood vulnerability is the function of sensitivity and adaptive capacity of population and critical infrastructure to the flood. To compute flood risk, there are 27 indicators in total used under the four components of risk (Figure 76).

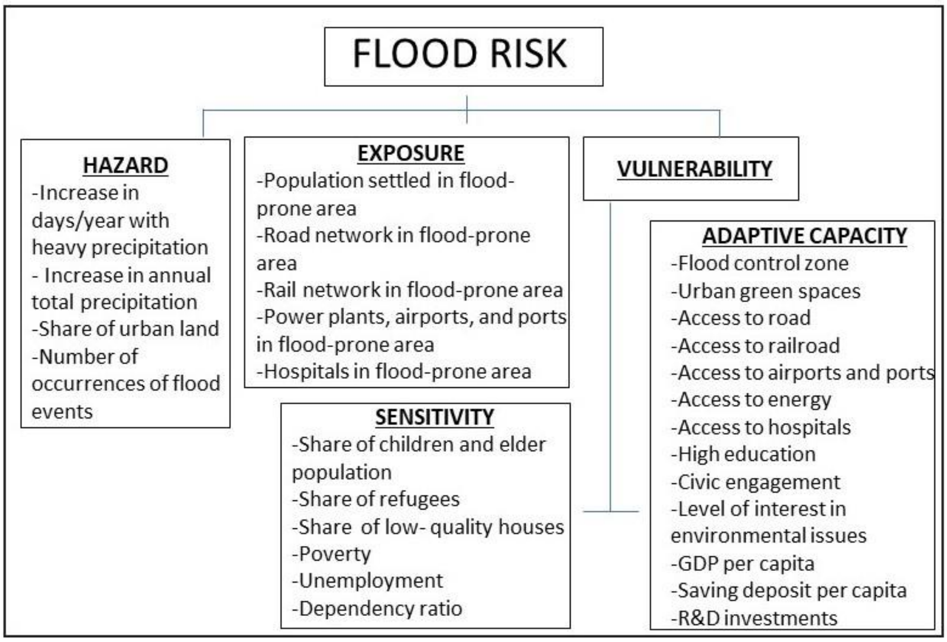

Figure 76: Indicators Scheme for Flood Risk

Flood risk index is prepared according to the methods mentioned in the previous chapter. In this vein, flood hazard, flood exposure, flood sensitivity, and flood adaptive capacity sub-indices are generated and aggregated to obtain flood risk index.

5.3.4.1. Flood Hazard

Four indicators are selected to represent hazard dimension of flood risk: increase in days/year with heavy precipitation (HEAVY_PRECIP), increase in annual total precipitation (PRECIP), the share of urban land in the total provincial area (URBAN_LAND), and the number of occurrences of flood events (NU_FLOOD). First, as it is indicated in Table 133, Cronbach's alpha is calculated for these four variables before the PCA/FA since the number of items does not allow more than one factor to exist (Raubenheimer, 2004).

Table 133: The Internal Reliability

Reliability Statistics

Cronbach's Alpha	N of Items
0,449	4

Since 0.449 is lower than 0.6 which, is an acceptable threshold for reliability (Robinson et al., 1991; Bagozzi and Yi, 1988; Wim et al., 2008; Van Griethuijsen et al., 2015; Ursachi et al., 2015), item-total statistics are examined (Table 134). BUILT-UP is removed from the indicator list because Cronbach's alpha would increase to 0.69 if this item is deleted.

Table 134: Item-Total Statistics

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
HEAVY_ PRECIP	0,0000000	3,584	0,370	0,190	0,244
PRECIP	0,0000000	3,257	0,479	0,374	0,118
BUILTUP	0,0000000	5,552	-0,120	0,023	0,690
NO_FLOOD	0,0000000	3,579	0,372	0,312	0,243

Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) measures how strongly the variables being tested correlate. Raw data becomes suitable for conducting a factor analysis if the KMO is greater than 0.50 (Kaiser, 1974; Hair et al., 2006; Field, 2009). Since KMO value is over 0.5 and significance level for the Bartlett's test is below 0.05, there is substantial correlation in the data (Table 135). Therefore, the results meet the assumptions to proceed with PCA/FA.

Table 135: The KMO and Bartlett's Test Score

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,621
Bartlett's Test of Sphericity	Approx. Chi-Square	44,010
	df	3
	Sig.	0,000

According to Table 136, there is a positive correlation between number of flood events per flooded area (NU_FLOOD), heavy precipitation (HEAVY_PRECIP), and increase in annual precipitation (PRECIP) ($p<0$ .05).

Table 136: Correlation Matrix

Correlation Matrix[a]

		HEAVY_PRECIP	PRECIP	NU_FLOOD
Correlation	HEAVY_PRECIP	1,000	0,426	0,304
	PRECIP	0,426	1,000	0,546
	NU_FLOOD	0,304	0,546	1,000

a. Determinant = 0,569

The total variance explained for measuring this construct is 61.95% (Table 137), which is acceptable as it exceeds the minimum 30% as one-factor model (Büyüköztürk, 2007; Çokluk et al., 2016). Therefore, selected indicators represent hazard factor.

Table 137: Total Variance Explained

Total Variance Explained

Component	Initial Eigenvalues Total	Initial Eigenvalues % of Variance	Initial Eigenvalues Cumulative %	Extraction Sums of Squared Loadings Total	Extraction Sums of Squared Loadings % of Variance	Extraction Sums of Squared Loadings Cumulative %
1	1,858	61,946	61,946	1,858	61,946	61,946
2	0,710	23,667	85,613			
3	0,432	14,387	100,000			

Extraction Method: Principal Component Analysis.

Table 138 demonstrates the loadings of the three variables on hazard factor extracted. The results indicate that all the indicators make statistically significant contributions to the hazard factor, with loads higher than 0.32 (Tabachnick and Fidell, 2014).

Table 138: The Components and Their Respective Items

Component Matrix[a]

	Component 1
PRECIP	0,855
NU_FLOOD	0,793
HEAVY_PRECIP	0,706

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Weights are assigned according to the approach used by Nicoletti et al. (2000). In this context, Table 139 shows the factor loadings, and squared factor loadings scaled to unity sum, which are used to compute weights.

Table 139: Factor Loadings of Hazard Indicators

Factor Loading		**Squared Factor Loading (scaled to unity sum)**
	Factor 1	Factor 1
PRECIP	0,855	**0,393**
NO_FLOOD	0,793	**0,339**
HEAVY_PRECIP	0,706	**0,268**
Explained Variance	1,858392	
Explained Variance/Total Variance	**1**	

Table 140 indicates weights for the hazard indicators based on principal components method for the extraction of the common factors.

Table 140: Weights for the Hazard Indicators

Indicators	**Weight**
PRECIP	0,393
NO_FLOOD	0,339
HEAVY_PRECIP	0,268

Flood hazard index is calculated in SPSS by multiplying the normalized variables raised to the power of their weights as it is indicated in the methods chapter of the thesis. Flood hazard map is prepared based on the hazard index score using natural breaks classification by defining five classes that represent very low, low, moderate, high, and very high flood hazard, respectively.

The flood hazard index represents the aggregate of hazard from four indicators: increase in days/year with heavy precipitation (HEAVY_PRECIP), increase in annual total precipitation (PRECIP), the share of urban land in the total provincial area (URBAN_LAND), and the number of occurrences of flood events (NU_FLOOD). The results show that high or very high flood hazard level is observed in 27% of the total number of provinces (Table 141).

Table 141: Number of Provinces in terms of Flood Hazard Levels

Flood Hazard Level	**Number of Provinces**	**Share (%)**
Very Low Flood Hazard	3	3,7
Low Flood Hazard	29	35,8
Moderate Flood Hazard	27	33,3
High Flood Hazard	19	23,5
Very High Flood Hazard	3	3,7
Total	81	100

Provinces with high or very high flood hazard concentrates in the mid-north and north-eastern of Turkey. Provinces with very high flood hazard prevail in Giresun, Trabzon, and Rize located in the north-eastern part (Figure 77).

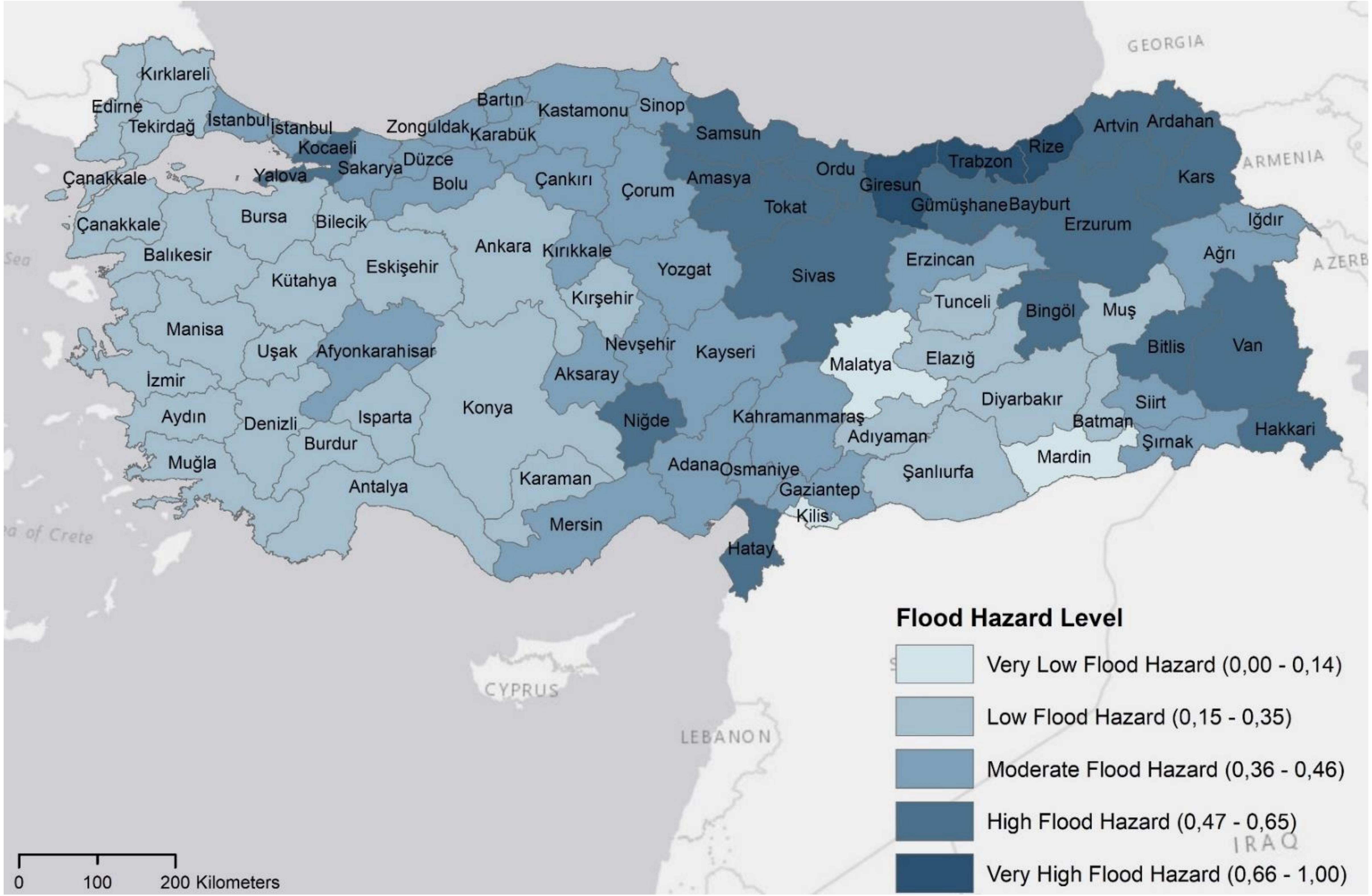

Figure 77: Flood Hazard Level of the Provinces in Turkey

5.3.4.2. Flood Exposure

Five indicators are selected to represent exposure dimension of flood risk: population settled in flood-prone area (POP_FLOOD), road network in flood-prone areas (ROAD_FLOOD), rail network in flood-prone area (RAIL_FLOOD), power plants, airports, and ports in flood-prone area (PAP_FLOOD), hospitals in flood-prone area (HOSP_FLOOD).

KMO and Bartlett's Test Score is calculated. KMO value being equal to 0.63 and a significance level for the Bartlett's test below 0.05 indicate there is substantial correlation in the data (Table 142).

Table 142: The KMO and Bartlett's Test Score

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,625
Bartlett's Test of Sphericity	Approx. Chi-Square	58,772
	df	10
	Sig.	0,000

According to Table 143, population settled in flood-prone area has a moderate positive correlation with the share of road network in flood-prone area (r=0.55, p<0.05) and a weak positive relationship with hospitals in flood-prone area (r=0.39, p <0.05).

Table 143: Correlation Matrix

Correlation Matrix[a]		POP_ FLOOD	ROAD_ FLOOD	RAIL_ FOOD	HOSP_ FLOOD	PAP_ FLOOD
Correlation	POP_FLOOD	1,000	0,552	0,132	0,389	-0,044
	ROAD_FLOOD	0,552	1,000	0,361	0,364	0,055
	RAIL_FOOD	0,132	0,361	1,000	0,180	0,109
	HOSP_FLOOD	0,389	0,364	0,180	1,000	-0,121
	PAP_FLOOD	-0,044	0,055	0,109	-0,121	1,000

a. Determinant = 0,468

The total variance explained (Table 144) for measuring this construct is 63% which exceeds the minimum threshold of 30% in one-factor solutions (Büyüköztürk, 2007; Çokluk et al., 2016). Therefore, selected indicators represent exposure factor.

Table 144: Total Variance Explained

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2,027	40,532	40,532	2,027	40,532	40,532	1,979	39,580	39,580
2	1,123	22,461	62,993	1,123	22,461	62,993	1,171	23,412	62,993
3	0,814	16,286	79,279						
4	0,643	12,858	92,137						
5	0,393	7,863	100,000						

Extraction Method: Principal Component Analysis.

A parallel analysis is conducted to decide the number of factors to retain. Parallel analysis indicates that eigenvalues of the first factor obtained from PCA are greater than the one obtained from PA (Table 145). Therefore, one factor is decided to be retained since the eigenvalue of the second factor's simulated data is higher than that of the actual data.

Table 145: Eigenvalues Retrieved from PCA and PA

Factor	Eigenvalues obtained from PCA	Eigenvalues obtained from PA
1	**2,027**	**1,473**
2	1,123	1,225
3	0,814	1,077
4	0,643	0,956
5	0,393	0,823

Scree plot covering the factors and respective eigenvalues also shows that there is one factor above the interpolation line of Parallel Analysis (Figure 78). Therefore, one factor is decided to be retained.

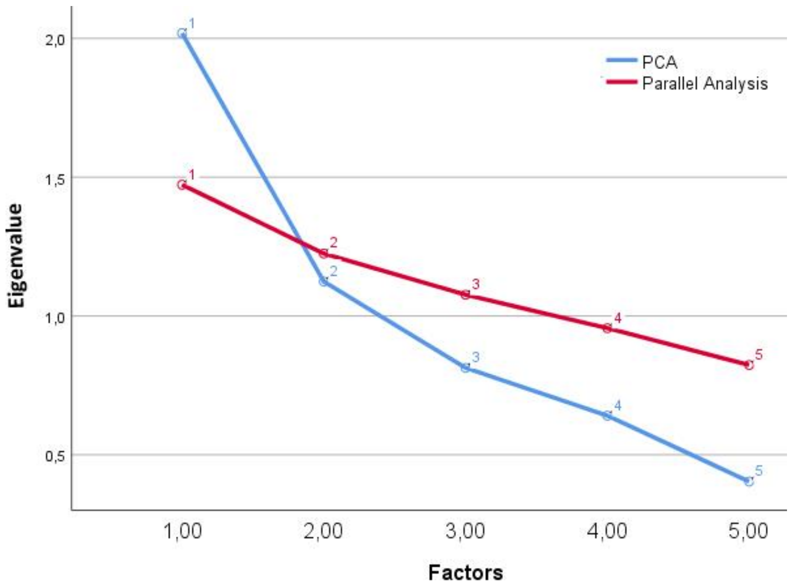

Figure 78: Scree Plot of Parallel Analysis

Cronbach's alpha was calculated for these five variables loaded on factor 1 (Table 146).

Table 146: The Internal Reliability

Reliability Statistics	
Cronbach's Alpha	N of Items
0,552	5

Since 0.55 is lower than 0.6, which is an acceptable threshold for reliability (Robinson et al., 1991; Bagozzi and Yi, 1988; Wim et al., 2008; Van Griethuijsen et al., 2015; Ursachi et al., 2015), item-total statistics is examined (Table 147). PAP_FLOOD is removed from the indicator list because Cronbach's alpha would increase to 0.663 if this item is deleted.

Table 147: Item-Total Statistics

Item-Total Statistics	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
POP_FLOOD	0,0000000	5,896	0,424	0,429
ROAD_FLOOD	0,0000000	5,291	0,579	0,325
RAIL_FOOD	0,0000000	6,390	0,309	0,499
HOSP_FLOOD	0,0000000	6,329	0,323	0,491
PAP_FLOOD	0,0000000	7,955	0,000	0,663

After removing PAP_FLOOD from the items, KMO and Bartlett’s Test Score is calculated. KMO value being equal to 0.63 and a significance level for the Bartlett’s test below 0.05 indicate there is substantial correlation in the data (Table 148).

Table 148: The KMO and Bartlett’s Test Score

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,633
Bartlett's Test of Sphericity	Approx. Chi-Square	55,956
	df	6
	Sig.	0,000

The total variance explained (Table 149) for measuring this construct is 50.7% which exceeds the minimum threshold of 30% in one-factor solutions (Büyüköztürk, 2007; Çokluk et al., 2016). Therefore, selected indicators represent exposure factor.

Table 149: Total Variance Explained

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2,027	50,663	50,663	2,027	50,663	50,663
2	0,906	22,662	73,324			
3	0,673	16,818	90,142			

Extraction Method: Principal Component Analysis.

Table 150 indicates the loadings of the variables on exposure factor extracted. The results indicate that all the indicators make statistically significant contributions to the exposure factor, with loads higher than 0.32 (Tabachnick and Fidell, 2014).

Table 150: The Components and Their Respective Items

Component Matrix[a]

	Component 1
ROAD FLOOD	0,838
POP FLOOD	0,774
HOSP FLOOD	0,680
RAIL FOOD	0,513

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Weights are assigned according to the approach used by Nicoletti et al. (2000). In this context, Table 151 shows the factor loadings, and squared factor loadings scaled to unity sum, which are used to compute weights.

Table 151: Factor Loadings of Exposure Indicators

Factor Loading		**Squared Factor Loading (scaled to unity sum)**
	Factor 1	Factor 1
ROAD_FLOOD	0,838	**0,346**
POP_FLOOD	0,774	**0,295**
HOSP_FLOOD	0,680	**0,228**
RAIL_FLOOD	0,513	**0,130**
Explained Variance	2,027	
Explained Variance/Total Variance	**1**	

Table 152 indicates weights for the exposure indicators based on principal components method for the extraction of the common factors.

Table 152: Weights for the Exposure Indicators

Indicators	**Weight**
ROAD_FLOOD	0,346
POP_FLOOD	0,295
HOSP_FLOOD	0,228
RAIL_FLOOD	0,130

Flood exposure index is calculated in SPSS by multiplying the normalized variables raised to the power of their weights as it was explained in the methods chapter of the thesis. Flood exposure map is prepared based on the exposure index score using natural breaks classification by defining five classes that represent very low, low, moderate, high, and very high exposure to flood, respectively.

The flood index represents the aggregate of exposure from four indicators: population settled in flood-prone area (POP_FLOOD), road network in flood-prone areas (ROAD_FLOOD), rail network in flood-prone area (RAIL_FLOOD), and hospitals in flood-prone area (HOSP_FLOOD). According to Table 153, more than one third of the provinces have high or very high exposure to flood.

Table 153: Number of Provinces in terms of Flood Exposure Levels

Flood Exposure Level	**Number of Provinces**	**Share (%)**
Very Low Exposure to Flood	12	14,8
Low Exposure to Flood	25	30,9
Moderate Exposure to Flood	15	18,5
High Exposure to Flood	18	22,2
Very High Exposure to Flood	11	13,6
Total	81	100

Provinces that are very highly exposed to flood are particularly evident in the inner part (Amasya, Tokat Sivas, Çankırı, Niğde, Bilecik, Eskişehir, and Afyonkarahisar), and eastern part (Bayburt, Erzurum, Muş, and Van) (Figure 79).

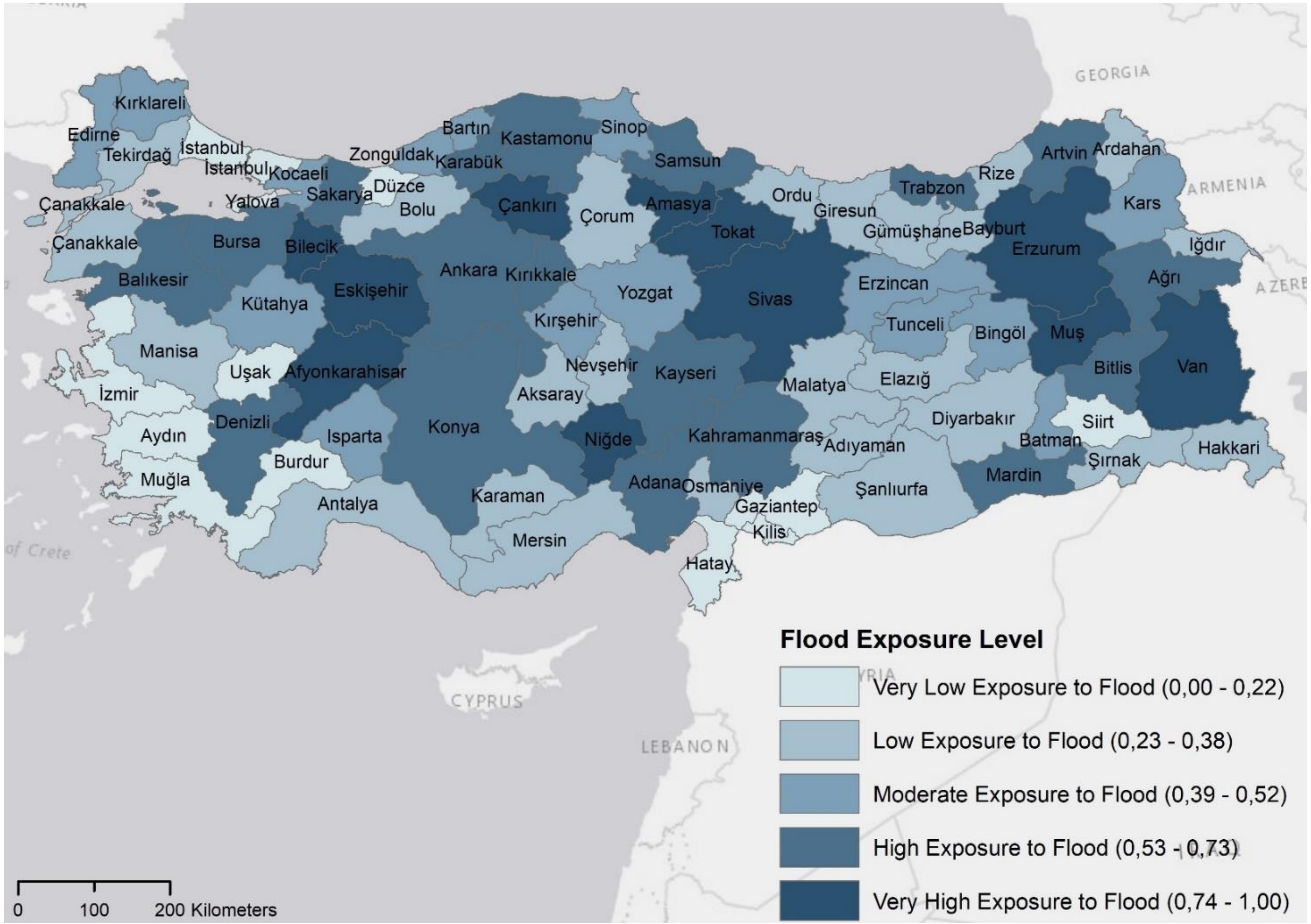

Figure 79: Flood Exposure Level of the Provinces in Turkey

5.3.4.3. Flood Sensitivity

Six indicators are selected to represent sensitivity dimension of flood risk: Share of children and elder population (CHLD_ELDER), share of refugees (REFUGEES), the share of low-quality houses (LOWQ_HOUSES), poverty (PVRTY), unemployment (UNEMP), and dependency ratio (DEPND).

KMO and Bartlett's Test Score is calculated. KMO value being equal to 0.71 and a significance level for the Bartlett's test below 0.05 indicate there is substantial correlation in the data (Table 154).

Table 154: The KMO and Bartlett's Test Score

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,708
Bartlett's Test of Sphericity	Approx. Chi-Square	214,472
	df	15
	Sig.	0,000

According to Table 155, indicators are correlated with each other. There is a strong positive correlation between poverty rates and low-quality houses (r=0.84). The poverty rate is also positively correlated with dependency ratio and unemployment, as expected. The share of the children and elderly population is, on the other hand, negatively correlated with the rest of the variables.

Table 155: Correlation Matrix

Correlation Matrix[a]

		CHILD_ ELDER	REFUGEES	LOWQ_ HOUSES	PVRTY	UNEMP	DEPND
Correlation	CHILD_ELDER	1,000	-0,073	-0,255	-0,262	-0,386	-0,098
	REFUGEES	-0,073	1,000	0,127	0,209	0,144	0,287
	LOWQ_HOUSES	-0,255	0,127	1,000	0,835	0,364	0,658
	PVRTY	-0,262	0,209	0,835	1,000	0,501	0,748
	UNEMP	-0,386	0,144	0,364	0,501	1,000	0,534
	DEPND	-0,098	0,287	0,658	0,748	0,534	1,000

a. Determinant = 0,062

According to total variance explained table (Table 156), two factors have eigenvalues above 1 and they explain 67.8% of the total variance.

Table 156: Total Variance Explained

Total Variance Explained

Component	Initial Eigenvalues Total	Initial Eigenvalues % of Variance	Initial Eigenvalues Cumulative %	Extraction Sums of Squared Loadings Total	Extraction Sums of Squared Loadings % of Variance	Extraction Sums of Squared Loadings Cumulative %	Rotation Sums of Squared Loadings Total	Rotation Sums of Squared Loadings % of Variance	Rotation Sums of Squared Loadings Cumulative %
1	3,044	50,740	50,740	3,044	50,740	50,740	2,596	43,260	43,260
2	1,023	17,045	67,785	1,023	17,045	67,785	1,472	24,525	67,785
3	0,930	15,499	83,284						
4	0,617	10,277	93,562						
5	0,244	4,059	97,620						
6	0,143	2,380	100,000						

Extraction Method: Principal Component Analysis.

A parallel analysis is conducted to decide the number of factors to retain. Parallel analysis indicates that eigenvalues of the first factor obtained from PCA are greater than the one obtained from PA. However, the eigenvalue of the second factor in the actual data is 1.023, whereas it is 1.292 when retrieved from PA (Table 157). Therefore, one factor is decided to be retained because the eigenvalue of the second factor's simulated data is higher than that of the actual data.

Table 157: Eigenvalues Retrieved from PCA and PA

Factor	Eigenvalues obtained from PCA	Eigenvalues obtained from PA
1	**3,044**	**1,519**
2	1,023	1,292
3	0,930	1,113
4	0,617	0,997
5	0,244	0,900
6	0,143	0,748

Scree plot covering the factors and respective eigenvalues also shows that there is one factor above the interpolation line of Parallel Analysis (Figure 80). Therefore, one factor is decided to be retained, and PCA is rerun so as to extract one factor.

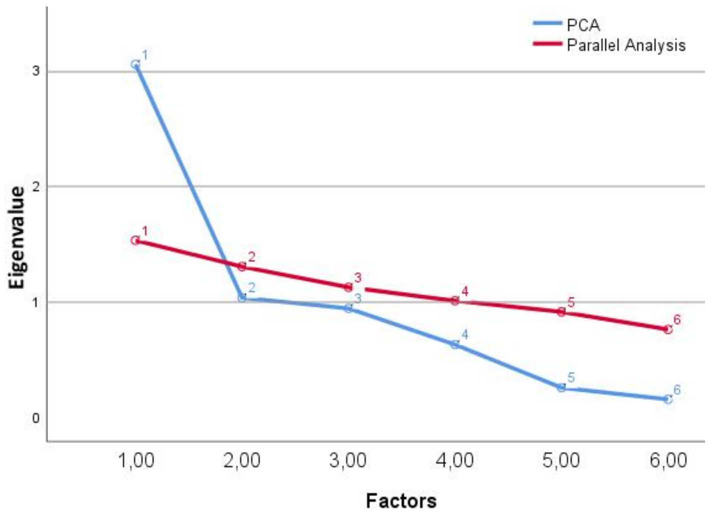

Figure 80: Scree Plot of Parallel Analysis

After determining the number of factors retained, the new table of total variance explained is generated. One factor extracted explains 50.7% of the total variance (Table 158), which is acceptable as it ranges between 40% and 60% (Büyüköztürk, 2007; Çokluk et al., 2016). Therefore, selected indicators represent sensitivity factor.

Table 158: Total Variance Explained

Total Variance Explained						
	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3,044	50,740	50,740	3,044	50,740	50,740
2	1,023	17,045	67,785			
3	0,930	15,499	83,284			
4	0,617	10,277	93,562			
5	0,244	4,059	97,620			
6	0,143	2,380	100,000			

Extraction Method: Principal Component Analysis.

Table 159 presents the loadings of the six variables on sensitivity factor extracted. The results indicate that all the indicators make statistically significant contributions to the sensitivity factor, with loads higher than 0.32 (Tabachnick and Fidell, 2014).

Table 159: The Components and Their Respective Items

Component Matrix[a]

	Component 1
PVRTY	0,915
DEPND	0,855
LOWQ_HOUSES	0,845
UNEMP	0,698
CHILD_ELDER	-0,408
REFUGEES	0,330

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Cronbach's alpha is calculated for these six variables loaded on factor 1 (Table 160). 0.63 is greater than 0.6 threshold for reliability (Robinson et al., 1991; Bagozzi and Yi, 1988; Wim et al., 2008; Van Griethuijsen et al., 2015; Ursachi et al., 2015).

Table 160: The Internal Reliability

Reliability Statistics

Cronbach's Alpha	N of Items
0,632	6

Weights are assigned according to the approach used by Nicoletti et al. (2000). In this context, Table 161 shows the factor loadings, and squared factor loadings scaled to unity sum, which were used to compute weights.

Table 161: Factor Loadings of Sensitivity Indicators

Factor Loading		**Squared Factor Loading (scaled to unity sum)**
	Factor 1	Factor 1
PVRTY	0,915	0,275
DEPND	0,855	0,240
LOWQ_HOUSES	0,845	0,234
UNEMP	0,698	0,160
CHLD_ELDER	-0,408	0,055
REFUGEES	0,330	0,036
Explained Variance	3,044	
Explained Variance/Total Variance	**1**	

Table 162 indicates weights for the sensitivity indicators based on principal components method for the extraction of the common factors.

Table 162: Weights for the Sensitivity Indicators

Indicators	**Weight**
PVRTY	0,275
DEPND	0,240
LOWQ_HOUSES	0,234
UNEMP	0,160
CHLD_ELDER	0,055
REFUGEES	0,036

Flood sensitivity index is calculated in SPSS by multiplying the normalized variables raised to the power of their weights as it is indicated in the methods chapter of the thesis. Flood sensitivity map is prepared based on the sensitivity index score using natural breaks classification by defining five classes that represent very low, low, moderate, high, and very high sensitivity to flood, respectively. The flood sensitivity index represents the aggregate of sensitivity from five indicators: share of children and elder population (CHLD_ELDER), the share of low-quality houses (LOWQ_HOUSES), poverty (PVRTY), unemployment (UNEMP), and dependency ratio (DEPND). According to Table 163, the number of provinces with high or very high sensitivity constitutse one-third of the 81 provinces.

Table 163: Number of Provinces in terms of Flood Sensitivity Levels

Flood Sensitivity Level	**Number of Provinces**	**Share (%)**
Very Low Sensitivity to Flood	7	8,6
Low Sensitivity to Flood	13	16,0
Moderate Sensitivity to Flood	34	42,0
High Sensitivity to Flood	15	18,5
Very High Sensitivity to Flood	12	14,8
Total	81	100

Provinces with high flood sensitivity are mostly concentrated in the eastern and south-eastern part of Turkey as it is also the case for heat wave, drought, and forest fire sensitivity. Kilis, Adıyaman, Şanlıurfa, Diyarbakır, Mardin, Batman, Şırnak, Siirt, Bitlis, Muş, Van, and Ağrı are the provinces most sensitive to flood (Figure 81).

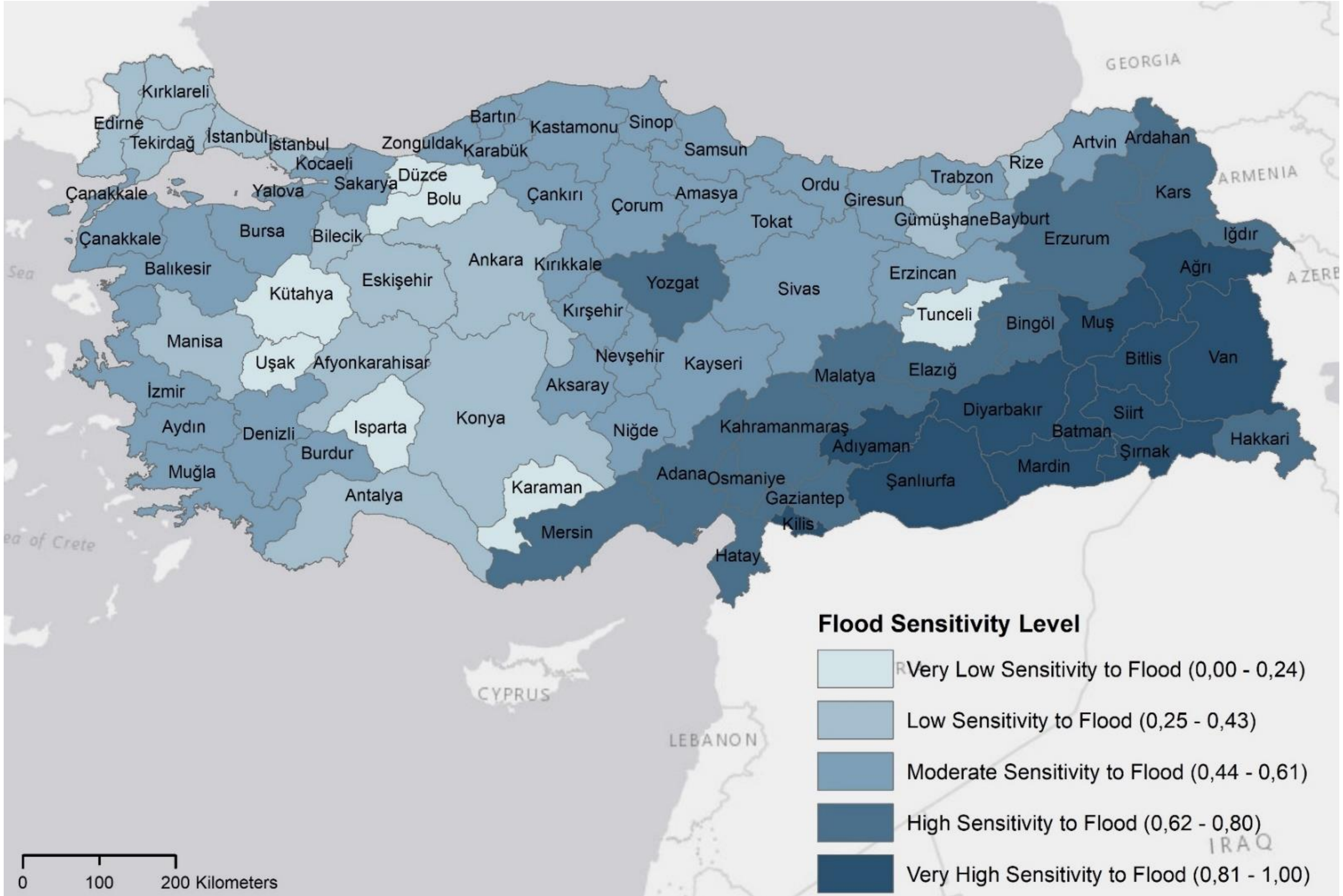

Figure 81: Flood Sensitivity Level of the Provinces in Turkey

5.3.4.4. Flood Adaptive Capacity

13 indicators are selected to represent adaptive capacity dimension of flood risk: Flood control zone (FLOOD_CONTROL), urban green spaces (GREEN), access to road network (ROAD), access to railroad (RAIL), access to airports and ports (AIRPORT_PORT), access to energy (ENERGY), access to hospitals (HOSPIT), high education (HIGH_EDU), civic engagement (CIVIC_ENG), level of interest in environmental issues (ENV_INT), GDP per capita (GDPPERC), saving deposit per capita (SAV_DEP), and R&D investments (R&D_INV).

KMO and Bartlett's Test Score is calculated. KMO value being equal to 0.71 and a significance level for the Bartlett's test below 0.05 indicate there is substantial correlation in the data (Table 164).

Table 164: The KMO and Bartlett's Test Score

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,705
Bartlett's Test of Sphericity	Approx. Chi-Square	677,325
	df	78
	Sig.	0,000

Correlation matrix is analyzed, determinant was lower than 0.0001 (Field, 2000); thus, there is multicollinearity. R&D_INV and HOSPIT are highly correlated (r=0.91). Therefore, R&D_INV is removed from the indicator list since HOSPIT is more critical variable for adaptive capacity for flood (Table 165).

Table 165: Correlation Matrix

Correlation Matrix[a]

		FLOOD_CONTROL	GREEN	ROAD	RAIL	AIRPORT_PORT	ENERGY	HOSPIT	CIVIC_ENG	ENV_INT	HIGH_EDU	GDPPERC	SAV_DEP	R&D_INV
Correlation	FLOOD_CONTROL	1,000	0,549	0,271	-0,001	0,053	-0,052	0,105	0,127	-0,054	0,256	0,321	0,165	-0,034
	GREEN	0,549	1,000	0,551	0,478	-0,099	-0,083	0,566	0,101	-0,091	0,370	0,458	0,331	0,497
	ROAD	0,271	0,551	1,000	0,602	0,097	-0,059	0,725	0,276	-0,013	0,367	0,604	0,540	0,617
	RAIL	-0,001	0,478	0,602	1,000	-0,184	-0,003	0,672	0,213	0,048	0,354	0,575	0,450	0,670
	AIRPORT_PORT	0,053	-0,099	0,097	-0,184	1,000	0,238	-0,057	0,128	0,082	0,118	0,090	0,170	-0,092
	ENERGY	-0,052	-0,083	-0,059	-0,003	0,238	1,000	-0,082	0,257	0,177	0,167	0,130	0,048	-0,109
	HOSPIT	0,105	0,566	0,725	0,672	-0,057	-0,082	1,000	0,118	0,069	0,353	0,521	0,607	0,909
	CIVIC__ENG	0,127	0,101	0,276	0,213	0,128	0,257	0,118	1,000	0,529	0,200	0,279	0,138	0,097
	ENV_INT	-0,054	-0,091	-0,013	0,048	0,082	0,177	0,069	0,529	1,000	0,197	0,037	0,053	0,051
	HIGH_EDU	0,256	0,370	0,367	0,354	0,118	0,167	0,353	0,200	0,197	1,000	0,758	0,762	0,491
	GDPPERC	0,321	0,458	0,604	0,575	0,090	0,130	0,521	0,279	0,037	0,758	1,000	0,759	0,543
	SAV_DEP	0,165	0,331	0,540	0,450	0,170	0,048	0,607	0,138	0,053	0,762	0,759	1,000	0,665
	R&D_INV	-0,034	0,497	0,617	0,670	-0,092	-0,109	**0,909**	0,097	0,051	0,491	0,543	0,665	1,000

a. Determinant = 0,000

KMO and Bartlett's Test Score is re-calculated. KMO value being equal to 0.7 and a significance level for the Bartlett's test below 0.05 indicate there is substantial correlation in the data (Table 166).

Table 166: The KMO and Bartlett's Test Score

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,703
Bartlett's Test of Sphericity	Approx. Chi-Square	496,869
	df	66
	Sig.	0,000

Correlation matrix is analyzed again, determinant became higher than 0.0001 (Field, 2000), thus, there is no multicollinearity. According to total variance explained table (Table 167), four factors have eigenvalues above 1.0 and they explain 72.86% of the total variance.

Table 167: Total Variance Explained

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4,486	37,385	37,385	4,486	37,385	37,385	4,052	33,766	33,766
2	1,826	15,217	52,602	1,826	15,217	52,602	1,605	13,373	47,139
3	1,273	10,609	63,211	1,273	10,609	63,211	1,558	12,981	60,120
4	1,158	9,646	72,857	1,158	9,646	72,857	1,528	12,737	72,857
5	0,864	7,198	80,055						
6	0,798	6,653	86,708						
7	0,506	4,213	90,921						
8	0,347	2,891	93,812						
9	0,270	2,248	96,060						
10	0,221	1,839	97,899						
11	0,146	1,217	99,116						
12	0,106	0,884	100,000						

Extraction Method: Principal Component Analysis.

A parallel analysis is conducted to decide the number of factors to retain. Parallel analysis shows that eigenvalues of the first two factors obtained from PCA are greater than those obtained from PA. However, the eigenvalue of the third factor in the actual data is 1.27, whereas it is 1.44 when retrieved from PA (Table 168).

Therefore, two factors are decided to be retained as the eigenvalue of the third factor's simulated data is higher than that of the actual data.

Table 168: Eigenvalues Retrieved from PCA and PA

Factor	Eigenvalues obtained from PCA	Eigenvalues obtained from PA
1	**4,486**	**1,879**
2	**1,826**	**1,608**
3	1,273	1,442
4	1,158	1,283
5	0,864	1,191

Scree plot covering the factors and respective eigenvalues also shows that there are two factors above the interpolation line of Parallel Analysis (Figure 82). Therefore, two factors are decided to be retained, and PCA is rerun so as to extract two factors.

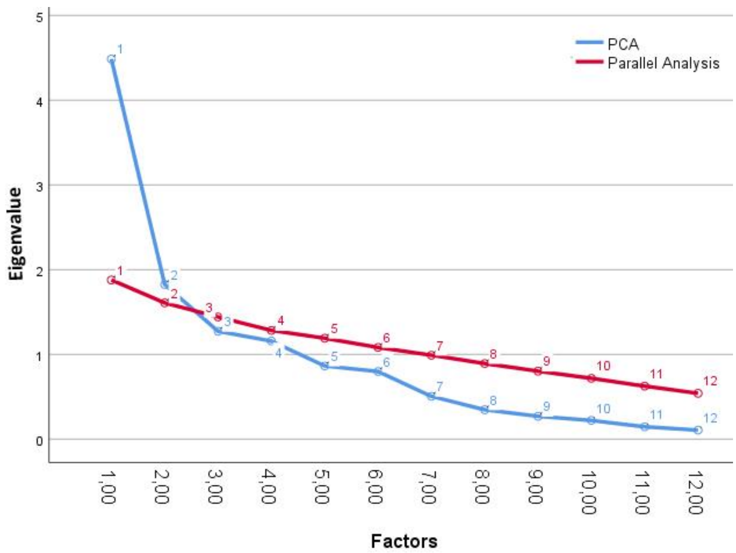

Figure 82: Scree Plot of Parallel Analysis

After determining the number of factors retained, the new table of total variance explained is generated. Two factors extracted explains 52.6% of the total variance (Table 169), which is acceptable as it is greater than 40% (Büyüköztürk, 2007; Çokluk et al., 2016). Therefore, selected indicators represent adaptive capacity factor.

Table 169: Total Variance Explained

Total Variance Explained									
	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4,486	37,385	37,385	4,486	37,385	37,385	4,390	36,587	36,587
2	1,826	15,217	52,602	1,826	15,217	52,602	1,922	16,015	52,602
3	1,273	10,609	63,211						
4	1,158	9,646	72,857						
5	0,864	7,198	80,055						
6	0,798	6,653	86,708						
7	0,506	4,213	90,921						
8	0,347	2,891	93,812						
9	0,270	2,248	96,060						
10	0,221	1,839	97,899						
11	0,146	1,217	99,116						
12	0,106	0,884	100,000						

Extraction Method: Principal Component Analysis.

Table 170 shows the loadings of the 12 variables on the factors extracted. The results indicate that all the indicators make statistically significant contributions to the adaptive capacity factor.

Table 170: Rotated Component Matrix

Rotated Component Matrix[a]	Component	
	1	2
GDPPERC	0,834	
ROAD	0,819	
HOSPIT	0,815	
SAV_DEP	0,775	
RAIL	0,745	
GREEN	0,740	
HIGH_EDU	0,673	0,391
FLOOD_CONTROL	0,394	
ENV_INT		0,690
CIVIC_ENG		0,684
ENERGY		0,632
AIRPORT_PORT		0,490

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.

Cronbach's alpha is calculated for the two factors retained (Table 171). The alpha value is 0.88 and greater than 0.6 reliability threshold for factor 1; however, it is 0.55 and lower than the threshold for factor 2 (Robinson et al., 1991; Bagozzi and Yi, 1988; Wim et al., 2008; Van Griethuijsen et al., 2015; Ursachi et al., 2015).

Table 171: The Internal Reliability

	Cronbach's Alpha	N of Items
Factor 1	0,875	8
Factor 2	0,552	4

Item-total statistics are examined and ENERGY and AIRPORT_PORT are removed because Cronbach's alpha would increase to 0.69 if these items are deleted. After removing two items, KMO and Bartlett's Test Score is re-calculated. KMO value being equal to 0.71 and a significance level for the Bartlett's test below 0.05 indicate there is substantial correlation in the data (Table 172).

Table 172: The KMO and Bartlett's Test Score

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,709
Bartlett's Test of Sphericity	Approx. Chi-Square	470,834
	df	45
	Sig.	0,000

According to total variance explained table (Table 173), four factors have eigenvalues above 1.0 and they explain 82.74% of the total variance.

Table 173: Total Variance Explained

Total Variance Explained

Component	Initial Eigenvalues Total	Initial Eigenvalues % of Variance	Initial Eigenvalues Cumulative %	Extraction Sums of Squared Loadings Total	Extraction Sums of Squared Loadings % of Variance	Extraction Sums of Squared Loadings Cumulative %	Rotation Sums of Squared Loadings Total	Rotation Sums of Squared Loadings % of Variance	Rotation Sums of Squared Loadings Cumulative %
1	4,481	44,809	44,809	4,481	44,809	44,809	2,774	27,741	27,741
2	1,534	15,340	60,149	1,534	15,340	60,149	2,419	24,190	51,931
3	1,191	11,912	72,061	1,191	11,912	72,061	1,556	15,555	67,486
4	1,068	10,678	82,739	1,068	10,678	82,739	1,525	15,253	82,739
5	0,534	5,337	88,076						
6	0,440	4,396	92,472						
7	0,272	2,722	95,194						
8	0,224	2,242	97,437						
9	0,147	1,472	98,908						
10	0,109	1,092	100,000						

Extraction Method: Principal Component Analysis.

A parallel analysis was conducted to decide the number of factors to retain. Parallel analysis indicates that eigenvalues of the first two factors obtained from PCA is greater than those obtained from PA. However, the eigenvalue of the third factor in the actual data is 1.19, whereas it is 1.37 when retrieved from PA (Table 174). Therefore, two factors are decided to be retained because the eigenvalue of the third factor's simulated data is higher than that of the actual data.

Table 174: Eigenvalues Retrieved from PCA and PA

Factor	Eigenvalues obtained from PCA	Eigenvalues obtained from PA
1	**4,481**	**1,823**
2	**1,534**	**1,498**
3	1,191	1,374
4	1,068	1,211
5	0,534	1,104

Scree plot covering the factors and respective eigenvalues also shows that there are two factors above the interpolation line of Parallel Analysis (Figure 83). Therefore, two factors are decided to be retained, and PCA is rerun so as to extract two factors.

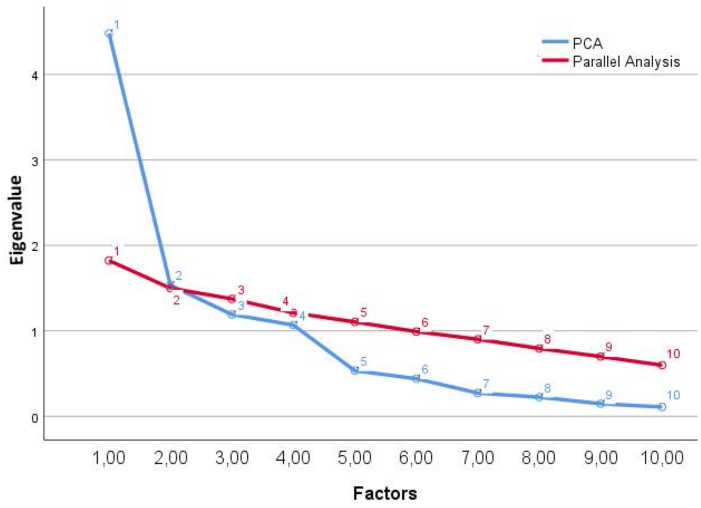

Figure 83: Scree Plot of Parallel Analysis

After determining the number of factors retained, the new table of total variance explained is generated. Two factors extracted explains 60.15% of the total variance (Table 175), which is acceptable as it is greater than 40% (Büyüköztürk, 2007; Çokluk et al., 2016). Therefore, selected indicators represent adaptive capacity factor.

Table 175: Total Variance Explained

Total Variance Explained									
	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4,481	44,809	44,809	4,481	44,809	44,809	4,359	43,593	43,593
2	1,534	15,340	60,149	1,534	15,340	60,149	1,656	16,556	60,149
3	1,191	11,912	72,061						
4	1,068	10,678	82,739						
5	0,534	5,337	88,076						
6	0,440	4,396	92,472						
7	0,272	2,722	95,194						
8	0,224	2,242	97,437						
9	0,147	1,472	98,908						
10	0,109	1,092	100,000						

Extraction Method: Principal Component Analysis.

Table 176 shows the loadings of the 10 variables on the factors extracted. The results indicate that all the indicators make statistically significant contributions to the adaptive capacity factor.

Table 176: Rotated Component Matrix

Rotated Component Matrix[a]

	Component	
	1	2
GDPPERC	0,841	
ROAD	0,813	
HOSPIT	0,799	
SAV_DEP	0,782	
GREEN	0,745	
RAIL	0,720	
HIGH_EDU	0,680	
FLOOD_CONTROL	0,415	
ENV_INT		0,875
CIVIC_ENG		0,795

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.

Cronbach's alpha is calculated for the two factors retained (Table 177). The alpha values are 0.88 and 0.69 for factor 1 and factor 2, respectively. These values are greater than 0.6 threshold for reliability (Robinson et al., 1991; Bagozzi and Yi, 1988; Wim et al., 2008; Van Griethuijsen et al., 2015; Ursachi et al., 2015).

Table 177: The Internal Reliability

	Cronbach's Alpha	N of Items
Factor 1	0,875	8
Factor 2	0,692	2

Weights are assigned according to the approach used by Nicoletti et al. (2000). In this context, Table 178 shows the rotated factor loadings, and squared factor loadings scaled to unity sum, which are used to compute weights.

Table 178: Factor Loadings of Adaptive Capacity Indicators

Factor Loading			Squared Factor Loading (scaled to unity sum)	
	Factor 1	Factor 2	Factor 1	Factor 2
GDPPERC	0,841	0,212	**0,162**	0,027
ROAD	0,813	0,058	**0,152**	0,002
HOSPIT	0,799	0,039	**0,146**	0,001
SAV_DEP	0,782	0,190	**0,140**	0,022
GREEN	0,745	-0,189	**0,127**	0,022
RAIL	0,720	0,121	**0,119**	0,009
HIGH_EDU	0,680	0,319	**0,106**	0,062
FLOOD_CONTROL	0,415	-0,142	**0,040**	0,012
ENV_INT	-0,068	0,875	0,001	**0,462**
CIVIC_ENG	0,171	0,795	0,007	**0,381**
Explained Variance	4,359	1,656		
Explained Variance/ Total Variance	**0,725**	**0,275**		

Table 179 indicates weights for the adaptive capacity indicators based on principal components method for the extraction of the common factors.

Table 179: Weights for the Adaptive Capacity Indicators

Indicators	**Weight**
GDPPERC	0,124
ROAD	0,115
HOSPIT	0,112
SAV_DEP	0,107
GREEN	0,097
RAIL	0,091
HIGH_EDU	0,081
FLOOD_CONTROL	0,030
ENV_INT	0,134
CIVIC_ENG	0,110

Flood adaptive capacity index is calculated in SPSS by multiplying the normalized variables raised to the power of their weights as it is indicated in the methods chapter of the thesis. Flood adaptive capacity map is prepared based on the adaptive capacity index score using natural breaks classification by defining five classes that represent very low, low, moderate, high, and very high adaptive capacity flood, respectively.

The flood adaptive capacity index represents the aggregate of adaptive capacity from 10 indicators: flood control zone (FLOOD_CONTROL), urban green spaces (GREEN), access to road network (ROAD), access to railroad (RAIL), access to hospitals (HOSPIT), high education (HIGH_EDU), civic engagement (CIVIC_ENG), level of interest in environmental issues (ENV_INT), GDP per capita (GDPPERC), saving deposit per capita (SAV_DEP). In this vein, more than 20% of the provinces have low or very low capacity to adapt to flood (Table 180).

Table 180: Number of Provinces in terms of Flood Adaptive Capacity Levels

Flood Adaptive Capacity Level	**Number of Provinces**	**Share (%)**
Very Low Adaptive Capacity to Flood	3	3,7
Low Adaptive Capacity to Flood	15	18,5
Moderate Adaptive Capacity to Flood	27	33,3
High Adaptive Capacity to Flood	29	35,8
Very High Adaptive Capacity to Flood	7	8,6
Total	81	100

As mentioned above, more than one-fifth of the provinces have low or very low levels of adaptive capacity. Şırnak, Hakkari, and Ağrı have the lowest capacity to adapt to flood. In addition, Afyonkarahisar, and Aksaray in the inner part, Bolu, Kastamonu, Çorum in the north, Giresun, Gümüşhane, and Ardahan in the north-east, and many provinces located between the south-eastern and eastern boundary are the provinces with low adaptive capacity (Figure 84).

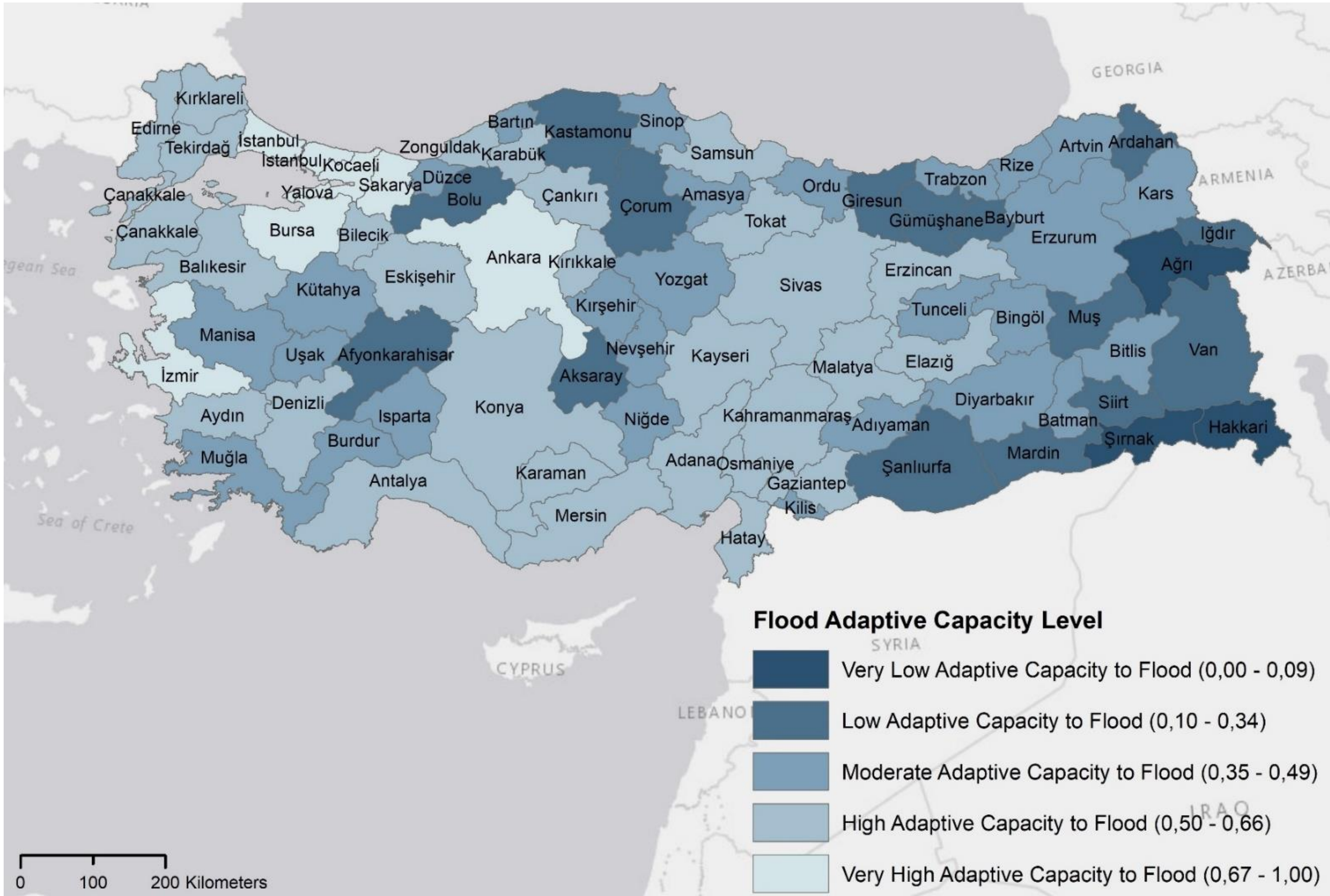

Figure 84: Flood Adaptive Capacity Level of the Provinces in Turkey

5.3.4.5. Flood Vulnerability and Risk Profiles of Provinces

Vulnerability as a function of sensitivity and adaptive capacity, has a positive functional relationship with sensitivity, and a negative functional relationship with adaptive capacity, which leads to vulnerability increases as sensitivity increases and adaptive capacity decreases, or vice versa, as it was previously discussed in Chapter 2.

The flood vulnerability index is thus calculated using flood sensitivity index and flood adaptive capacity index which are addressed in previous parts. Results indicate that 40% of the provinces have high or very high levels of flood vulnerability (Table 181).

Table 181: Number of Provinces in terms of Flood Vulnerability Level

Flood Vulnerability Level	**Number of Provinces**	**Share (%)**
Very Low Vulnerability of to Flood	9	11,1
Low Vulnerability to Flood	16	19,8
Moderate Vulnerability to Flood	24	29,6
High Vulnerability to Flood	18	22,2
Very High Vulnerability to Flood	14	17,3
Total	81	100

As Figure 84 shows, the south-eastern and eastern parts of Turkey have higher levels of flood vulnerability due to very high levels of sensitivity and very low levels of adaptive capacity, as it is also observed in heat wave, drought, and forest fire vulnerability (Figure 85).

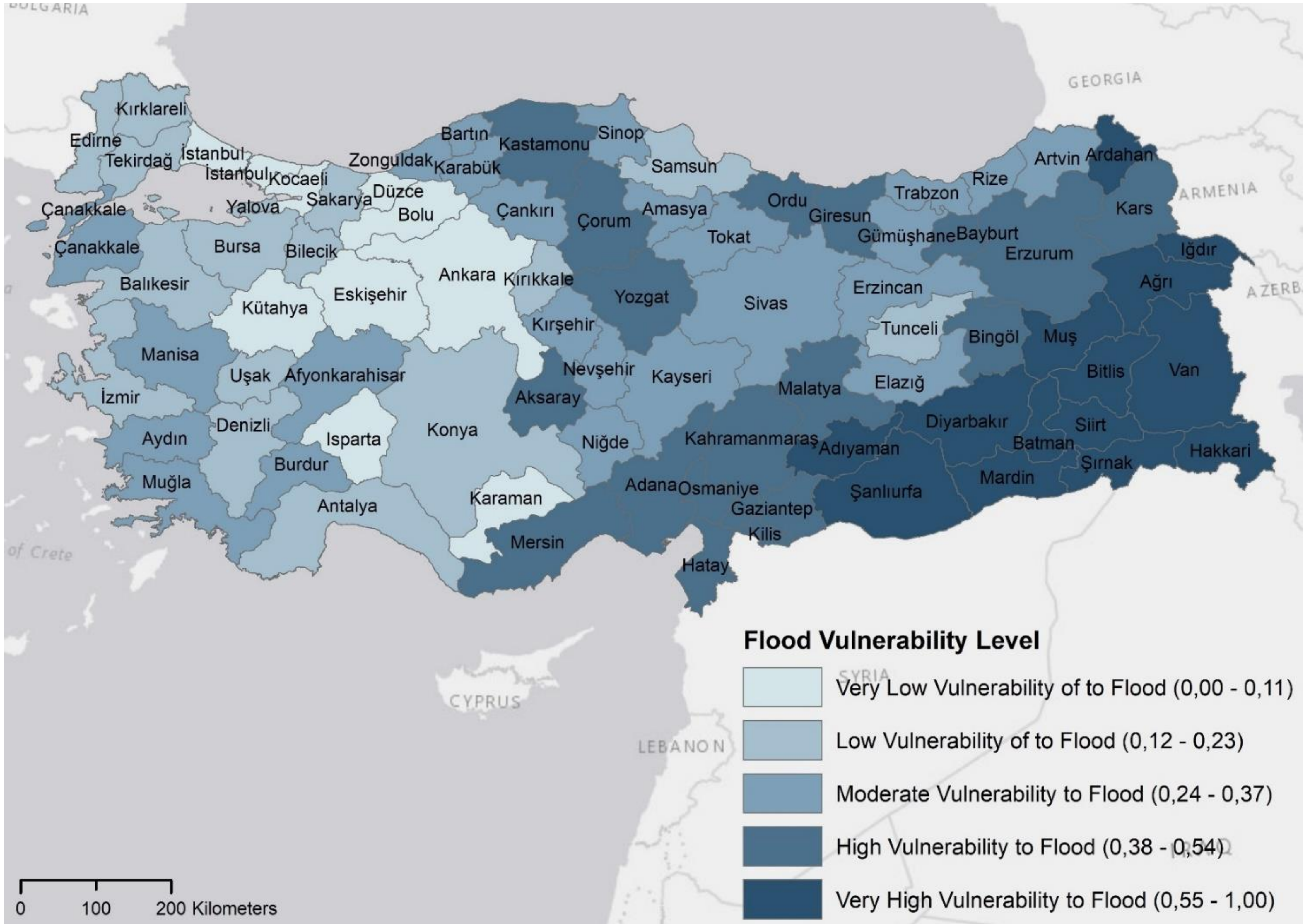

Figure 85: Flood Vulnerability Level of the Provinces in Turkey

Flood risk index is calculated in SPSS by multiplying the sub-indices of hazard, exposure, sensitivity, and dividing the result by adaptive capacity in accordance with the methods chapter of the thesis. The results of flood risk index indicate the risk levels of provinces, which are represented using the natural breaks classification technique in SPSS to show the results of this study. In this context, the flood risk index value is categorized into five classes to explain the relative position of each province that represent the very low, low, moderate, high, and very high risk of flood, respectively.

The results show that 31% of provinces are of high or very high levels of flood risk (Table 182).

Table 182: Number of Provinces in terms of Flood Risk Levels

Flood Risk Level	**Number of Provinces**	**Share (%)**
Very Low Risk of Flood	12	14,8
Low Risk of Flood	19	23,5
Moderate Risk of Flood	25	30,9
High Risk of Flood	14	17,3
Very High Risk of Flood	11	13,6
Total	81	100

After categorizing provinces in terms of their risk values, risk levels are mapped using ArcGis 10.7 as it is presented in Figure 83. Flood risk map reveals a scattered picture throughout Turkey. Çankırı, Amasya, Tokat, Sivas, Niğde in the inner part, Trabzon and Bayburt in the north-eastern part and Erzurum, Ağrı, Muş, Bitlis, and Van in the eastern part represent the provinces with very high flood risk (Figure 86).

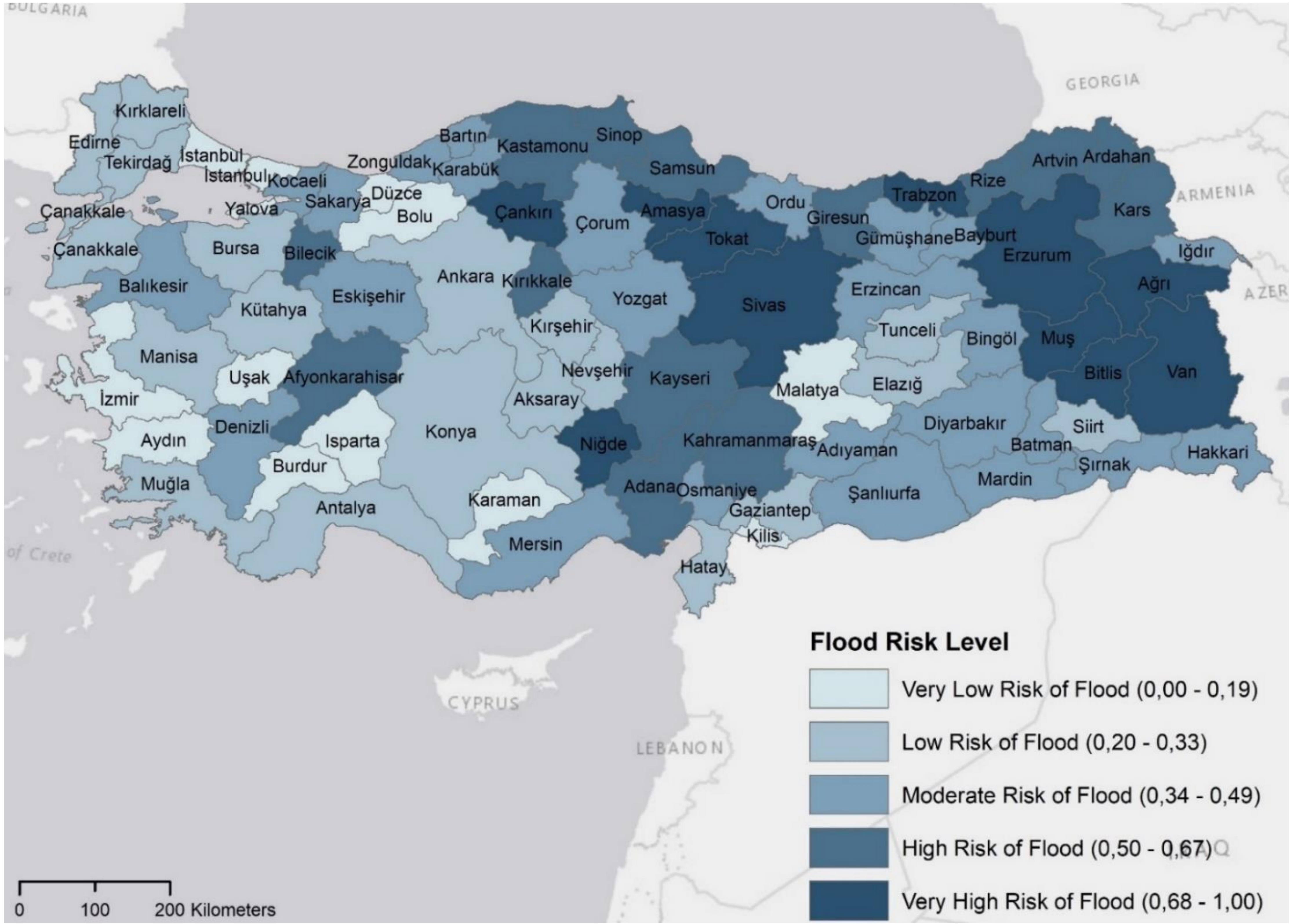

Figure 86: Flood Risk Level

5.3.5. Overall Climate Risk

In this study, climate risks are evaluated in terms of heat, drought, forest fire, and drought separately. In order to provide decision-makers with a general and easily understandable overview of the overall risk levels of provinces, the risk levels of provinces in each risk type (heat wave, drought, forest fire, and flood) are synthesized through which the individual risk level classification that is previously elaborated in Chapter 4. In this respect, 4-7, 7.1-9.98, 9.99-12.99, 13-15.99, and 16-20 points represent very low, low, moderate, high, and very high climate risk, respectively, based on the standard deviation classification technique which is used because the data is normally distributed (Table 183).

Table 183: Overall Risk Score and Level of Provinces

Province	Heat Risk Score	Drought Risk Score	Forest Fire Risk Score	Flood Risk Score	Overall Risk Score	Overall Risk Level
Adana	2	3	4	4	13	High
Adıyaman	4	4	4	3	15	High
Afyonkarahisar	3	5	3	4	15	High
Ağrı	4	5	2	5	16	Very High
Aksaray	3	5	2	2	12	Moderate
Amasya	3	4	4	5	16	Very High
Ankara	5	3	3	2	13	High
Antalya	4	4	4	2	14	High
Ardahan	1	1	1	4	7	Very Low
Artvin	2	1	3	4	10	Moderate
Aydın	3	4	3	1	11	Moderate
Balıkesir	3	4	4	3	14	High
Bartın	1	1	2	3	7	Very Low
Batman	1	2	4	3	10	Moderate
Bayburt	3	2	1	3	9	Low
Bilecik	2	3	1	4	10	Moderate
Bingöl	1	2	3	3	9	Low
Bitlis	1	2	3	5	11	Moderate
Bolu	3	3	2	1	9	Low
Burdur	3	4	4	1	12	Moderate
Bursa	3	3	1	2	9	Low
Çanakkale	2	4	4	2	12	Moderate
Çankırı	2	3	3	5	13	High
Çorum	3	3	4	3	13	High
Denizli	3	5	3	3	14	High
Diyarbakır	1	3	4	3	11	Moderate
Düzce	1	1	1	1	4	Very Low
Edirne	3	3	2	2	10	Moderate
Elazığ	3	3	3	2	11	Moderate
Erzincan	3	4	3	3	13	High
Erzurum	2	4	4	5	15	High

Table 183 (continued)

Eskişehir	3	3	1	3	10	Moderate
Gaziantep	5	4	4	2	15	High
Giresun	1	1	2	4	8	Low
Gümüşhane	1	2	2	3	8	Low
Hakkari	1	2	3	3	9	Low
Hatay	2	3	3	2	10	Moderate
Iğdır	1	3	1	3	8	Low
Isparta	3	3	4	1	11	Moderate
İstanbul	5	1	2	1	9	Low
İzmir	4	3	2	1	10	Moderate
Kahramanmaraş	3	5	5	4	17	Very High
Karabük	1	1	2	3	7	Very Low
Karaman	2	4	4	1	11	Moderate
Kars	1	2	1	4	8	Low
Kastamonu	3	3	4	4	14	High
Kayseri	5	5	3	4	17	Very High
Kırıkkale	3	3	4	4	14	High
Kırklareli	3	3	3	2	11	Moderate
Kırşehir	3	4	2	2	11	Moderate
Kilis	2	2	2	1	7	Very Low
Kocaeli	3	1	1	3	8	Low
Konya	4	5	4	2	15	High
Kütahya	2	3	3	2	10	Moderate
Malatya	3	4	4	1	12	Moderate
Manisa	2	3	3	2	10	Moderate
Mardin	2	4	5	3	14	High
Mersin	4	5	5	3	17	Very High
Muğla	3	4	3	2	12	Moderate
Muş	3	5	4	5	17	Very High
Nevşehir	3	3	2	2	10	Moderate
Niğde	3	4	3	5	15	High
Ordu	3	2	3	3	11	Moderate
Osmaniye	1	2	3	3	9	Low
Rize	2	1	2	4	9	Low
Sakarya	3	3	1	3	10	Moderate
Samsun	2	2	3	4	11	Moderate
Siirt	1	2	5	2	10	Moderate
Sinop	2	2	3	4	11	Moderate
Sivas	2	4	4	5	15	High
Şanlıurfa	4	5	3	3	15	High
Şırnak	2	3	5	3	13	High
Tekirdağ	3	3	3	2	11	Moderate
Tokat	3	4	4	5	16	Very High
Trabzon	3	1	2	5	11	Moderate
Tunceli	2	2	2	2	8	Low
Uşak	3	3	2	1	9	Low
Van	2	4	3	5	14	High
Yalova	3	2	1	1	7	Very Low
Yozgat	2	4	4	3	13	High
Zonguldak	1	1	1	3	6	Very Low

The results show that 36% of provinces are of high or very high levels of climate risk. Moderate climate risk, on the other hand, are observed in 30 provinces, which is equal to 37% of the provinces. (Table 184).

Table 184: Number of Provinces in terms of Climate Risk Level

Climate Risk Level	**Number of Provinces**	**Share (%)**
Very Low Climate Risk	7	8,6
Low Climate Risk	15	18,5
Moderate Climate Risk	30	37,0
High Climate Risk	22	27,2
Very High Climate Risk	7	8,6
Total	81	100,0

After categorizing provinces in terms of their overall risk scores, risk levels are mapped using ArcGis 10.7 as it is presented in Figure 87. According to the results, Amasya and Tokat in the north, Mersin, Kahramanmaraş, and Kayseri in the south, and Muş and Ağrı in the east part of Turkey have the highest climate risk (Figure 87).

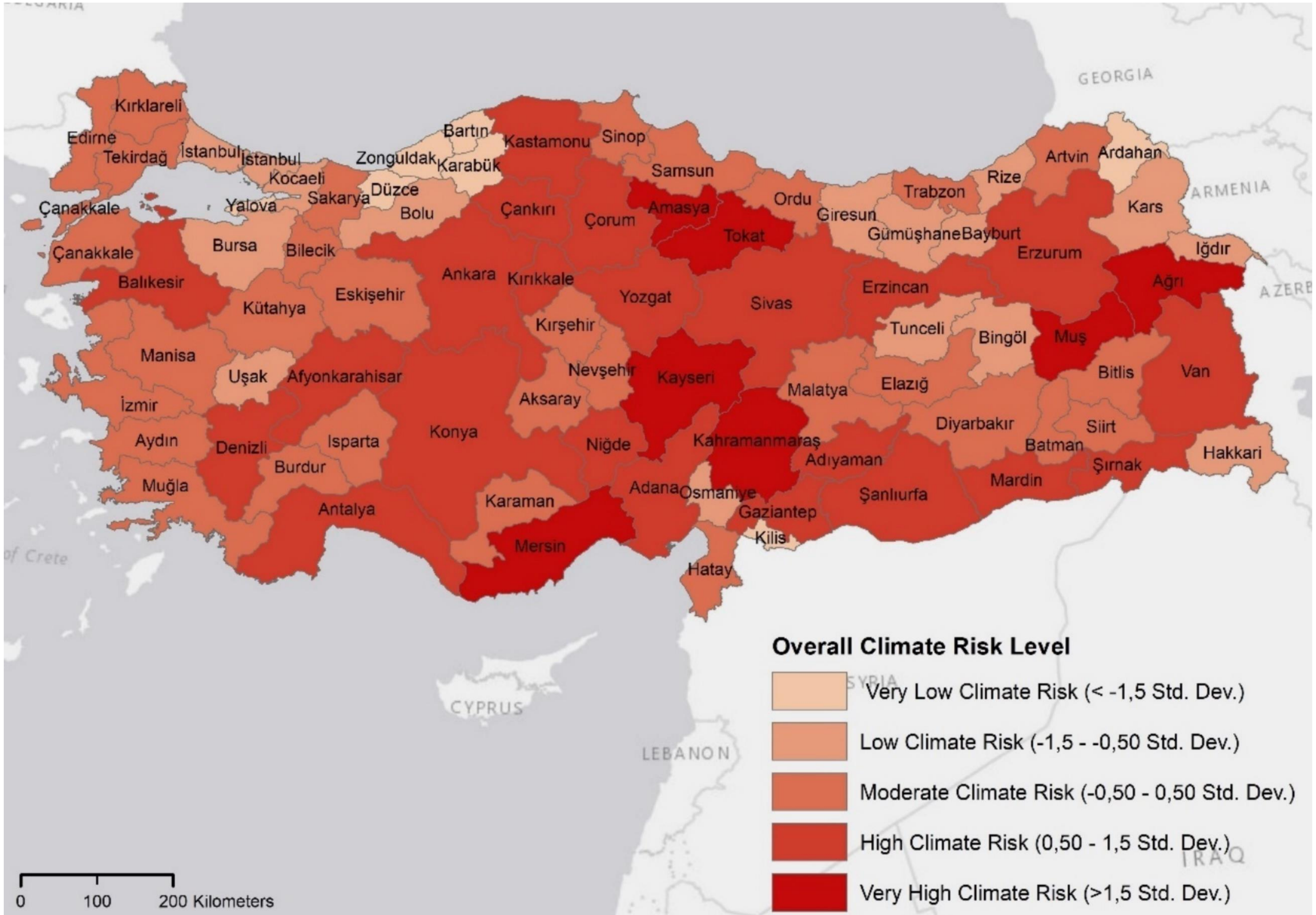

Figure 87: Overall Climate Risk Level

CHAPTER 6

DISCUSSION AND CONCLUSION

Mitigation is vital to minimize the adverse impacts of climate change; however, even though mitigation strategies succeed, the negative impacts are expected to continue. Since it becomes less and less likely to keep the warming below 2°C (Liu and Raftery, 2021) and to eliminate the impacts entirely, considering the insufficiency of the current policy and pledge trajectories of countries (Climate Action Tracker, 2021), mitigation does not suffice to combat climate change and needs to be supported by adaptation actions which are instrumental in reducing impacts and increasing the resilience of the systems in a continuous and transformative process (Smith et al., 2011). Adaptation is recognized as a "global challenge" in Paris Agreement in which "enhancing adaptive capacity, strengthening resilience, and reducing vulnerability to climate change" together are determined as a global goal on adaptation (UNFCCC 2016, Paris Agreement, Art. 7). Sixth Assessment Report of IPCC highlights that the world needs an urgent action since exceeding 1.5°C threshold brings ecosystems and human society to the limits of adaptation (IPCC, 2022).

According to Schlosberg (2017), climate adaptation needs to address and challenge the drivers of risk and vulnerability. The understanding of vulnerability in the climate change community was long at odds with that in the disaster risk reduction discipline due to differences in conceptualizing vulnerability and discrepancy of the former includes climate parameters (in the context of exposure) as one of the determinants of vulnerability. 5th Assessment Report is a paradigm change in this vein, a risk-based framework started to be adopted by IPCC, which is a substantial progress towards the integration of climate change adaptation and disaster risk-reduction approaches.

In this vein, this thesis adopts the framework highlighted in the 5th Assessment Report, a risk-based approach, and aims to assess climate risks and vulnerabilities in Turkey at the provincial level in order for decision-makers and spatial planners to compare the relative climate risk and vulnerability at different spatial levels, to prioritize and manage the areas of concern and to direct spatial development policies accordingly.

This chapter includes four parts. The first part covers a discussion on heat wave, drought, forest fire, flood, and overall climate risk assessment. The second part emphasizes the level of connectedness between climate adaptation policy and actions and spatial planning via the case of Turkey. In this vein, the adaptation action plans, which are the concrete outputs of climate adaptation action, have been examined. By the same token, this part also provides an overview of spatial planning at different spatial scales and discusses how the spatial planning system addresses climate risks and vulnerabilities in Turkey. The third and fourth parts focus on the evaluation of the research method, and limitations and further research, respectively.

6.1. Discussion on the Heat, Drought, Forest Fire, Flood Risk, and Overall Climate Risk Assessments

The assessment of risk and vulnerability is conducted in two parts. The first part includes the analysis of meteorological parameters in the context of climate hazard, which is required for the risk analysis to proceed. Six indicators are used for this analysis, including increase in annual mean temperature, annual maximum temperature, the number of hot days, the number of tropical nights, as well as decrease/increase in annual total precipitation and the number of days with heavy precipitation, and results are presented.

Similar to past research, the results indicate that temperatures increased in almost all part of Turkey, which is in line with the findings of Şen (2013), MoEU (2018), Türkeş (2019). For annual mean temperatures, 77 provinces indicate statistically significant increasing trends. When maximum temperatures are considered, 77 provinces indicate an increasing trend, 22 of which is not statistically significant at 0.1 level, which is in parallel to the findings by Toros (2012) highlighting maximum temperatures have been increasing in Turkey. In the same vein, the number of hot days has been increasing all over Turkey, according to the results. 79 provinces have an increasing trend in the number of hot days, 8 of which is not statistically significant at 0.1 level. The spatial representation of the trend highly overlaps with the spatial distribution of the findings of Toros (2012) and supports the emphasis of MoEU (2018) on the increase in summer days and warm days.

As for tropical nights, they are in a statistically significant increasing trend for 58 provinces, especially those located in coastal zone. This is consistent with the findings of Erlat and Türkeş (2017) and to the Seventh National Communication of Turkey under the UNFCCC (MoEU, 2018), which the latter put emphasis on the coastal stations, especially the Mediterranean coast, for making the substantial contribution to the increasing trend in the number of tropical nights. Being located in the Mediterranean coast, indeed, Mersin stands out as the province where the most increase is seen in both annual mean, annual maximum temperature, and hot days/year with maximum temperature greater than 30 °C, according to the result of the analysis explained above.

As for the precipitation, the analysis shows that 86% of the provinces do not indicate a statistically significant trend in the annual mean precipitation, which is in line with the wide acceptance of the global erratic pattern of precipitation due to climate change. 10 provinces show a statistically significant increasing trend and the majority of which are located in the Black Sea region, which is consistent with the findings of Türkeş (2019).

Similar to the results of precipitation trend analysis, 78% of the provinces do not result in a statistically significant trend. There is an increasing trend in the number of days with heavy precipitation in 17 provinces which are mainly located in the Black Sea Region.

As highlighted above, the assessment of risk and vulnerability is conducted in two parts. The second part includes the risk and vulnerability assessment of 81 provinces. This is realized by assessing heat wave, drought, forest fire, and flood risk and vulnerabilities separately by creating composite indexes in terms of hazard, exposure, sensitivity, adaptive capacity, vulnerability, and risk. The primary findings of the assessment are summarized below. The assessment indicated that in almost every part of Turkey, there are provinces with high or very high levels of vulnerability and risk that require urgent action.

Findings on the Heat Wave Risk Assessment

According to the findings of the heat wave risk assessment, Mersin ranks first in the hazard dimension, Istanbul in the exposure dimension, and Şırnak and Şanlıurfa in the vulnerability dimension of heat wave risk. High or very high heat wave hazard levels are observed in 40% of the total number of provinces. Although the heat wave hazard map reveals a scattered picture for very high hazard throughout the west half of Turkey, it shows a high concentration of provinces with high hazard in the inner, north-western, and south-western parts. 14% of provinces show high/very high level of exposure to heat wave.

Provinces that are highly and very highly sensitive to heat wave prevails in the southern, south-eastern, and eastern parts of Turkey. Şanlıurfa, Diyarbakır, Mardin, Şırnak, and Batman are the most sensitive provinces with their high poverty, unemployment, dependency status, and significant landcover changes. Moreover, provinces with very low adaptive capacity are particularly evident in the majority of the south-eastern part and Afyonkarahisar in the western part of Turkey. One-fifth of the provinces with low adaptive capacity locates in the west half of Turkey. The provinces with poor adaptive capacity concentrating in the eastern and south-eastern parts of Turkey have some features in common: deficiencies in educational level, civic engagement, income and savings per capita, access to health care, and urban green spaces. Because of high sensitivity and low adaptive capacity, 28% of the provinces are of high or very high levels of vulnerability to heat wave. The low adaptive capacity of western provinces, which constitutes 20% of 81 provinces are found to be compensated by low sensitivity to heat wave.

İstanbul, Gaziantep, Ankara, and Kayseri are at very high risk of heat wave, respectively. The population of these four provinces is more than 21 million (TurkStat, 2022), including a high number of children and elderly, low-income groups, and refugee populations that are proved to be highly sensitive to heat wave. The expected increase in the intensity and frequency of heat wave may add up to a sharp loss of productivity and direct damage to infrastructure. Increases in the frequency of heat waves may result in several problems for various sectors, such as water quality and crop yield may decrease, water demand, the number of forest fire and heat-related diseases and mortality may increase. Table 185 shows the heat wave risk and vulnerability profiles of the provinces with their sub-dimensions.

Table 185: Summary of Heat Wave Risk and Vulnerability Profiles of Provinces

Provinces	Hazard	Exposure	Sensitivity	Adaptive Capacity	Vulnerability	Risk
Adana	Very Low	High	High	High	Moderate	Low
Adıyaman	Moderate	Moderate	High	Low	High	High
Afyonkarahisar	Moderate	Low	Low	Very Low	High	Moderate
Ağrı	High	Low	High	Very Low	Very High	High
Aksaray	High	Low	Moderate	Low	Moderate	Moderate
Amasya	Very High	Low	Low	Low	Moderate	Moderate
Ankara	High	High	Low	Very High	Very Low	Very High
Antalya	Moderate	High	Low	High	Very Low	High
Ardahan	Very Low	Very Low	Moderate	Low	High	Very Low
Artvin	Moderate	Very Low	Low	Moderate	Low	Low
Aydın	Moderate	Low	Moderate	High	Moderate	Moderate
Balıkesir	High	Low	Low	High	Low	Moderate
Bartın	Very Low	Very Low	Low	Low	Low	Very Low
Batman	Very Low	Moderate	Very High	Low	Very High	Very Low
Bayburt	Moderate	Low	Low	Low	Moderate	Moderate
Bilecik	Very High	Very Low	Low	Moderate	Low	Low
Bingöl	Very Low	Low	Moderate	Low	High	Very Low
Bitlis	Very Low	Very Low	High	Low	High	Very Low
Bolu	Moderate	Low	Low	Low	Moderate	Moderate
Burdur	Very High	Low	Moderate	Low	Moderate	Moderate
Bursa	Very Low	High	Moderate	Very High	Low	Moderate
Çanakkale	High	Low	Low	High	Low	Low
Çankırı	High	Very Low	Low	Moderate	Low	Low
Çorum	Very High	Low	Moderate	Low	Moderate	Moderate
Denizli	Very High	Moderate	Low	High	Low	Moderate
Diyarbakır	Very Low	Low	Very High	Low	Very High	Very Low
Düzce	Very Low	Moderate	Very Low	Moderate	Very Low	Very Low
Edirne	High	Low	Low	Moderate	Low	Moderate
Elazığ	Moderate	Low	Moderate	High	Moderate	Moderate
Erzincan	High	Low	Low	Moderate	Low	Moderate
Erzurum	Low	Low	Moderate	Moderate	Moderate	Low
Eskişehir	Low	High	Low	High	Very Low	Moderate
Gaziantep	Moderate	High	High	Moderate	High	Very High
Giresun	Very Low	Low	Low	Low	Moderate	Very Low
Gümüşhane	Very Low	Very Low	Low	Low	Low	Very Low
Hakkari	Very Low	Very Low	High	Very Low	High	Very Low

Table 185 (continued)

Provinces	Hazard	Exposure	Sensitivity	Adaptive Capacity	Vulnerability	Risk
Hatay	Very Low	Moderate	High	High	High	Low
Iğdır	Very Low	Low	Moderate	Low	High	Very Low
Isparta	High	Moderate	Very Low	Low	Low	Moderate
İstanbul	High	Very High	Moderate	Very High	Very Low	Very High
İzmir	Very Low	Very High	Moderate	Very High	Low	High
Kahramanmaraş	Moderate	Low	High	Moderate	High	Moderate
Karabük	Very Low	Low	Low	Moderate	Low	Very Low
Karaman	Moderate	Low	Very Low	High	Very Low	Low
Kars	Very Low	Very Low	Moderate	Low	High	Very Low
Kastamonu	High	Low	Moderate	Low	Moderate	Moderate
Kayseri	High	High	Moderate	High	Moderate	Very High
Kırıkkale	Very High	Moderate	Moderate	High	Low	Moderate
Kırklareli	Very High	Low	Low	High	Low	Moderate
Kırşehir	Very High	Low	Moderate	Low	Moderate	Moderate
Kilis	Very Low	Moderate	High	Low	High	Low
Kocaeli	Very Low	High	Moderate	Very High	Very Low	Moderate
Konya	Moderate	Moderate	Low	Moderate	Low	High
Kütahya	Moderate	Low	Very Low	Low	Very Low	Low
Malatya	Very High	Low	Moderate	Moderate	Moderate	Moderate
Manisa	Very Low	Moderate	Low	Low	Moderate	Low
Mardin	Very Low	Low	Very High	Low	Very High	Low
Mersin	Very High	Moderate	High	High	High	High
Muğla	High	Low	Moderate	High	Low	Moderate
Muş	Moderate	Low	High	Very Low	Very High	Moderate
Nevşehir	Very High	Low	Moderate	Low	Moderate	Moderate
Niğde	High	Low	Moderate	Low	Moderate	Moderate
Ordu	Moderate	Low	Moderate	High	Low	Moderate
Osmaniye	Very Low	Low	High	Moderate	High	Very Low
Rize	Moderate	Low	Low	Moderate	Low	Low
Sakarya	Very High	Moderate	Moderate	Very High	Low	Moderate
Samsun	Very Low	High	Low	High	Low	Low
Siirt	Very Low	Low	High	Very Low	Very High	Very Low
Sinop	Low	Low	Moderate	Moderate	Moderate	Low
Sivas	High	Very Low	Moderate	Moderate	Moderate	Low
Şanlıurfa	Moderate	Moderate	Very High	Very Low	Very High	High
Şırnak	Very Low	Low	Very High	Very Low	Very High	Low
Tekirdağ	Very High	Moderate	Low	High	Low	Moderate
Tokat	Very High	Low	Low	Moderate	Low	Moderate
Trabzon	Moderate	Moderate	Low	High	Low	Moderate
Tunceli	Moderate	Very Low	Very Low	Moderate	Very Low	Low
Uşak	High	Moderate	Very Low	Low	Low	Moderate
Van	Very Low	Very Low	High	Very Low	Very High	Low
Yalova	Very High	Moderate	Moderate	Very High	Low	Moderate
Yozgat	High	Very Low	Moderate	Low	Moderate	Low
Zonguldak	Very Low	Low	Low	Moderate	Low	Very Low

Findings on the Drought Risk Assessment

The findings on the assessment of drought risk and vulnerability indicate that Mersin and Muğla in terms of hazard, Konya in terms of exposure and Şırnak in terms of vulnerability have the highest index results for heat wave. High or very high drought hazard levels prevail in approximately half of the total number of provinces which are evident in the majority of inner, north-western, and southwestern parts of Turkey. 38% of the provinces are classified as highly and very highly exposed to drought. Provinces most exposed to drought hazard are observed mainly throughout western, southwestern, and inner parts of Turkey.

Provinces with high sensitivity are primarily concentrated in the eastern and south-eastern parts of Turkey, as is the case for heat wave sensitivity as well. Batman and Şırnak are the most sensitive provinces to drought due to having a considerable number of species in Red List category, agricultural GDP, poverty, unemployment, and dependency ratio. There are only four provinces with a very high adaptive capacity to drought. 54% of the provinces have low/very low capacity to adapt. Provinces with the lowest adaptive capacity prevail in the eastern and southeastern part, Afyonkarahisar in the western part, and Osmaniye in the south. As a result, the south-eastern part of Turkey is particularly vulnerable to drought due to high sensitivity and low adaptive capacity, as it is also observed for heat wave vulnerability. Siirt, Şırnak, Batman, and Mardin are the most vulnerable provinces to drought.

30 provinces are of high/very high levels of drought risk concentrating mainly in the inner, southern, and eastern parts of Turkey. There is a medium to very high drought risk in all provinces of Turkey except for the provinces on the northern line and a few provinces in the southeast region. Most of these provinces are the locomotives of agricultural production with their productive agricultural land, which the rural population is highly dependent on for living and the urban population for being fed. Moreover, these 30 provinces are home to %46 of the species in Red List category in Turkey. Being already critically endangered, endangered, and vulnerable species according to IUCN classification, these species are at stake considering the increasing drought frequency and intensity.

Higher drought risk levels threaten the welfare of the poor in rural areas, particularly those who have low levels of access to modern agricultural inputs, critical infrastructure, and education. Therefore, drought adaptation policies, especially the ones focusing on water, agriculture, forestry, and biodiversity need to take rural contexts into account. Diversifying regional economies on different sectors of activity and reducing the dependence of GDP on agriculture may also serve to reduce drought risk in provinces with higher risk levels.

Table 186 indicates the drought risk and vulnerability profiles of the provinces with their sub-dimensions.

Table 186: Summary of Drought Risk and Vulnerability Profiles of Provinces

Provinces	Hazard	Exposure	Sensitivity	Adaptive Capacity	Vulnerability	Risk
Adana	Very Low	Very High	Moderate	High	Low	Moderate
Adıyaman	High	Low	High	Low	Moderate	High
Afyonkarahisar	Moderate	Very High	Low	Very Low	Moderate	Very High
Ağrı	High	Moderate	High	Very Low	High	Very High
Aksaray	High	Very High	Low	Low	Low	Very High
Amasya	Moderate	Moderate	Moderate	Low	Moderate	High
Ankara	High	Very High	Low	Very High	Very Low	Moderate
Antalya	High	Very High	Low	Moderate	Low	High
Ardahan	Very Low	Low	Moderate	Low	Moderate	Very Low
Artvin	Moderate	Very Low	Moderate	Moderate	Low	Very Low
Aydın	High	High	Low	Moderate	Low	High
Balıkesir	Very High	Very High	Low	Moderate	Low	High
Bartın	Very Low	Very Low	Low	Moderate	Low	Very Low
Batman	Very Low	Very Low	Very High	Very Low	Very High	Low
Bayburt	Moderate	Very Low	Moderate	Low	Moderate	Low
Bilecik	Very High	Low	Low	Low	Low	Moderate
Bingöl	Low	Very Low	Moderate	Low	Moderate	Low
Bitlis	Very Low	Low	High	Very Low	High	Low
Bolu	Moderate	Low	Low	Low	Low	Moderate
Burdur	Very High	High	Low	Low	Low	High
Bursa	Low	Very High	Low	High	Very Low	Moderate
Çanakkale	High	High	Low	Moderate	Low	High
Çankırı	High	Low	Low	Low	Low	Moderate
Çorum	High	Low	Moderate	Low	Moderate	Moderate
Denizli	Very High	Very High	Low	Moderate	Low	Very High
Diyarbakır	Very Low	Moderate	Very High	Low	High	Moderate
Düzce	Low	Low	Very Low	Moderate	Very Low	Very Low
Edirne	Moderate	High	Low	Moderate	Low	Moderate
Elazığ	High	Low	Moderate	Moderate	Low	Moderate
Erzincan	Very High	Moderate	Low	Low	Low	High
Erzurum	Moderate	High	Moderate	High	Low	High
Eskişehir	High	High	Low	High	Very Low	Moderate
Gaziantep	Moderate	High	Moderate	Moderate	Low	High
Giresun	Very Low	Low	Moderate	Low	Moderate	Very Low
Gümüşhane	Low	Low	Low	Low	Low	Low
Hakkari	Low	Very Low	High	Very Low	High	Low
Hatay	Low	High	Moderate	Low	Moderate	Moderate
Iğdır	Low	Moderate	High	Low	Moderate	Moderate
Isparta	High	High	Very Low	High	Very Low	Moderate
İstanbul	High	Low	Low	Very High	Very Low	Very Low
İzmir	Low	Very High	Moderate	Very High	Very Low	Moderate
Kahramanmaraş	High	High	High	Low	Moderate	Very High
Karabük	Low	Very Low	Low	Moderate	Low	Very Low
Karaman	High	High	Very Low	Low	Low	High
Kars	Very Low	Moderate	Moderate	Low	Moderate	Low
Kastamonu	Moderate	Moderate	Low	Low	Low	Moderate
Kayseri	High	Very High	Moderate	Moderate	Low	Very High
Kırıkkale	Very High	Low	High	Low	Moderate	Moderate
Kırklareli	High	Moderate	Moderate	Moderate	Low	Moderate
Kırşehir	Very High	Moderate	Low	Low	Low	High

Table 186 (continued)

Provinces	Hazard	Exposure	Sensitivity	Adaptive Capacity	Vulnerability	Risk
Kilis	Low	Very Low	Very High	Low	High	Low
Kocaeli	Low	Low	Moderate	Very High	Very Low	Very Low
Konya	High	Very High	Low	High	Very Low	Very High
Kütahya	Moderate	Moderate	Very Low	Moderate	Very Low	Moderate
Malatya	Very High	High	Low	Low	Low	High
Manisa	Low	Very High	Low	Low	Low	Moderate
Mardin	Low	Low	Very High	Very Low	Very High	High
Mersin	Very High	Very High	Moderate	High	Low	Very High
Muğla	Very High	High	Low	Moderate	Low	High
Muş	High	Moderate	High	Very Low	High	Very High
Nevşehir	Very High	Moderate	Low	Low	Low	Moderate
Niğde	High	High	Low	Low	Low	High
Ordu	Low	Very Low	Moderate	Moderate	Moderate	Low
Osmaniye	Very Low	Moderate	High	Very Low	High	Low
Rize	Low	Very Low	Low	Moderate	Low	Very Low
Sakarya	Moderate	Moderate	Low	High	Very Low	Moderate
Samsun	Very Low	Very High	Low	High	Very Low	Low
Siirt	Very Low	Very Low	Very High	Very Low	Very High	Low
Sinop	Very Low	Low	Moderate	Low	Moderate	Low
Sivas	High	High	Moderate	Moderate	Low	High
Şanlıurfa	High	Very High	High	Very Low	High	Very High
Şırnak	Low	Very Low	Very High	Very Low	Very High	Moderate
Tekirdağ	High	Moderate	Moderate	High	Low	Moderate
Tokat	Very High	Moderate	Moderate	Low	Moderate	High
Trabzon	Very Low	Very Low	Low	High	Very Low	Very Low
Tunceli	High	Very Low	Very Low	Moderate	Very Low	Low
Uşak	High	Low	Very Low	Low	Low	Moderate
Van	Low	High	High	Very Low	High	High
Yalova	High	Very Low	Moderate	Moderate	Low	Low
Yozgat	High	Moderate	High	Low	Moderate	High
Zonguldak	Very Low	Very Low	Low	Moderate	Low	Very Low

Findings on the Forest Fire Risk Assessment

The findings on the assessment of forest fire risk and vulnerability show that Mersin ranks first in the hazard dimension, Antalya and Muğla in the exposure dimension, and Şırnak in the vulnerability dimension of forest fire risk. High or very high forest fire hazard level is prominent in approximately half of the total number of provinces. There is a high concentration of provinces with high hazard in the inner, north-western, south-western, and southern parts. Provinces that are highly and very highly exposed to forest fire, which constitute approximately half of the entire provinces, are observed in the majority of western, southwestern, and southern parts, in Samsun and Kastamonu in the northern part of Turkey. Notably, the provinces exposed to forest fire are concentrated mainly in the coastal areas.

Highly and very highly sensitive provinces to forest fire which represent one-third of the entire provinces are mostly located in the east half of the country. Provinces with very high sensitivity are the ones with high dependency ratio and forest poverty and they are mostly concentrated in the south-eastern part of Turkey. The capacity to adapt to forest fires is classified as low or very low in 38% of the provinces. Most provinces have a moderate to very low degree of adaptive capacity to forest fire. Turkey's southeastern and eastern provinces, as well as Afyonkarahisar in the west, have the lowest capacity to adapt to forest fire. As a result, the vulnerability to forest fire is high/very high in one-fifth of the provinces. Due to very high levels of sensitivity and very low levels of adaptive capacity, the south-eastern region of Turkey is more vulnerable to forest fires than other parts of the country, which was also observed in sensitivity to heat waves and drought. Kilis, Mardin, Batman, Siirt, and Şırnak are most vulnerable to forest fire, as they are also to drought except Kilis. Despite its moderate adaptive capacity, Kilis’s very high sensitivity gives rise to very high level of vulnerability to forest fire. Contrary to Kilis, Afyonkarahisar’s low sensitivity is found to compensate its very low adaptive capacity and result in low vulnerability.

As for risk, Mersin, Kahramanmaraş, Mardin, Şırnak, and Siirt are the provinces at most risk of forest fire. Mersin's risk level is the consequence of very high exposure and hazard, and high vulnerability, whereas Kahramanmaraş's risk level is the result of very high exposure and hazard with moderate vulnerability. Moderate exposure and very high vulnerability explain very high forest fire risk in Mardin, Şırnak, and Siirt provinces. Provinces with high or very high risk constitute one-third of the entire provinces. These 27 provinces have a forest village population of 2.75 million people and are home to 35% of species in Turkey. Recent experiences show that forest fire has threatened not only forest villages but also urban areas which increasingly intertwined with forests, especially in the coastal areas of the country, which makes it more challenging considering the direct impacts of forest fire on human health, ecosystem functioning, forest structure, food security and the natural resources-based livelihoods. The forest fire risk and vulnerability profiles of the provinces with their sub-dimensions are indicated in Table 187.

Table 187: Summary of Forest Fire Risk and Vulnerability Profiles of Provinces

Provinces	Hazard	Exposure	Sensitivity	Adaptive Capacity	Vulnerability	Risk
Adana	Very Low	High	High	High	High	High
Adıyaman	High	Low	High	Low	Moderate	High
Afyonkarahisar	Moderate	Very High	Low	Very Low	Low	Moderate
Ağrı	Moderate	High	High	Very Low	High	Low
Aksaray	High	Low	Moderate	Moderate	Low	Low
Amasya	Moderate	Very High	High	Moderate	Moderate	High
Ankara	High	High	Low	Very High	Low	Moderate
Antalya	High	Low	Moderate	High	Low	High
Ardahan	Very Low	Low	Moderate	Low	Moderate	Very Low
Artvin	Moderate	High	Low	Moderate	Low	Moderate
Aydın	High	Very Low	Low	Moderate	Low	Moderate
Balıkesir	Very High	High	Moderate	High	Low	High
Bartın	Very Low	Moderate	Low	Moderate	Low	Low
Batman	Very Low	Moderate	Very High	Very Low	Very High	High
Bayburt	Moderate	Low	Moderate	Low	Moderate	Very Low
Bilecik	Very High	Very High	Very Low	Moderate	Very Low	Very Low
Bingöl	Low	Moderate	Moderate	Low	Moderate	Moderate
Bitlis	Very Low	High	High	Very Low	Moderate	Moderate
Bolu	Moderate	Low	Very Low	Moderate	Very Low	Low
Burdur	Very High	Very Low	Moderate	Moderate	Moderate	High
Bursa	Low	High	Very Low	Very High	Very Low	Very Low
Çanakkale	High	Low	Low	High	Low	High
Çankırı	High	Very High	Moderate	Moderate	Moderate	Moderate
Çorum	High	Low	High	Low	Moderate	High
Denizli	Very High	High	Low	High	Very Low	Moderate
Diyarbakır	Very Low	Low	Very High	Low	High	High
Düzce	Low	Very Low	Very Low	Moderate	Very Low	Very Low
Edirne	Moderate	Moderate	Low	Moderate	Low	Low
Elazığ	High	Low	Moderate	High	Low	Moderate
Erzincan	High	Moderate	Moderate	Moderate	Moderate	Moderate
Erzurum	Moderate	Very High	Moderate	Moderate	Moderate	High
Eskişehir	High	Very High	Very Low	High	Very Low	Very Low
Gaziantep	Moderate	Very Low	High	Moderate	Moderate	High
Giresun	Very Low	Low	Moderate	Moderate	Moderate	Low
Gümüşhane	Low	Low	Low	Low	Low	Low
Hakkari	Low	Low	Moderate	Very Low	Moderate	Moderate
Hatay	Low	Very Low	High	Moderate	Moderate	Moderate
Iğdır	Low	Low	Moderate	Low	Moderate	Very Low
Isparta	High	Moderate	Moderate	High	Low	High
İstanbul	High	Very Low	Low	Very High	Very Low	Low
İzmir	Low	Very Low	Low	Very High	Very Low	Low
Kahramanmaraş	Very High	High	High	Low	High	Very High
Karabük	Low	High	Low	High	Low	Low
Karaman	High	Low	High	Moderate	Moderate	High
Kars	Very Low	Moderate	Moderate	Low	Moderate	Very Low
Kastamonu	Moderate	High	Moderate	Low	Moderate	High
Kayseri	High	High	Moderate	High	Low	Moderate
Kırıkkale	Very High	High	High	Moderate	High	High
Kırklareli	High	Moderate	Moderate	High	Low	Moderate
Kırşehir	Very High	Moderate	Moderate	Moderate	Low	Low
Kilis	Low	Very Low	Very High	Low	Very High	Low
Kocaeli	Low	Moderate	Very Low	Very High	Very Low	Very Low
Konya	High	High	Moderate	Moderate	Low	High
Kütahya	High	Moderate	Low	Moderate	Low	Moderate
Malatya	Very High	Low	High	Low	Moderate	High
Manisa	Low	Low	Low	Low	Low	Moderate
Mardin	Low	High	Very High	Very Low	Very High	Very High
Mersin	Very High	Low	Moderate	High	Moderate	Very High
Muğla	Very High	Very Low	Low	High	Very Low	Moderate
Muş	Moderate	Very High	High	Very Low	High	High
Nevşehir	High	Low	Moderate	Moderate	Moderate	Low
Niğde	High	Very High	Moderate	Low	Moderate	Moderate
Ordu	Low	Low	Moderate	Moderate	Moderate	Moderate
Osmaniye	Very Low	Low	High	Low	High	Moderate

Table 187 (continued)

Provinces	Hazard	Exposure	Sensitivity	Adaptive Capacity	Vulnerability	Risk
Rize	Low	Low	Low	Moderate	Low	Low
Sakarya	Moderate	High	Very Low	Very High	Very Low	Very Low
Samsun	Very Low	High	Moderate	High	Low	Moderate
Siirt	Very Low	Very Low	Very High	Very Low	Very High	Very High
Sinop	Very Low	Moderate	High	Moderate	Moderate	Moderate
Sivas	High	Very High	High	Moderate	Moderate	High
Şanlıurfa	High	Low	High	Very Low	High	Moderate
Şırnak	Low	Low	Very High	Very Low	Very High	Very High
Tekirdağ	High	Low	High	High	Moderate	Moderate
Tokat	Very High	Very High	Moderate	Low	Moderate	High
Trabzon	Very Low	High	Low	High	Low	Low
Tunceli	High	Moderate	Very Low	Low	Very Low	Low
Uşak	High	Very Low	Low	Low	Low	Low
Van	Low	Very High	High	Very Low	High	Moderate
Yalova	High	Very Low	Very Low	High	Very Low	Very Low
Yozgat	High	Moderate	High	Low	High	High
Zonguldak	Very Low	Moderate	Moderate	High	Low	Very Low

Findings on the Flood Risk Assessment

According to the findings on the assessment of flood risk, Trabzon, Rize, and Giresun in terms of hazard, Çankırı, Eskişehir and Amasya in terms of exposure, and Şırnak and Ağrı in terms of vulnerability are the provinces with extreme flood index results. High or very high flood hazard level is observed in more than one-fourth of the provinces with a concentration in the mid-north and north-eastern of Turkey. Giresun, Trabzon, and Rize are the provinces with very high levels of hazard. Moreover, 29 provinces are highly/very highly exposed to flood. Most exposure prevails in the inner and the eastern parts.

27 provinces which show high/very high flood sensitivity are evident in the eastern and south-eastern parts of Turkey, similar to heat wave, drought, and forest fire sensitivity. Provinces with very high flood sensitivity are found to suffer low-quality housing, high poverty, and dependency ratios. The adaptive capacity of more than one-fifth of the provinces is found as low or very low. Afyonkarahisar and Aksaray in the inner, Bolu, Kastamonu, and Çorum in the north, Giresun, Gümüşhane, and Ardahan in the northeast, as well as many provinces throughout the south-eastern and eastern borders, are provinces with low adaptive capacity. The capacity to adapt to flooding is least in Şırnak, Hakkari, and Ağrı, which are characterized by low flood control zone per flood-prone area, low share of urban green space, limited

access to road, railroad, and hospitals, low levels of civic engagement, income, and savings. Therefore, because of very high levels of sensitivity and low/very low levels of adaptive capacity, 40% of the provinces are classified as highly/very highly vulnerable to flood, which are evident in the south-eastern and eastern parts.

Very high flood risk is concentrated in inner, north-eastern, and eastern parts of Turkey. 25 provinces indicate high/very high flood risk. There are 855363 people living in the flood-prone area in these provinces. This is equal to more than 10% of total population of the country. In addition, there are 1 airport, 11 power plants, and 273 hospitals located in the flood-prone area in these provinces at high risk or very high risk. Critical infrastructure is particularly vital systems whose failures could bring serious consequences for overall functionality in a province and intensifies the flood impact. 22 of these 25 provinces also have moderate to very high levels of vulnerability to flood. Table 188 represents the flood risk and vulnerability profiles of the provinces with their sub-dimensions.

Table 188: Summary of Flood Risk and Vulnerability Profiles of Provinces

Provinces	Hazard	Exposure	Sensitivity	Adaptive Capacity	Vulnerability	Risk
Adana	Moderate	High	High	High	High	High
Adıyaman	Low	Low	Very High	Moderate	Very High	Moderate
Afyonkarahisar	Moderate	Very High	Low	Low	Moderate	High
Ağrı	Moderate	High	Very High	Very Low	Very High	Very High
Aksaray	Moderate	Low	Moderate	Low	High	Low
Amasya	High	Very High	Moderate	Moderate	Moderate	Very High
Ankara	Low	High	Low	Very High	Very Low	Low
Antalya	Low	Low	Low	High	Low	Low
Ardahan	High	Low	High	Low	Very High	High
Artvin	High	High	Moderate	Moderate	Moderate	High
Aydın	Low	Very Low	Moderate	High	Moderate	Very Low
Balıkesir	Low	High	Moderate	High	Low	Moderate
Bartın	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Batman	Low	Moderate	Very High	Moderate	Very High	Moderate
Bayburt	High	Low	Moderate	Low	High	Moderate
Bilecik	Low	Very High	Low	High	Low	High
Bingöl	High	Moderate	High	Moderate	High	Moderate
Bitlis	High	High	Very High	Moderate	Very High	Very High
Bolu	Moderate	Low	Very Low	Low	Very Low	Very Low
Burdur	Low	Very Low	Moderate	Moderate	Moderate	Very Low
Bursa	Low	High	Moderate	Very High	Low	Low
Çanakkale	Low	Low	Moderate	High	Moderate	Low
Çankırı	Moderate	Very High	Moderate	High	Moderate	Very High
Çorum	Moderate	Low	Moderate	Low	High	Moderate
Denizli	Low	High	Moderate	High	Low	Moderate
Diyarbakır	Low	Low	Very High	Moderate	Very High	Moderate
Düzce	Moderate	Very Low	Very Low	Moderate	Very Low	Very Low

Table 188 (continued)

Provinces	Hazard	Exposure	Sensitivity	Adaptive Capacity	Vulnerability	Risk
Edirne	Low	Moderate	Low	High	Low	Low
Elazığ	Low	Low	High	High	Moderate	Low
Erzincan	Moderate	Moderate	Moderate	High	Moderate	Moderate
Erzurum	High	Very High	High	Moderate	High	Very High
Eskişehir	Low	Very High	Low	High	Very Low	Moderate
Gaziantep	Moderate	Very Low	High	High	High	Low
Giresun	Very High	Low	Moderate	Low	High	High
Gümüşhane	High	Low	Low	Low	Moderate	Moderate
Hakkari	High	Low	High	Very Low	Very High	Moderate
Hatay	High	Very Low	High	High	High	Low
Iğdır	Moderate	Low	High	Low	Very High	Moderate
Isparta	Low	Moderate	Very Low	Moderate	Very Low	Very Low
İstanbul	Moderate	Very Low	Low	Very High	Very Low	Very Low
İzmir	Low	Very Low	Moderate	Very High	Low	Very Low
Kahramanmaraş	Moderate	High	High	High	High	High
Karabük	Moderate	High	Moderate	High	Moderate	Moderate
Karaman	Low	Low	Very Low	High	Very Low	Very Low
Kars	High	Moderate	High	Moderate	High	High
Kastamonu	Moderate	High	Moderate	Low	High	High
Kayseri	Moderate	High	Moderate	High	Moderate	High
Kırıkkale	Moderate	High	Moderate	High	Low	High
Kırklareli	Low	Moderate	Low	High	Low	Low
Kırşehir	Low	Moderate	Moderate	Moderate	Moderate	Low
Kilis	Very Low	Very Low	Very High	Moderate	High	Very Low
Kocaeli	High	Moderate	Moderate	Very High	Very Low	Moderate
Konya	Low	High	Low	High	Low	Low
Kütahya	Low	Moderate	Very Low	Moderate	Very Low	Low
Malatya	Very Low	Low	High	High	High	Very Low
Manisa	Low	Low	Low	Moderate	Moderate	Low
Mardin	Very Low	High	Very High	Low	Very High	Moderate
Mersin	Moderate	Low	High	High	High	Moderate
Muğla	Low	Very Low	Moderate	Moderate	Moderate	Low
Muş	Low	Very High	Very High	Low	Very High	Very High
Nevşehir	Moderate	Low	Moderate	Moderate	Moderate	Low
Niğde	High	Very High	Moderate	Moderate	Moderate	Very High
Ordu	High	Low	Moderate	Moderate	High	Moderate
Osmaniye	Moderate	Low	High	High	High	Moderate
Rize	Very High	Low	Low	Moderate	Moderate	High
Sakarya	Moderate	High	Moderate	Very High	Low	Moderate
Samsun	High	High	Moderate	High	Low	High
Siirt	Moderate	Very Low	Very High	Low	Very High	Low
Sinop	Moderate	Moderate	Moderate	Moderate	Moderate	High
Sivas	High	Very High	Moderate	High	Moderate	Very High
Şanlıurfa	Low	Low	Very High	Low	Very High	Moderate
Şırnak	Moderate	Low	Very High	Very Low	Very High	Moderate
Tekirdağ	Low	Low	Low	High	Low	Low
Tokat	High	Very High	Moderate	High	Moderate	Very High
Trabzon	Very High	High	Moderate	Moderate	Moderate	Very High
Tunceli	Low	Moderate	Very Low	Moderate	Low	Low
Uşak	Low	Very Low	Very Low	Moderate	Low	Very Low
Van	High	Very High	Very High	Low	Very High	Very High
Yalova	High	Very Low	Moderate	Very High	Low	Very Low
Yozgat	Moderate	Moderate	High	Moderate	High	Moderate
Zonguldak	Moderate	Moderate	Moderate	High	Moderate	Moderate

Evaluation of the Overall Climate Risk Assessment

Although the highest climate risk prevails in Amasya and Tokat in the north, Mersin, Kahramanmaraş, and Kayseri in the south, and Muş and Ağrı in the east part of Turkey, the overall climate risk assessment show that 36% of provinces are of high or very high levels of climate risk. The individual and overall risk levels of provinces are provided in Table 189. The steps of the risk analysis addressed in the previous chapters allow tracing back the causes of risk results.

Table 189: Individual and Overall Risk Levels of Provinces

Province	Heat Risk Level	Drought Risk Level	Forest Fire Risk Level	Flood Risk Level	Overall Risk Level
Adana	Low	Moderate	High	High	High
Adıyaman	High	High	High	Moderate	High
Afyonkarahisar	Moderate	Very High	Moderate	High	High
Ağrı	High	Very High	Low	Very High	Very High
Aksaray	Moderate	Very High	Low	Low	Moderate
Amasya	Moderate	High	High	Very High	Very High
Ankara	Very High	Moderate	Moderate	Low	High
Antalya	High	High	High	Low	High
Ardahan	Very Low	Very Low	Very Low	High	Very Low
Artvin	Low	Very Low	Moderate	High	Moderate
Aydın	Moderate	High	Moderate	Very Low	Moderate
Balıkesir	Moderate	High	High	Moderate	High
Bartın	Very Low	Very Low	Low	Moderate	Very Low
Batman	Very Low	Low	High	Moderate	Moderate
Bayburt	Moderate	Low	Very Low	Moderate	Low
Bilecik	Low	Moderate	Very Low	High	Moderate
Bingöl	Very Low	Low	Moderate	Moderate	Low
Bitlis	Very Low	Low	Moderate	Very High	Moderate
Bolu	Moderate	Moderate	Low	Very Low	Low
Burdur	Moderate	High	High	Very Low	Moderate
Bursa	Moderate	Moderate	Very Low	Low	Low
Çanakkale	Low	High	High	Low	Moderate
Çankırı	Low	Moderate	Moderate	Very High	High
Çorum	Moderate	Moderate	High	Moderate	High
Denizli	Moderate	Very High	Moderate	Moderate	High
Diyarbakır	Very Low	Moderate	High	Moderate	Moderate
Düzce	Very Low	Very Low	Very Low	Very Low	Very Low
Edirne	Moderate	Moderate	Low	Low	Moderate
Elazığ	Moderate	Moderate	Moderate	Low	Moderate
Erzincan	Moderate	High	Moderate	Moderate	High
Erzurum	Low	High	High	Very High	High
Eskişehir	Moderate	Moderate	Very Low	Moderate	Moderate
Gaziantep	Very High	High	High	Low	High
Giresun	Very Low	Very Low	Low	High	Low
Gümüşhane	Very Low	Low	Low	Moderate	Low
Hakkari	Very Low	Low	Moderate	Moderate	Low
Hatay	Low	Moderate	Moderate	Low	Moderate
Iğdır	Very Low	Moderate	Very Low	Moderate	Low

Table 189 (continued)

Isparta	Moderate	Moderate	High	Very Low	Moderate
İstanbul	Very High	Very Low	Low	Very Low	Low
İzmir	High	Moderate	Low	Very Low	Moderate
Kahramanmaraş	Moderate	Very High	Very High	High	Very High
Karabo	Very Low	Very Low	Low	Moderate	Very Low
Karaman	Low	High	High	Very Low	Moderate
Kars	Very Low	Low	Very Low	High	Low
Kastamonu	Moderate	Moderate	High	High	High
Kayseri	Very High	Very High	Moderate	High	Very High
Kırıkkale	Moderate	Moderate	High	High	High
Kırklareli	Moderate	Moderate	Moderate	Low	Moderate
Kırşehir	Moderate	High	Low	Low	Moderate
Kilis	Low	Low	Low	Very Low	Very Low
Kocaeli	Moderate	Very Low	Very Low	Moderate	Low
Konya	High	Very High	High	Low	High
Kütahya	Low	Moderate	Moderate	Low	Moderate
Malatya	Moderate	High	High	Very Low	Moderate
Manisa	Low	Moderate	Moderate	Low	Moderate
Mardin	Low	High	Very High	Moderate	High
Mersin	High	Very High	Very High	Moderate	Very High
Muğla	Moderate	High	Moderate	Low	Moderate
Muş	Moderate	Very High	High	Very High	Very High
Nevşehir	Moderate	Moderate	Low	Low	Moderate
Niğde	Moderate	High	Moderate	Very High	High
Ordu	Moderate	Low	Moderate	Moderate	Moderate
Osmaniye	Very Low	Low	Moderate	Moderate	Low
Rize	Low	Very Low	Low	High	Low
Sakarya	Moderate	Moderate	Very Low	Moderate	Moderate
Samsun	Low	Low	Moderate	High	Moderate
Siirt	Very Low	Low	Very High	Low	Moderate
Sinop	Low	Low	Moderate	High	Moderate
Sivas	Low	High	High	Very High	High
Şanlıurfa	High	Very High	Moderate	Moderate	High
Şırnak	Low	Moderate	Very High	Moderate	High
Tekirdağ	Moderate	Moderate	Moderate	Low	Moderate
Tokat	Moderate	High	High	Very High	Very High
Trabzon	Moderate	Very Low	Low	Very High	Moderate
Tunceli	Low	Low	Low	Low	Low
Uşak	Moderate	Moderate	Low	Very Low	Low
Van	Low	High	Moderate	Very High	High
Yalova	Moderate	Low	Very Low	Very Low	Very Low
Yozgat	Low	High	High	Moderate	High
Zonguldak	Very Low	Very Low	Very Low	Moderate	Very Low

Therefore, these provinces may be prioritized for the purpose of allocating resources, managing current and future climate risk, identifying options that reduce exposure and vulnerability of coupled human and natural systems. There are three main action domains based on the three components of risk in order to reduce and manage climate risks:

- Hazard Reduction: Limiting the increase in the frequency and intensity of hazards is directly related to and achieved by robust mitigation actions such as reducing GHG emissions and increasing natural carbon sinks. Although the level of hazard is something that can be influenced by global actions, local commitments cannot be underestimated. Hazards also include tipping points in the climate system and crossing one climate tipping point may also trigger others. As a result, hazards may appear in locations where they did not previously occur. Therefore, there is a strong and urgent need to pursue actions to limit the global temperature increase to well below 2°C or even to 1.5°C and to accelerate strategies for this purpose.

- Exposure Reduction: The degree of exposure is determined by the level of hazard and the characteristics of the relevant location that hazard occurs. The increasing intensification and frequency of hazards may also produce novel exposures. Therefore, from national to local levels, the necessary actions should be taken to reduce the exposure of coupled human and natural systems to climate hazards in order to decrease climate risks.

- Vulnerability Reduction: The actions to reduce the vulnerability of coupled human and natural systems to climate hazards should be taken by decreasing sensitivities and increasing the adaptive capacities of these systems. In this sense, it can be possible to restore natural and human systems to their formerly functionally robust state under current climate impacts. This requires a strong economy, improved access to finance and technology, effective governance and strong institutions to address climate adaptation.

Globally, there are numerous studies focusing on risk and vulnerability assessments to support policy makers and planners in producing adaptation options and risk reduction measures. However, in Turkey, these studies are very limited in number and do not have sufficient scope to guide planning and decision-making processes. Therefore, putting risk and vulnerability assessments in practice still falls short because of the lack of necessary linkages between the concepts of risk, vulnerability and adaptation and the spatial planning system. Although risk and vulnerability framework and their determinants are straightforward in climate change research, integrating this knowledge into planning stages has not yet become a concern in the spatial planning discipline. This situation poses an important challenge in reducing climate risks, of which its spatial aspect is one of the determinants. The inability of the planning discipline, considering its future-oriented mission, to integrate the risk into the planning processes is a planning problem in itself.

6.2. The (Dis)Connection Between Climate Adaptation Policy and Mainstream Spatial Planning

To address climate risks, it is imperative to understand how exposed and vulnerable natural and human systems are to a given level of hazard for generating appropriate planning policies and plans. As long as not to produce unintended results leading to maladaptation, spatial planning can reduce the exposure and vulnerability, therefore risk, when planners have a certain level of information regarding risks and vulnerabilities in a planning area, which can be obtained from risk and vulnerability assessment. For example, growing the settlement into a river zone will directly make the community exposed to heavy precipitation and flood events, or a functional change of urban green space into a built-up area will increase the exposure of the population, or the absence of critical infrastructure will decrease the capacity of a socio-economic system to adapt to a hazard.

As previously discussed, local and regional levels are especially prominent for planning and implementing adaptation measures. Considering its place-based nature, adaptation is highly dependent on spatial planning and its main products, mainstream spatial plans. In Turkey, climate adaptation planning and spatial planning is two-fold at the local/regional level. While adaptation planning proceeds mainly through local adaptation action plans and sustainable energy and climate action plan at this level, spatial plans are expected to include climate adaptation measures and consider climate change in planning strategies. However, while the former does not assess climate risks and vulnerabilities at the local level and pays little or no attention to the spatiality of adaptation, the latter does not address climate risks and vulnerabilities and therefore could not take the necessary adaptation measures to reduce the risks and vulnerabilities.

6.2.1. Climate Adaptation Action Planning and Its Relationship with Spatial Planning in Turkey

There are several greater metropolitan municipalities that focus on adaptation action: Bursa Sustainable Energy and Climate Adaptation Plan (2017), Trabzon Sustainable Energy and Climate Adaptation Plan (2019), Denizli Climate Change Action Plan (2019), Izmir Sustainable Energy and Climate Action Plan (2020), Izmir Green City Action Plan (2020), Istanbul Climate Change Action Plan (2021), Ankara Local Climate Change Action Plan (2021). Moreover, there are some other municipalities whose works regarding climate adaptation are in progress. Ankara Greater Municipality has been preparing Green City Action Plan to improve climate adaptation. In addition, UNDP has been working on the preparation of urban adaptation strategy and action plans for 4 pilot metropolitan cities, Konya, Muğla, Sakarya, and Samsun. To sum up, when the ongoing action plans are completed, the number of municipalities developing strategies for climate adaptation will have increased to 10. However, when these studies are examined in detail, it can be concluded that the spatial dimension of these plans is lacking, the spatial relationship with vulnerabilities and risks is not established. Moreover, the emphasis is mostly on the hazard component, and detailed information about exposed and vulnerable systems has not been found. Although climate action plans in general have the potential to contribute to the spatial planning process, they do not contain sufficient information and scope to give input to the spatial plans in Turkey.

On the other hand, spatial plans at different levels do not address climate risk and vulnerabilities as well, which is elaborated in the next part.

6.2.2. Spatial Planning and Its Relationship with Climate Risk, Vulnerability, and Adaptation in Turkey

In Turkey, spatial plans are prepared as Spatial Strategy Plans, Territorial Plans (Çevre Düzeni Planı) and Land Development Plans (İmar Planı) in terms of the area they cover and their purposes. In this context, the planning hierarchy consists of National Spatial Strategy Plan, Territorial Plans, Master Plans and Implementation Development Plans. This thesis attempts to investigate National Spatial Strategy Plan to understand the extent of which it takes action to prepare for and adjust to both the current and future impact of climate change. This attempt can be repeated for Territorial Plans or Land Development Plans.

NSSP is a plan that relates national development policies and regional development strategies at the spatial level, evaluates regional plans by taking into account the economic and social potential, goals and strategies, transportation relations and physical thresholds, and establishes the relationship between spatial policies and strategies related to sectors. It therefore coordinates regional development strategies, steer lower-level plans and investments accordingly.

National Spatial Strategy Plan of Turkey (hereinafter NSSP) started to be prepared in 2018 under the consultancy of Istanbul Technical University. It has not been completed yet, but draft versions are available. The plan's vision for 2050 is achieving "an inclusive, livable, innovative, competitive, climate change and disaster responsive, resilient and sustainable country". In line with Turkey's vision and goals, the aims of the National Spatial Strategy Plan are:

- Creating people-oriented, sustainable, resilient, smart cities with high socio-economic status,
- Ensuring a balanced distribution of infrastructure and services in accordance with development policies, covering urban and rural areas for economic and social development,
- Supporting the necessary spatial arrangements and infrastructure for the provision of competitive settlements,
- **Ensuring the integration of sectoral priorities, spatial development, and environmental policies for a sustainable environment by taking adaptation to climate change into account.**

One of the aims of the plan directly emphasizes on the climate adaptation. Within the scope of the plan, a total of 21 strategic targets and 82 strategies were determined. The 6th target that directly focuses on climate adaptation is "increasing adaptation and resilience to the impacts of climate change". The rest of the targets are also connected and related to climate adaptation. Strategies and actions of the 6th target is given below:

- Target 6: Increasing adaptation and resilience to the impacts of climate change
    - Strategy 6.1: Supporting land use decisions with spatial plans and urban development strategies in line with national climate change policies
        - Action 6.1.1: Issues related to sustainable urban development in the context of climate change will be added to the legislation.
        - Action 6.1.2: Conditions for the preparation of future climate projections will be updated.
        - Action 6.1.3: Spatial land use decisions that concern climate change will be handled in line with national policies.
    - Strategy 6.2: Making climate assessments mandatory in sectoral decisions
        - Action 6.2.1: Within the scope of increasing adaptation and resilience to the effects of climate change, legislative arrangements will be carried out for sector-based conditions.

        - Action 6.2.2: The impact of sectoral and investment decisions on climate change will be monitored and evaluated.
    - Strategy 6.3: Reducing water use and energy consumption and producing spatial planning principles in order to reduce the effects of climate change in existing tourism destinations

When strategies and actions are considered, the most striking issue of this target is not being grounded on climate risks and vulnerability analysis. As it is previously elaborated, developing an adaptation strategy and measure first necessitates identifying what and who are vulnerable to what stress, in what way, as well as what is the capacity to adapt to changing conditions. Therefore, this target does not have the necessary content and context in terms of climate adaptation.

Another point to mention is that Action 6.2.2 is prominent with its approach to adaptation. There is an apparent inconsistency between the action and its associated target because adaptation requires assessing the climate vulnerabilities and risks on sectors before making any decisions regarding these sectors and investments. Monitoring and evaluating the impacts after investing in sectors may exacerbate the current climate challenges; therefore, it cannot be considered an adaptation action. Another issue that needs to be mentioned regarding this target is its narrow scope. Inexplicably, tourism destinations have been addressed in a separate strategy, while different natural and socio-economic systems have been excluded and given no emphasis.

NSSP has a multi-centered development scenario that has been developed in order to eliminate the spatial, economic and sectoral imbalances between the east and the west of the country. The scenario includes the Urban Development Clusters – Attraction Foci (A, B, C, and D) and the Urban Development Clusters - Priority Development Foci (E, F, G, H, İ, J and K) as it is indicated in Figure 88. While the attraction foci are concentrated in the western region of the country, the priority development foci are predominantly in the central and eastern regions. Istanbul is defined as the first level attraction focus of the country. In the western region, the provinces of Tekirdağ, Kocaeli, Sakarya, Bursa, İzmir, Ankara, and Antalya are defined as the second-level attraction foci. There are no provinces defined as second level attraction foci in the central and eastern regions. The third level attraction foci include Yalova, Eskişehir, Denizli, Konya, Adana, and Gaziantep provinces. Manisa, Muğla, Mersin, Hatay, and Kayseri are the provinces at the fourth level attraction foci. Priority development foci, on the other hand, are Malatya, Sivas, Samsun, Ordu, Giresun, Trabzon, Şanlıurfa, Mardin, Van, Diyarbakır, Erzurum and Kars provinces.

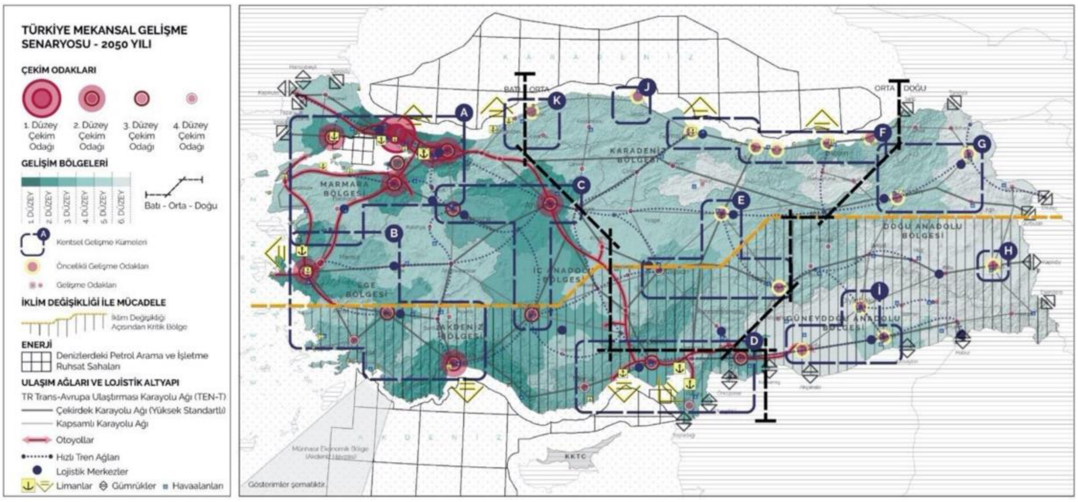

Figure 88: Türkiye's Spatial Development Scenario (MoEU, 2020)

NSSP aims to direct new functions (manufacturing industry) that attract the population in the first, second, and third level attraction foci in the western region to lower-level attraction foci and promote regional specialization for balanced development. This means that the population is steered towards Manisa, Muğla, Mersin, Hatay, Kayseri, Malatya, Sivas, Samsun, Ordu, Giresun, Trabzon, Şanlıurfa, Mardin, Van, Diyarbakır, Erzurum and Kars provinces. Since some of these provinces have high or very high overall climate risks, demographic growth in hazard-prone locations in these provinces can increase the population exposed and ultimately lead to further risk.

Therefore, spatial development scenario may take into consideration the level of hazard, exposure, vulnerability, and overall risk which are elaborated in Chapter 5, as well as consequences of events that have not yet occurred when steering the investments and population towards these provinces. There is a need for more comprehensive trade-off schemes between spatial planning and risk and vulnerability reduction.

Hazard is hardly managed through adaptation actions of spatial planning because reducing the occurrence of a hazard is directly related to and achieved by robust mitigation actions. However, spatial planning can play an important role in developing effective mitigation options such as promoting emission-intensive investments and land-use management.

Although it is challenging to achieve, a spatial plan can reduce the **exposure** to a hazard. The level of difficulty is dependent on the ability of an area or a system of concern to be relocated. For example, relocating human systems outside of a hazard-prone area can be considered a solution to avoid exposure to a hazard; however, it may not always be socially, environmentally, and economically feasible to shift all the systems of concern away from the hazard-prone area. Moreover, it may lead to undesirable consequences such as increased vulnerability or additional GHG emissions that exacerbate hazards. It is even more complicated when a system is of a fixed location, such as forests. As it is mentioned before, hazards may occur in locations where they did not before, which may also result in novel exposures through expansion of the area exposed and increase in the number of exposed systems. Considering the increasing concentration of people and assets in urban areas which are increasingly expanded into and intertwined with rural and forest area, it is of high importance to avoid development in areas of high climate-related hazard. In addition, exposure to climate hazards should be also determinant in the planning and decision-making process of major infrastructure projects as they consume a great deal of resources and produce a large amount of GHG during both construction and operation and may cause potential ecological destruction.

Spatial plan can reduce the **vulnerability** of natural and human systems to the impacts. Vulnerability reduction is related to how healthy and vital the system properties are. In this sense, it bases on reducing sensitivity and increasing the adaptive capacity of a system and this refers to reducing inner weaknesses and increasing the inner strengths of that system. Through spatial planning, the restoration of natural and human system to their functionally robust state under current climatic impacts can be achieved, which enables them to be better prepared for an uncertain future. Strategies to reduce risk and vulnerability can be developed.

Presence of human systems in hazard-prone areas indicates not only they are exposed to that hazard but also gives insights about the vulnerability level of these systems since these areas are typically home to low-income groups with limited capacity to adapt. In this sense, high exposure and vulnerability levels may be characterized by poverty, land degradation, poor urban planning, natural resource-dependent rural livelihoods with lower capacity to adapt and poor governance. Supporting vulnerable systems is the prerequisite for climate justice because vulnerability reduction can be framed in terms of fundamental human rights. All human and natural systems have a right to a basic level of protection from the adverse impacts of climate change that deteriorate their basic needs. Comprehending the vulnerability associated with certain social, economic, and decision processes in tandem with understanding of processes and probabilities of risk is necessary for effective planning for and response to climate change. In this vein, changes in economic, social, environmental, institutional, and cultural dynamics of a system affect the levels of exposure and vulnerability; therefore, the strategies regarding these issues should be meticulously built.

Adaptation also involves steps taken to mitigate the impacts of climate change on natural systems. Reducing additional human stresses, increasing habitat extent, connectivity, and regional heterogeneity can reduce exposure and vulnerability of natural systems. Nature-based solutions (NbS) can play a critical role for effective adaptation interventions.

Another point to highlight is that climate change leads to a particular governance challenge to the traditional analysis of institutions due to the multidimensional and multiscale nature of climate change adaptation. The recent special report of the Intergovernmental Panel on Climate Change, Global Warming of 1.5°C, highlights that “accountable multilevel governance”, which involves a variety of actors and institutions, is needed to address climate change. Adaptation is widely accepted as a multi-level governance issue and needs policy coordination both vertically and horizontally in order to respond to the impacts of climate change. When integration between levels is limited, it poses a challenge for an issue like climate change adaptation since it requires effective interaction across scales, levels of organization, and sectors, and collaborative cross-disciplinary efforts across research, policy and practice. Therefore, there is a need to promote “cooperation across administrative and sectoral boundaries” (Dabrowski, 2018, p.838). Risks may be better handled by actively including a variety of stakeholders in dialogue and creating networks for the exchange of ideas and solutions. In this vein, the development of a collaborative agenda is vital in order to address climate risk and vulnerability from the national to the local level in Turkey. The perceptions of the local communities and the most vulnerable groups are also vital in risk and vulnerability studies. Comprehending local vulnerability and perceived risk might offer a bottom-up perspective on adaptation needs that are unique to a given location. The local communities should be fully engaged in adaptation initiatives to be effective and durable.

For this reason, it has become a necessity to develop policies in all sectors and to include climate change in planning processes in order to adapt to the effects of climate change. Local governments should prepare climate action plans and take action to ensure the compatibility of these plans with spatial plans. In addition, they should include effective adaptation measures falling under their jurisdiction in their strategic plans, put them into practice, and measure and report their performance regarding these activities.

6.3. Evaluation of the Assessment Method

The assessment of risk and its determinants is required as a basis for deciding on efficient management of climate risks. Climate risk assessment helps to identify hotspots for developing evidence-based policies and strategies to reduce climate risk and vulnerabilities at various spatial and temporal scales. Moreover, it helps manage current and future climate risk, identify options that reduce exposure and vulnerability of coupled human and natural systems, allocating adaptation funds to particular vulnerable regions, sectors or groups of people. The findings of the climate risk assessment are considered to have greater practical usefulness to Turkey in that sense.

The risk and vulnerability assessment is conducted to provide a systematic, comprehensive, and extensible framework of comparable hazard-specific assessments at the national scale and provincial level. This is the first study that conducts a national level climate risk and vulnerability assessment based on the IPCC 2014 framework in Turkey. The units of analysis are the 81 provinces, also known as NUTS-3 regions of Turkey.

This study employs the risk framework of IPCC's 5th Assessment Report, in which hazard, exposure, and vulnerability are the co-functions of risk (IPCC, 2014b). To represent hazard, this work used climate indicators such as annual mean temperature, annual maximum temperature, number of hot days, number of tropical nights, annual total precipitation, number of days with heavy precipitation. Exposure is covered by indicators related to natural and human systems located where hazard occurs (e.g., road networks in flood-prone area). Vulnerability is covered by indicators of its determinants, that are sensitivity and adaptive capacity. Sensitivity is represented by indicators regarding the internal weaknesses (e.g., high dependency ratio increases sensitivity to drought hazard), while adaptive capacity is covered by those representing internal strengths of a system (e.g., the redundancy of urban green spaces increases the adaptive capacity. Risk and vulnerability assessment is conducted by combining the single indicators representing hazard, exposure and those representing sensitivity and adaptive capacity for each hazard (heat wave, drought, forest fire, and flood) based on historical data. Although the 2014 framework of IPCC considers vulnerability as independent from hazard, considering vulnerability with reference to a hazard is "contextual and practical" in responding to the question of "vulnerability to what?" (Sharma and Ravindranath, 2019, p. 4). In this vein, this study employs hazard-relevant indicators for all determinants of risk -hazard, exposure, and vulnerability. A consistent method is applied for indicator construction in which hundreds of scientific articles, institutional reports, and case studies were reviewed. Indicators are identified through a comprehensive and rigorous review of risk and vulnerability studies, the extensive set of indicators from a theoretical point of view are selected and then shortlisted for Turkish provinces. Data sources, temporal coverage, and data level are identified, and the list is revised based on the relevance, analytical soundness, timeliness, and availability of data in the Turkish context. Since the results of the risk assessment are highly dependent on the indicators used in the study, the relevance of each of the indicators is thoroughly argued, as are the selection criteria.

Another issue that makes the study important is related to the quantification of indicators. Climate indicators that constitute the hazard component are produced from data on temperature and precipitation including increase in hot days/year, increase in number of tropical nights, increase in annual mean temperature, decrease in annual total precipitation, increase in days/year with heavy precipitation, increase in annual maximum temperature. These indicators are quantified and analyzed using Mann-Kendall Test and Sen's Slope Estimator, which is processed using MAKESENS 1.0 software to find out the overall trend of temperature and precipitation for all 81 provinces for the time period, 1971 to 2018. In addition to the quantification of climate indicators for all climate hazards, the quantification of flood exposure indicators is also significant as these indicators are created as a result of a spatial analysis in ArcGis (e.g., the total length of rail network in a province that would be exposed to flooding in the event of a 1 in 100-year fluvial flood).

Large databases may have highly correlated indicator variables, which leads to multicollinearity. Multicollinearity weakens the statistical power of the analysis and results in the analysis gives misleading results. In order to enhance the manageability of the large amount of data, to avoid multicollinearity and redundancy in data, to weight the indicator variables Principal Component Analysis and Factor Analysis are used. Internal consistency is tested through Cronbach's Alpha in order to check if the total list of the variables measures the respective risk dimension. Hazard, exposure, sensitivity, and adaptive capacity index representing the degree of those in each province in Turkey is developed for heat wave, drought, forest fire, and flood based on a geometric aggregation of weighted factors obtained from PCA/FA. Therefore, heat wave, drought, forest fire, and flood risk assessments are presented individually and the overall climate risk is assessed through individual climate risks of the provinces.

The design of the assessment method is built robust, consistent, flexible, and adaptable so that changes in the indicators can be easily implemented without disrupting the research structure. When considering the comprehensiveness of data used, the structure of the method makes the research operational when indicator data is limited or a new indicator is added.

6.4. Limitations and Further Research

This part focuses on the limitations of the thesis as well as the recommendations for future research. As this chapter very much addresses these recommendations throughout this chapter, this part mainly focuses on the limitations. In this context, the thesis has several limitations regarding the assessment method, data availability and quality, and data level.

The limitation of the risk and vulnerability assessment conducted in the context of the thesis is its temporal frame. Risk and vulnerability are dynamic concepts and variy in space and time. A system's demographic, economic, social, institutional, governance, cultural, and environmental patterns vary over time, and these changes have an impact on trends in exposure and vulnerability (Oppenheimer et al., 2014). However, this study adopts a static assessment of current risks and vulnerabilities based on current and historical data to overcome the below-mentioned challenges of assessing future risk and vulnerability:

- Future risks can only be assessed using future projections of hazard, exposure, and vulnerability dimensions. Climate hazard projections can be conducted through climate modes; however, the uncertainty and complexity associated with climate change projections and the expertise they necessitate are challenging issues to manage. Moreover, vulnerability and exposure dynamics is difficult to project because of difficulties in predicting land-use and socio-economic changes.
- Projections are highly coupled with uncertainty and accuracy due to challenges related to the availability and quality of data

Assessing current risk and vulnerabilities can provide insights into possible future states; therefore, managing them helps deal with future risks and vulnerabilities. It is assumed that the more dramatically climate impact has increased in the past, the more likely it will continue to increase in the future. Therefore, addressing current risks is considered instrumental and the robust strategy for no-regret options and preparation for future risks, especially given their uncertainty.

Another limitation of the thesis is related to data availability and quality. Developing an index needs the analysis of a vast amount of data. The results of the risk assessment are highly dependent on the data used in the study. Thus, data availability and quality play an important role in that sense. Although it is problematic for other risk components, the most prominent limitation is related to hazard component. The main limitation of the hazard analysis is that meteorological data belongs to the station of central districts in the provinces. Such a limitation has arisen because the data sourced from Turkish Meteorologic Service do not contain the same level of information for each district in the same period. This situation proves challenging even in central districts of provinces, and the measurement period, which started in 1929 for some provinces, was recorded in the 1960s, 1970s and 1980s for some provinces. Moreover, data for some years and months are missing for these provinces, whose data started to be kept in late years. That is why Mann-Kendall Test and Sen's Slope Estimator is used for analysis since the test has low sensitivity to missing values and outliers and does not require the data to be distributed normally (Tabari et al., 2011, p.130). However, above mentioned missing climate data for some years and months in several provinces leads to results that are not statistically significant; thus, making it impossible to use these indicators. For instance, although decrease in summer precipitation is aimed to be used for drought and forest fire hazard, trends for 79 provinces are not significant at the 0.05 level. Similarly, decrease in rainy days in summer season is intended to be selected as an indicator; however, it indicates non-significant results for the majority of the provinces. To sum up, data quality and coverage vary from province to province, especially for climate-related indicators.

Although incorporating a vast amount of data into a composite index has a lot of appeals, the result may suffer oversimplifying. Although an assessment on this spatial scale inevitably includes simplifications, generalizations, and a certain level of abstraction, this thesis attempts to overcome these issues through a detailed and comprehensive data set and robust, consistent, and stable data analysis methods. In this vein, these index results are not considered as stand-alone metrics but as tools that are suitable for ranking and comparing provinces and prioritizing the ones with high risk or high vulnerability or high exposure in terms of adaptation strategies and resource allocation. Therefore, it may be used as a first screening analysis and a high-level entry point to determine where local climate risk assessments needs be conducted to develop appropriate adaptation policies because the present data do not allow for comprehensive conclusions about the distribution of hazard, exposure, vulnerability, and risk below the provincial level. As a result, the provincial level, which is also known as NUTS-3 level is considered a reasonable compromise between the national level with high generalization and the local level.

National level climate risk assessment offers fundamental inputs to assist decision-makers and spatial planners in comparing the relative risk of provinces countrywide; however, every spatial scale and level has their specific level of information. Therefore, the local level of risks, local trade-offs in risk control, local costs and benefits are the concerns of local level plans. In this vein, the climate risk assessment which is conducted at provincial level in the context of this study should also be done at the local level as part of Territorial Plans, Master Plans and Implementation Development Plans by using more detailed data with spatial aspects. In this respect, themost exposed and vulnerable systems can be identified and the reasons for their level of exposure and vulnerability can be understood. There is a lack of awareness of knowledge and resources to address and document the degree and extent of vulnerability in Turkey. This is also reflected in spatial planning discipline, which hardly considers climate vulnerability of human and natural systems. Although a number of local governments have undertaken adaptation action plans, they could not identify exposure and vulnerability of these systems in their jurisdictions thus could not reflect this information into their spatial plans, reports and other publications.

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APPENDICES

A. Mann-Kendall Test and Sen's Slope Estimator Results of Mean Annual Temperatures for 81 provinces for the time period, 1971-2018

Provinces	First year	Last Year	n	Mann-Kendall Trend		Sen's Slope
				Test Z	Significance	Q_{med}
Adana	1971	2018	48	3.76	***	0.019
Adıyaman	1971	2018	48	4.80	***	0.031
Afyonkarahisar	1971	2018	48	5.22	***	0.042
Ağrı	1971	2018	48	3.54	***	0.043
Aksaray	1971	2018	48	5.44	***	0.055
Amasya	1971	2018	48	3.71	***	0.031
Ankara	1971	2018	48	5.24	***	0.050
Antalya	1971	2018	48	3.47	***	0.029
Ardahan	1971	2018	48	4.82	***	0.048
Artvin	1971	2018	48	4.10	***	0.033
Aydın	1971	2018	48	5.50	***	0.033
Balıkesir	1971	2018	48	2.43	*	0.013
Bartın	1971	2018	48	3.69	***	0.027
Batman	1971	2018	48	1.83	+	0.019
Bayburt	1971	2018	48	4.55	***	0.044
Bilecik	1971	2018	48	4.94	***	0.039
Bingöl	1971	2018	48	3.04	**	0.029
Bitlis	1971	2018	48	0.55		0.005
Bolu	1971	2018	48	4.85	***	0.039
Burdur	1971	2018	48	4.77	***	0.034
Bursa	1971	2018	48	4.33	***	0.036
Çanakkale	1971	2018	48	5.09	***	0.039
Çankırı	1971	2018	48	3.66	***	0.029
Çorum	1971	2018	48	4.09	***	0.035
Denizli	1971	2018	48	6.44	***	0.054
Diyarbakır	1971	2018	48	1.59		0.01
Düzce	1971	2018	48	4.17	***	0.03
Edirne	1971	2018	48	4.89	***	0.04
Elazığ	1971	2018	48	4.47	***	0.04
Erzincan	1971	2018	48	5.10	***	0.05
Erzurum	1971	2018	48	-0.03		0.00
Eskişehir	1971	2018	48	1.27		0.01
Gaziantep	1971	2018	48	6.04	***	0.05
Giresun	1971	2018	48	4.22	***	0.03
Gümüşhane	1971	2018	48	3.29	**	0.03
Hakkari	1971	2018	48	4.04	***	0.04
Hatay	1971	2018	48	4.95	***	0.03
Iğdır	1971	2018	48	4.55	***	0.05
Isparta	1971	2018	48	5.46	***	0.04
İstanbul	1971	2018	48	5.44	***	0.05
İzmir	1971	2018	48	5.32	***	0.03
Kahramanmaraş	1971	2018	48	5.19	***	0.04
Karabük	1971	2018	36	2.85	**	0.03
Karaman	1971	2018	48	4.56	***	0.04
Kars	1971	2018	48	4.59	***	0.05
Kastamonu	1971	2018	48	3.71	***	0.03
Kayseri	1971	2018	48	5.61	***	0.05
Kırıkkale	1971	2018	48	3.99	***	0.04
Kırklareli	1971	2018	48	4.81	***	0.04
Kırşehir	1971	2018	48	4.02	***	0.04
Kilis	1971	2018	48	5.07	***	0.04
Kocaeli	1971	2018	48	4.91	***	0.04
Konya	1971	2018	48	2.88	**	0.03

Appendix A (continued)

Kütahya	1971	2018	48	5.36	***	0.04
Malatya	1971	2018	48	5.32	***	0.05
Manisa	1971	2018	48	4.58	***	0.03
Mardin	1971	2018	48	5.33	***	0.04
Mersin	1971	2018	48	7.21	***	0.06
Muğla	1971	2018	48	4.79	***	0.03
Muş	1971	2018	48	4.66	***	0.06
Nevşehir	1971	2018	48	4.77	***	0.05
Niğde	1971	2018	48	5.25	***	0.05
Ordu	1971	2018	48	5.70	***	0.05
Osmaniye	1986	2018	33	2.85	**	0.03
Rize	1971	2018	48	5.40	***	0.04
Sakarya	1971	2018	48	5.24	***	0.05
Samsun	1971	2018	48	5.00	***	0.04
Siirt	1971	2018	48	5.04	***	0.04
Sinop	1971	2018	48	4.54	***	0.04
Sivas	1971	2018	48	4.11	***	0.05
Şanlıurfa	1971	2018	48	5.51	***	0.04
Şırnak	1971	2018	30	4.06	***	0.04
Tekirdağ	1971	2018	48	4.90	***	0.04
Tokat	1971	2018	48	4.03	***	0.03
Trabzon	1971	2018	48	4.43	***	0.04
Tunceli	1971	2018	48	3.66	***	0.03
Uşak	1971	2018	48	5.08	***	0.03
Van	1971	2018	48	5.77	***	0.06
Yalova	1971	2018	48	4.75	***	0.04
Yozgat	1971	2018	48	5.10	***	0.05
Zonguldak	1971	2018	48	3.36	***	0.02

Note: Z: Mann-Kendall test, Qmed: Sen's slope estimator.
***, **, * and + indicate that the trends have 0.001, 0.01, 0.05 and 0.1 significance level, respectively. If the cell is blank, the significance level is greater than 0.1

B. Mann-Kendall Test and Sen's Slope Estimator Results of Annual Maximum Temperatures for 81 provinces for the time period, 1971-2018

				Mann-Kendall Trend		Sen's Slope
Provinces	**First year**	**Last Year**	**n**	**Test Z**	**Significance**	**Q** med
Adana	1971	2018	48	0.67		0.015
Adıyaman	1971	2018	48	3.55	***	0.051
Afyonkarahisar	1971	2018	48	1.76	+	0.032
Ağrı	1971	2018	48	2.29	*	0.042
Aksaray	1971	2018	48	2.36	*	0.033
Amasya	1971	2018	48	3.34	***	0.063
Ankara	1971	2018	48	2.40	*	0.034
Antalya	1971	2018	48	1.78	+	0.027
Ardahan	1971	2018	48	-0.35		-0.005
Artvin	1971	2018	48	1.93	+	0.042
Aydın	1971	2018	48	2.40	*	0.044
Balıkesir	1971	2018	48	1.79	+	0.035
Bartın	1971	2018	48	1.31		0.036
Batman	1971	2018	48	-0.11		0.000
Bayburt	1971	2018	48	2.89	**	0.044
Bilecik	1971	2018	48	3.74	***	0.074
Bingöl	1971	2018	48	-0.38		-0.003
Bitlis	1971	2018	47	-0.78		-0.013
Bolu	1971	2018	48	1.92	+	0.042
Burdur	1971	2018	48	3.63	***	0.070
Bursa	1971	2018	48	0.63		0.010
Çanakkale	1971	2018	48	1.87	+	0.033
Çankırı	1971	2018	48	3.28	**	0.061
Çorum	1971	2018	48	3.73	***	0.076
Denizli	1971	2018	48	3.66	***	0.067
Diyarbakır	1971	2018	48	0.53		0.01
Düzce	1971	2018	48	0.89		0.02
Edirne	1971	2018	48	2.58	**	0.05
Elazığ	1971	2018	48	1.89	+	0.03
Erzincan	1971	2018	48	3.45	***	0.05
Erzurum	1971	2018	48	2.79	**	0.04
Eskişehir	1971	2018	30	1.68	+	0.03
Gaziantep	1971	2018	48	1.99	*	0.03
Giresun	1971	2018	48	1.25		0.02
Gümüşhane	1971	2018	48	0.71		0.01
Hakkari	1971	2018	47	1.51		0.03
Hatay	1971	2018	48	0.91		0.03
Iğdır	1971	2018	48	1.44		0.02
Isparta	1971	2018	48	3.43	***	0.06
İstanbul	1971	2018	48	2.17	*	0.04
İzmir	1971	2018	48	0.85		0.01
Kahramanmaraş	1971	2018	48	3.51	***	0.07
Karabük	1971	2018	37	1.06		0.03
Karaman	1971	2018	48	1.71	+	0.03
Kars	1971	2018	48	0.63		0.01
Kastamonu	1971	2018	48	3.15	**	0.06
Kayseri	1971	2018	48	2.82	**	0.04
Kırıkkale	1971	2018	48	3.83	***	0.07
Kırklareli	1971	2018	48	2.24	*	0.06
Kırşehir	1971	2018	48	3.60	***	0.06
Kilis	1971	2018	48	2.50	*	0.04

Appendix B (continued)

Kocaeli	1971	2018	48	0.69		0.01
Konya	1971	2018	48	1.82	+	0.03
Kütahya	1971	2018	48	2.07	*	0.04
Malatya	1971	2018	48	3.16	**	0.06
Manisa	1971	2018	48	0.45		0.01
Mardin	1971	2018	48	1.38		0.01
Mersin	1971	2018	48	4.43	***	0.08
Muğla	1971	2018	48	3.70	***	0.07
Muş	1971	2018	48	2.07	*	0.03
Nevşehir	1971	2018	48	3.67	***	0.06
Niğde	1971	2018	48	3.32	***	0.04
Ordu	1971	2018	48	2.91	**	0.05
Osmaniye	1986	2018	33	0.26		0.01
Rize	1971	2018	48	2.49	*	0.05
Sakarya	1971	2018	48	1.78	+	0.04
Samsun	1971	2018	48	0.95		0.02
Siirt	1971	2018	48	1.02		0.02
Sinop	1971	2018	48	1.90	+	0.03
Sivas	1971	2018	48	3.14	**	0.07
Şanlıurfa	1971	2018	48	2.78	**	0.04
Şırnak	1971	2018	29	1.56		0.02
Tekirdağ	1971	2018	48	3.65	***	0.07
Tokat	1971	2018	48	3.95	***	0.08
Trabzon	1971	2018	40	2.20	*	0.07
Tunceli	1971	2018	48	2.26	*	0.03
Uşak	1971	2018	48	2.23	*	0.04
Van	1971	2018	48	1.43		0.03
Yalova	1971	2018	48	2.39	*	0.06
Yozgat	1971	2018	48	3.96	***	0.07
Zonguldak	1971	2018	48	0.85		0.02

Note: Z: Mann-Kendall test, Qmed: Sen's slope estimator.
***, **, * and + indicate that the trends have 0.001, 0.01, 0.05 and 0.1 significance level, respectively. If the cell is blank, the significance level is greater than 0.1
Source: Prepared by the author

C. Mann-Kendal1 l Test and Sen's Slope Estimator Results of Hot Days (Tmax>30 °C) for 81 provinces for the time period, 1971-2018

Provinces	First year	Last Year	n	Mann-Kendall Trend Test Z	Mann-Kendall Trend Significance	Sen's Slope Q_{med}
Adana	1971	2018	48	-0.69		-0.06
Adıyaman	1971	2018	48	3.34	***	0.33
Afyonkarahisar	1971	2018	48	5.20	***	0.70
Ağrı	1971	2018	48	3.81	***	0.56
Aksaray	1971	2018	48	4.31	***	0.69
Amasya	1971	2018	48	5.74	***	0.97
Ankara	1971	2018	48	4.72	***	0.75
Antalya	1971	2018	48	3.16	**	0.47
Ardahan	1971	2018	36	1.29		0.02
Artvin	1971	2018	48	2.61	**	0.24
Aydın	1971	2018	48	2.75	**	0.32
Balıkesir	1971	2018	48	5.49	***	1.03
Bartın	1971	2018	48	4.48	***	0.53
Batman	1971	2018	48	0.15		0.00
Bayburt	1971	2018	48	4.10	***	0.48
Bilecik	1971	2018	48	6.20	***	1.00
Bingöl	1971	2018	48	1.66	+	0.20
Bitlis	1971	2018	47	0.52		0.11
Bolu	1971	2018	48	3.72	***	0.46
Burdur	1971	2018	48	5.55	***	0.85
Bursa	1971	2018	48	5.15	***	0.78
Çanakkale	1971	2018	48	5.64	***	0.81
Çankırı	1971	2018	48	4.90	***	0.81
Çorum	1971	2018	48	5.50	***	0.91
Denizli	1971	2018	48	4.52	***	0.63
Diyarbakır	1971	2018	48	1.39		0.10
Düzce	1971	2018	48	4.54	***	0.78
Edirne	1971	2018	48	5.44	***	0.87
Elazığ	1971	2018	48	4.47	***	0.55
Erzincan	1971	2018	48	5.07	***	0.70
Erzurum	1971	2018	48	3.84	***	0.43
Eskişehir	1971	2018	32	4.47	***	0.68
Gaziantep	1971	2018	48	2.01	*	0.17
Giresun	1971	2018	44	1.58		0.06
Gümüşhane	1971	2018	48	1.77	+	0.26
Hakkari	1971	2018	47	3.14	**	0.56
Hatay	1971	2018	48	4.50	***	0.74
Iğdır	1971	2018	48	2.20	*	0.26
Isparta	1971	2018	48	4.51	***	0.71
İstanbul	1971	2018	48	5.80	***	0.86
İzmir	1971	2018	48	3.22	**	0.38
Kahramanmaraş	1971	2018	48	2.94	**	0.32
Karabük	1971	2018	37	2.43	*	0.54
Karaman	1971	2018	48	4.38	***	0.66
Kars	1971	2018	44	2.73	**	0.25
Kastamonu	1971	2018	48	4.68	***	0.60
Kayseri	1971	2018	48	4.38	***	0.63
Kırıkkale	1971	2018	48	4.32	***	0.65
Kırklareli	1971	2018	48	5.86	***	1.01
Kırşehir	1971	2018	48	5.32	***	0.89
Kilis	1971	2018	48	0.28		0.00

Appendix C (continued)

Kocaeli	1971	2018	48	6.40	***	1.03
Konya	1971	2018	48	4.34	***	0.63
Kütahya	1971	2018	48	4.03	***	0.46
Malatya	1971	2018	48	4.74	***	0.71
Manisa	1971	2018	48	2.16	*	0.26
Mardin	1971	2018	48	3.79	***	0.40
Mersin	1971	2018	48	6.85	***	1.56
Muğla	1971	2018	48	4.68	***	0.70
Muş	1971	2018	48	3.54	***	0.42
Nevşehir	1971	2018	48	4.96	***	0.73
Niğde	1971	2018	48	5.37	***	0.81
Ordu	1971	2018	45	4.73	***	0.33
Osmaniye	1986	2018	33	-0.16		-0.02
Rize	1971	2018	44	4.71	***	0.44
Sakarya	1971	2018	48	6.16	***	1.16
Samsun	1971	2018	48	3.66	***	0.13
Siirt	1971	2018	48	1.26		0.13
Sinop	1971	2018	41	3.99	***	0.10
Sivas	1971	2018	48	4.10	***	0.58
Şanlıurfa	1971	2018	48	3.45	***	0.31
Şırnak	1971	2018	29	3.60	***	0.50
Tekirdağ	1971	2018	48	5.79	***	0.71
Tokat	1971	2018	48	5.60	***	1.00
Trabzon	1971	2018	33	3.58	***	0.31
Tunceli	1971	2018	48	3.83	***	0.49
Uşak	1971	2018	48	4.71	***	0.72
Van	1971	2018	47	2.84	**	0.40
Yalova	1971	2018	48	6.79	***	1.04
Yozgat	1971	2018	48	4.60	***	0.40
Zonguldak	1971	2018	46	0.60		0.00

Note: Z: Mann-Kendall test, Qmed: Sen's slope estimator.
***, **, * and + indicate that the trends have 0.001, 0.01, 0.05 and 0.1 significance level, respectively. If the cell is blank, the significance level is greater than 0.1

D. Mann-Kendall Test and Sen's Slope Estimator Results of Tropical Nights (Tmin>20 °C) for 81 provinces for the time period, 1971-2018

Provinces	First year	Last Year	n	Mann-Kendall Trend			Sen's Slope
				Test S	Test Z	Significance	Q med
Adana	1971	2018	48		3.12	**	0.318
Adıyaman	1971	2018	48		3.65	***	0.337
Afyonkarahisar	1971	2018	15		0.87		0.000
Ağrı	1971	2018	10		-0.45		0.000
Aksaray	1971	2018	42		4.89	***	0.281
Amasya	1971	2018	46		4.49	***	0.333
Ankara	1971	2018	38		3.76	***	0.276
Antalya	1971	2018	48		4.38	***	1.333
Ardahan	1971	2018	1				
Artvin	1971	2018	42		4.32	***	0.400
Aydın	1971	2018	48		6.74	***	1.367
Balıkesir	1971	2018	48		3.56	***	0.333
Bartın	1971	2018	41		2.90	**	0.121
Batman	1971	2018	48		1.24		0.253
Bayburt	1971	2018	3	0			0.000
Bilecik	1971	2018	45		4.54	***	0.203
Bingöl	1971	2018	48		2.88	**	0.281
Bitlis	1971	2018	43		0.74		0.000
Bolu	1971	2018	11		0.91		0.000
Burdur	1971	2018	44		4.17	***	0.200
Bursa	1971	2018	47		6.12	***	0.630
Çanakkale	1971	2018	48		7.09	***	1.288
Çankırı	1971	2018	29		1.71	+	0.022
Çorum	1971	2018	11		0.10		0.000
Denizli	1971	2018	48		7.18	***	1.390
Diyarbakır	1971	2018	48	7	1.41		0.156
Düzce	1971	2018	45		4.53	***	0.286
Edirne	1971	2018	48		4.86	***	0.415
Elazığ	1971	2018	48	0	-0.28		-0.068
Erzincan	1971	2018	36		4.03	***	0.165
Erzurum	1971	2018	4	0	3.84		0.000
Eskişehir	1971	2018	15		1.10		0.000
Gaziantep	1971	2018	48		6.55	***	1.000
Giresun	1971	2018	48		5.99	***	1.126
Gümüşhane	1971	2018	5	2	1.77		0.000
Hakkari	1971	2018	47		4.33	***	0.500
Hatay	1971	2018	48		4.72	***	0.500
Iğdır	1971	2018	48		6.55	***	0.800
Isparta	1971	2018	28		2.59	**	0.067
İstanbul	1971	2018	48		6.63	***	1.286
İzmir	1971	2018	48		5.09	***	0.567
Kahramanmaraş	1971	2018	48		6.24	***	0.740
Karabük	1971	2018	28	0	1.84	+	0.070
Karaman	1971	2018	35	0	2.83	**	0.048
Kars	1971	2018	0	0	2.73		0.000
Kastamonu	1971	2018	2	-1	4.68		-0.222
Kayseri	1971	2018	6	-3	4.38		0.000
Kırıkkale	1971	2018	45	0	4.52	***	0.286
Kırklareli	1971	2018	47		4.99	***	0.500
Kırşehir	1971	2018	41	0	3.60	***	0.188
Kilis	1971	2018	48		6.25	***	1.035

Appendix D (continued)

Kocaeli	1971	2018	48		5.63	***	0.897
Konya	1971	2018	43	0	5.54	***	0.316
Kütahya	1971	2018	9	4	4.03		0.000
Malatya	1971	2018	48		5.04	***	0.741
Manisa	1971	2018	48		6.85	***	1.083
Mardin	1971	2018	48		4.09	***	0.429
Mersin	1971	2018	48		6.96	***	1.342
Muğla	1971	2018	48		5.53	***	0.725
Muş	1971	2018	41		5.37	***	0.320
Nevşehir	1971	2018	39		4.50	***	0.121
Niğde	1971	2018	18		-0.16		0.000
Ordu	1971	2018	48		6.04	***	1.154
Osmaniye	1986	2018	33		1.85	+	0.803
Rize	1971	2018	48		6.20	***	1.195
Sakarya	1971	2018	48		5.93	***	0.783
Samsun	1971	2018	48		5.45	***	0.977
Siirt	1971	2018	48		5.69	***	0.667
Sinop	1971	2018	48		5.16	***	1.055
Sivas	1971	2018	8	6	4.10		0.000
Şanlıurfa	1971	2018	48		5.98	***	0.750
Şırnak	1971	2018	29		2.84	**	0.659
Tekirdağ	1971	2018	48		6.11	***	1.143
Tokat	1971	2018	43		4.44	***	0.250
Trabzon	1971	2018	40		4.50	***	1.071
Tunceli	1971	2018	48		0.68		0.095
Uşak	1971	2018	36		3.04	**	0.094
Van	1971	2018	34		1.13		0.000
Yalova	1971	2018	48		4.82	***	0.833
Yozgat	1971	2018	18		4.60	***	0.400
Zonguldak	1971	2018	48		0.60		0.000

Note: Z: Mann-Kendall test, Qmed: Sen's slope estimator.
***, **, * and + indicate that the trends have 0.001, 0.01, 0.05 and 0.1 significance level, respectively. If the cell is blank, the significance level is greater than 0.1

E. Mann-Kendall Test and Sen's Slope Estimator Results of Annual Total Precipitation for 81 provinces for the time period, 1971-2018

Provinces	First year	Last Year	n	Mann-Kendall Trend Test Z	Significance	Sen's Slope Q_{med}
Adana	1971	2018	48	0.12		0.191
Adıyaman	1971	2018	48	0.45		0.902
Afyonkarahisar	1971	2018	48	1.59		1.138
Ağrı	1971	2018	48	-0.54		-0.600
Aksaray	1971	2018	48	0.28		0.197
Amasya	1971	2018	48	2.12	*	1.563
Ankara	1971	2018	48	0.51		0.510
Antalya	1971	2018	48	-0.60		-2.192
Ardahan	1971	2018	48	3.52	***	3.836
Artvin	1971	2018	48	0.81		1.061
Aydın	1971	2018	48	0.92		1.297
Balıkesir	1971	2018	48	1.46		1.656
Bartın	1971	2018	48	1.30		2.667
Batman	1971	2018	48	-0.08		-0.133
Bayburt	1971	2018	48	2.59	**	2.212
Bilecik	1971	2018	48	0.76		0.504
Bingöl	1971	2018	48	-0.06		-0.133
Bitlis	1971	2018	48	-1.08		-2.748
Bolu	1971	2018	48	0.40		0.369
Burdur	1971	2018	48	0.88		0.583
Bursa	1971	2018	48	1.21		1.376
Çanakkale	1971	2018	48	1.00		1.517
Çankırı	1971	2018	48	1.31		1.777
Çorum	1971	2018	48	-0.36		-0.360
Denizli	1971	2018	48	0.86		1.182
Diyarbakır	1971	2018	48	-0.02		-0.02
Düzce	1971	2018	48	-1.04		-1.46
Edirne	1971	2018	48	1.57		2.30
Elazığ	1971	2018	48	-0.54		-0.71
Erzincan	1971	2018	48	0.85		0.62
Erzurum	1971	2018	48	-0.32		-0.27
Eskişehir	1971	2018	48	-1.52		-0.90
Gaziantep	1971	2018	48	0.12		0.25
Giresun	1971	2018	48	2.39	*	3.75
Gümüşhane	1971	2018	48	1.29		1.23
Hakkari	1971	2018	47	-0.48		-0.57
Hatay	1971	2018	48	0.76		2.17
Iğdır	1971	2018	48	0.60		0.41
Isparta	1971	2018	48	0.90		1.10
İstanbul	1971	2018	48	-0.83		-1.20
İzmir	1971	2018	48	0.56		0.91
Kahramanmaraş	1971	2018	48	0.84		1.60
Karabük	1997	2018	22	-0.45		-3.58
Karaman	1971	2018	48	-0.95		-0.82
Kars	1971	2018	48	3.12	**	3.50
Kastamonu	1971	2018	48	1.26		1.59
Kayseri	1971	2018	48	0.99		0.97
Kırıkkale	1971	2018	48	0.10		0.12
Kırklareli	1971	2018	48	0.67		1.40
Kırşehir	1971	2018	48	0.45		0.31
Kilis	1971	2018	48	-1.55		-2.20

Appendix E (continued)

Kocaeli	1971	2018	48	1.36		2.06
Konya	1971	2018	48	0.19		0.10
Kütahya	1971	2018	48	0.31		0.53
Malatya	1971	2018	48	-1.73	+	-1.39
Manisa	1971	2018	48	-0.60		-1.11
Mardin	1986	2018	25	-0.63		-5.36
Mersin	1971	2018	48	1.34		2.73
Muğla	1971	2018	48	0.17		0.57
Muş	1971	2018	48	0.56		0.73
Nevşehir	1971	2018	48	-0.70		-0.79
Niğde	1971	2018	48	1.68	+	1.26
Ordu	1971	2018	48	0.79		0.83
Osmaniye	1986	2018	32	-0.31		-1.36
Rize	1971	2018	48	1.65	+	4.83
Sakarya	1971	2018	48	1.08		1.89
Samsun	1971	2018	48	2.28	*	2.60
Siirt	1971	2018	48	-0.08		-0.05
Sinop	1971	2018	48	2.92	**	4.28
Sivas	1971	2018	48	0.92		0.82
Şanlıurfa	1971	2018	48	-1.08		-1.07
Şırnak	1971	2018	27	1.13		2.20
Tekirdağ	1971	2018	48	0.94		1.16
Tokat	1971	2018	48	0.76		0.64
Trabzon	1971	2018	48	2.32	*	3.16
Tunceli	1971	2018	48	0.72		1.11
Uşak	1971	2018	48	0.84		1.11
Van	1971	2018	48	1.47		1.07
Yalova	1971	2018	48	0.74		1.11
Yozgat	1971	2018	48	0.31		0.38
Zonguldak	1971	2018	48	0.05		0.07

Note: Z: Mann-Kendall test, Qmed: Sen's slope estimator.
***, **, * and + indicate that the trends have 0.001, 0.01, 0.05 and 0.1 significance level, respectively. If the cell is blank, the significance level is greater than 0.1
Source: Prepared by the author

F. Mann-Kendall Test and Sen's Slope Estimator Results of Heavy Precipitation (RR>10 mm) for 81 provinces for the time period, 1971-2018

				Mann-Kendall Trend			Sen's Slope
Provinces	**First year**	**Last Year**	**n**	**Test S**	**Test Z**	**Significance**	**Q med**
Adana	1971	2018	48		-0,46		-0,011
Adıyaman	1971	2018	48		0,35		0,000
Afyonkarahisar	1971	2018	48		1,83	+	0,058
Ağrı	1971	2018	48		-0,17		0,000
Aksaray	1971	2018	48		-0,13		0,000
Amasya	1971	2018	48		2,54	*	0,132
Ankara	1971	2018	48		0,70		0,025
Antalya	1971	2018	47		-0,25		0,000
Ardahan	1971	2018	48		2,82	**	0,164
Artvin	1971	2018	48		1,00		0,044
Aydın	1971	2018	48		1,17		0,083
Balıkesir	1971	2018	48		1,40		0,062
Bartın	1971	2018	48		1,77	+	0,097
Batman	1971	2018	48		-0,57		0,000
Bayburt	1971	2018	48		1,04		0,040
Bilecik	1971	2018	48		0,93		0,035
Bingöl	1971	2018	48		-0,39		0,000
Bitlis	1971	2018	47		-0,54		-0,026
Bolu	1971	2018	48		1,19		0,050
Burdur	1971	2018	48		1,12		0,057
Bursa	1971	2018	48		1,09		0,051
Çanakkale	1971	2018	48		0,23		0,000
Çankırı	1971	2018	48		1,64		0,077
Çorum	1971	2018	48		2,02	*	0,071
Denizli	1971	2018	48		-0,46		0,000
Diyarbakır	1971	2018	48		0,58		0,03
Düzce	1971	2018	48		-0,46		0,00
Edirne	1971	2018	48		2,07	*	0,13
Elazığ	1971	2018	48		-0,57		0,00
Erzincan	1971	2018	48		0,78		0,00
Erzurum	1971	2018	48		-0,54		0,00
Eskişehir	1971	2018	25		-0,52		-0,03
Gaziantep	1971	2018	48		0,00		0,00
Giresun	1971	2018	48		2,46	*	0,14
Gümüşhane	1971	2018	48		0,43		0,00
Hakkari	1971	2018	48		0,02		0,00
Hatay	1971	2018	48		-0,33		0,00
Iğdır	1971	2018	46		0,70		0,00
Isparta	1971	2018	48		0,44		0,00
İstanbul	1971	2018	48		1,26		0,06
İzmir	1971	2018	48		1,06		0,06
Kahramanmaraş	1971	2016	46		0,84		0,07
Karabük	1971	2018	37		-0,57		0,00
Karaman	1971	2018	48		0,49		0,00
Kars	1971	2018	48		1,83	+	0,09
Kastamonu	1971	2018	48		2,46	*	0,12
Kayseri	1971	2018	48		0,50		0,00
Kırıkkale	1971	2018	48		0,96		0,03
Kırklareli	1971	2018	48		1,24		0,09
Kırşehir	1971	2018	48		-0,24		0,00
Kilis	1971	2018	48		-0,60		0,00

Appendix F (continued)

Kocaeli	1971	2018	48		1,73	+	0,13
Konya	1971	2018	48		0,20		0,00
Kütahya	1971	2018	48		0,61		0,00
Malatya	1971	2018	48		-0,93		-0,03
Manisa	1971	2018	48		0,30		0,00
Mardin	1971	2018	48		-1,69	+	-0,12
Mersin	1971	2018	48		0,06		0,00
Muğla	1971	2018	48		0,56		0,05
Muş	1971	2018	48		0,75		0,05
Nevşehir	1971	2018	48		-0,40		0,00
Niğde	1971	2018	48		1,96	+	0,07
Ordu	1971	2018	48		0,43		0,00
Osmaniye	1986	2018	33		0,47		0,05
Rize	1971	2018	48		1,24		0,07
Sakarya	1971	2018	48		0,92		0,05
Samsun	1971	2018	48		2,40	*	0,10
Siirt	1971	2018	48		-0,12		0,00
Sinop	1971	2018	48		2,78	**	0,19
Sivas	1971	2018	48		1,00		0,04
Şanlıurfa	1971	2018	48		-1,43		-0,08
Şırnak	1971	2018	30		-0,13		0,00
Tekirdağ	1971	2018	48		0,05		0,00
Tokat	1971	2018	48		2,08	*	0,08
Trabzon	1971	2018	40		3,43	***	0,21
Tunceli	1971	2018	48		1,29		0,08
Uşak	1971	2014	44		0,67		0,00
Van	1971	2018	48		2,14	*	0,07
Yalova	1971	2018	48		0,93		0,04
Yozgat	1971	2018	48		1,45		0,07
Zonguldak	1971	2018	48		1,89	+	0,11

Note: Z: Mann-Kendall test, Qmed: Sen's slope estimator.
***, **, * and + indicate that the trends have 0.001, 0.01, 0.05 and 0.1 significance level, respectively. If the cell is blank, the significance level is greater than 0.1

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